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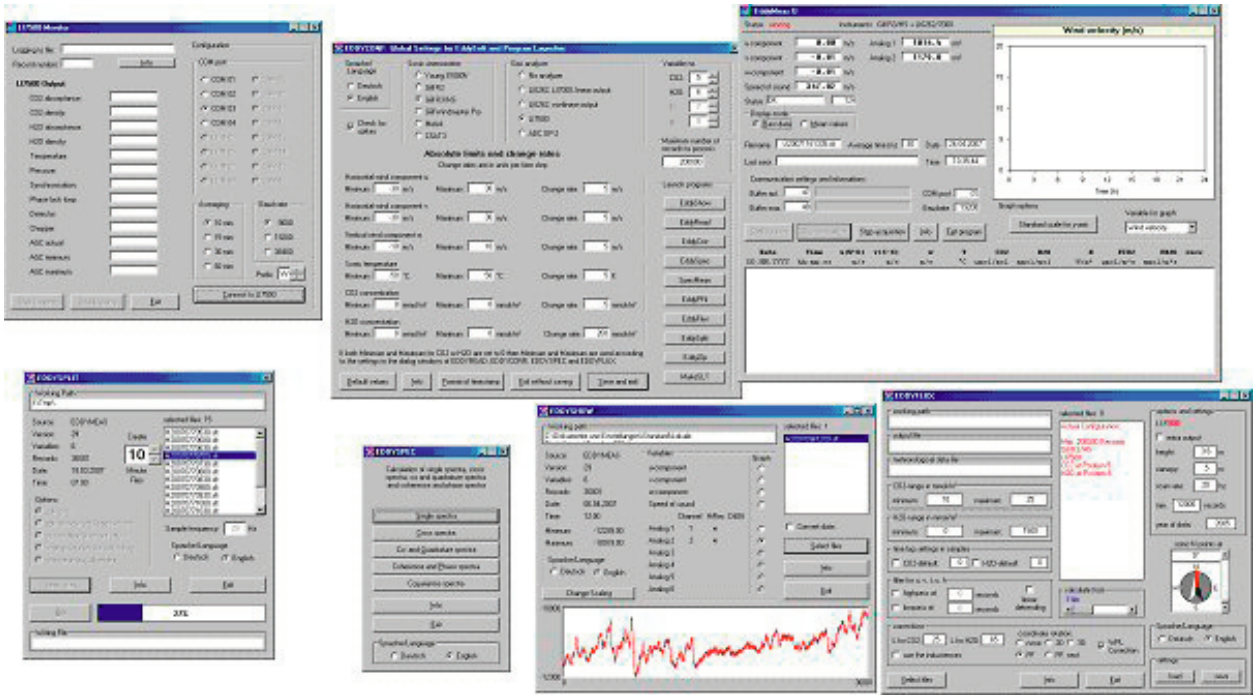
TECHNICAL REPORTS 10



EddySoft
Documentation of a Software Package to Acquire and Process Eddy Covariance Data

by

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ISSN 1615-7400

MAX-PLANCK-GESELLSCHAFT

Technical Reports - Max-Planck-Institut für Biogeochemie 10, 2007

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Documentation of a Software Package
to Acquire and Process Eddy Covariance Data

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Abstract

This report describes the useage of the software package EddySoft for acquisition and processing of eddy covariance data in form of a manual. Furthermore the algorithms applied for post-processing of eddy covariance raw data are presented.
The data acquisition part of the software package is able to collect data from several different types of sonic anemometers and gas analysers for carbon dioxide and water vapour at a high sampling frequency. It can initiate automated calibration routines for closed path gas analysers and is able to send preliminary results such as fluxes of CO_2 and H_2O to external devices.
The post processing programs offer tools to visualize high frequency raw data and to carry out statistical tests such as spectral and correlation analysis. Parameters which are needed to correct the fluxes of sensible and latent heat and of carbon dioxide can be determined and tools to convert and archive the raw data are available. Finally averages and variances of wind components, temperature, concentrations of CO_2 and H_2O, corrected fluxes of sensible and latent heat and of carbon dioxide as well as data quality flags and a number of other variables and parameters can be calculated.

Contents

1 EDDYMEAS – data acquisition

EDDYMEAS is a 32-bit WINDOWS (95/98/NT/2000/XP) application written in VISUAL BASIC with a graphical user interface. A screen resolution of at least 800 x 600 is required. The program is run from the Start-menu selecting EDDYMEAS. Before running EDDYMEAS with a Gill R2 or R3 or HS or a WindMaster Pro use the Rcom program from Gill and set the baud rate of the sonic to a value of 9600 or 19200. When using a sonic from Young or Metek take a terminal program and set the baud rate to a value of 9600 or 19200.
If immediately after program start the error message Runtime error 13 Type mismatch appears on the screen the Date/Time formats in the Regional Settings of the Control Panel must be changed. For the short date style TT.MM.JJJJ must be used and the date separator must be set to dot (.). For the time style HH:mm:ss must be used and the time separator must be set to colon (:). Make sure to use upper and lower case letters as shown above.
This problem should be fixed now, please report if it happens nevertheless.
As well it is strongly recommended to set the decimal symbol to dot (.) and the list separator to comma (,) using the Number dialog in the Regional Settings.

At the moment the program is restricted to be used only in conjunction with Gill sonic anemometers R2, R3, HS and WindMaster Pro or Young sonic 81000V or Metek USA-1 in the standard or turbulence scientific version. The R2 may be used in continuous or block mode (selectable by jumper in the instrument).
It is possible (tested) to acquire more than one eddy system simultaneously with one computer. Simply create two subdirectories each containing EDDYMEAS and all other programs and files which are called or used by EDDYMEAS. Then EDDYMEAS needs to be started from both subdirectories with the appropriate settings. To better distinguish between the different running copies of EDDYMEAS the site or station prefix character is added to the caption of the main window. So on the buttons in the task bar or while pressing Alt Tab (to switch between the applications) the application name EDDYMEAS appears together with this prefix character (e.g. EDDYMEAS H).

When EDDYMEAS starts running the following message appears while the program searches for available COM-ports:

Figure 1: The EDDYMEAS load message

After loading completed it is necessary to firstly select the type of sonic anemometer and the correct COM-port to which the sonic or the interface is connected to and then

to configure the anemometer and the data acquisition by clicking on the Configuration button.

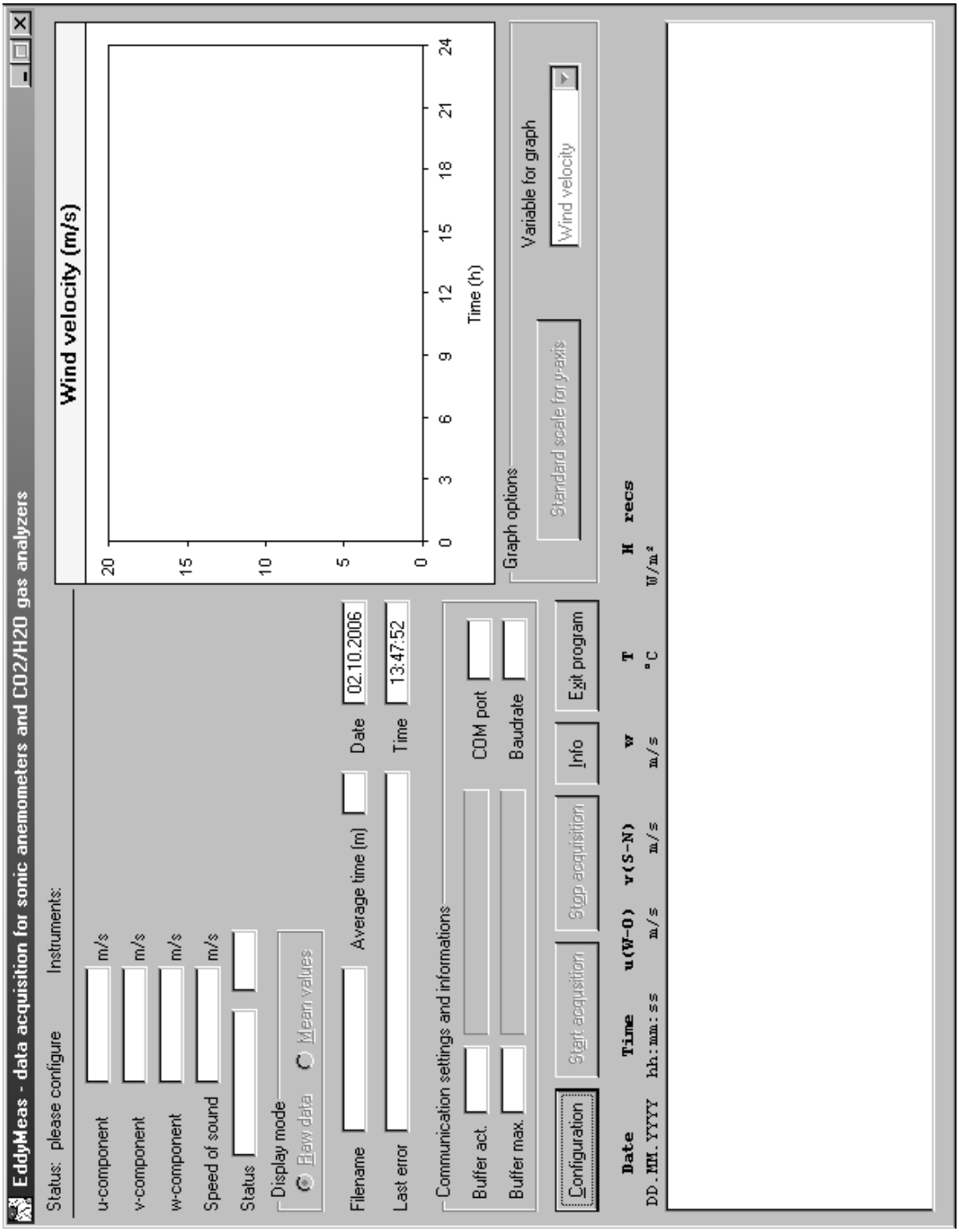


Figure 2: The EDDYMEAS window before configuration

After the Configuration button was pressed, a dialog window (figure 3) opens showing 16 possible COM-port options where only those are enabled which are existing on the computer and which are currently available.

If COM-ports are not being detected which are definitely in the system and which are not being used by another application then it may be the case that the input buffer size of 32 kByte which EDDYMEAS tries to allocate is not supported by the COM-port driver (e.g. USB to serial or ethernet to serial converters). In this special case an ascii-file named ComBuffer.cfg must be created within the programs directory. This file consists of just two lines and must look like the following example:

```
[InBufferSize]
16000
```

where the number in the second line defines the input buffer size. Different numbers must be tried to find out which buffer size is supported by the driver.

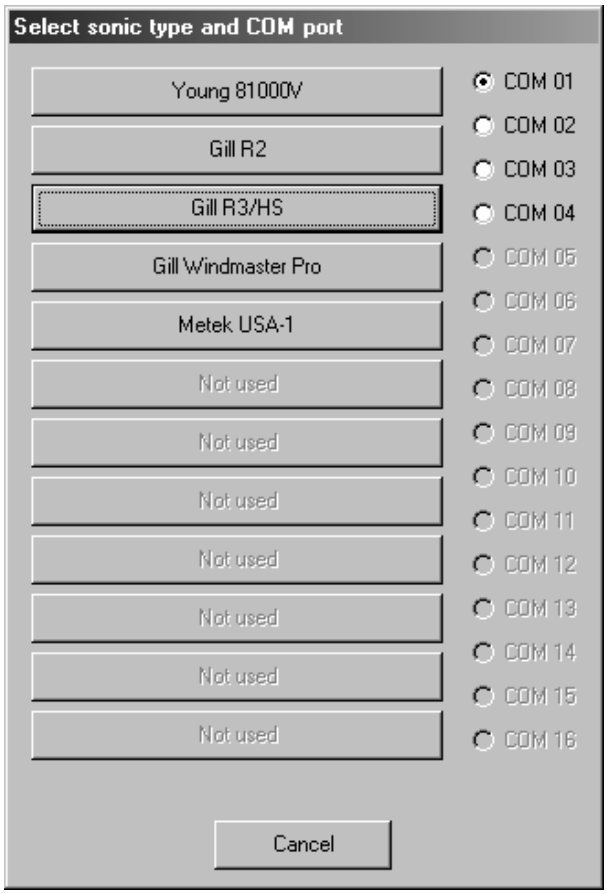


Figure 3: Dialog to select COM-port and sonic anemometer in use

After selecting the COM-port and pressing one of the sonic anemometer buttons (Young 81000V or Gill R2 or Gill R3/HS or Gill Windmaster Pro or Metek USA-1), the program starts to search for the anemometer at different baud rates starting at 9600 baud. This procedure takes several seconds while the actual baud rate is displayed. If no connection to the anemometer could be established and the message "No instrument found. Try again." appears, then check whether the serial cable between the computer and the communication interface or anemometer is plugged in and whether all components of the system are switched on. In some cases initial communication problems may also lead to this message, they usually disappear when the Configuration button is pressed again. Some computers showed persistent problems detecting the sonic. Changing the input and output buffer size of the serial port in the system settings usually solved the problem as well as once selecting a different COM- port where no instrument was attached to.

If the connection to the desired type of anemometer has been established once, this particular dialog window will not be shown again anymore, even if the Configuration button is pressed again at a later stage.

Before the data acquisition from the sonics is started they are switched to particular baud rates allowing the desired amount of data to be transmitted via the serial connection. These baud rates are 19200 for the Gill R2, the Gill R3/HS, the Young 81000V and the

Windmaster Pro and 19200 or 38400 or 57600 for the Metek USA-1 depending on the number of analog channels to be collected.
After the desired anemometer is found, the main configuration dialog appears. In case of the Gill R2 being used, it takes several seconds after having selected the anemometer until the configuration dialog window opens.

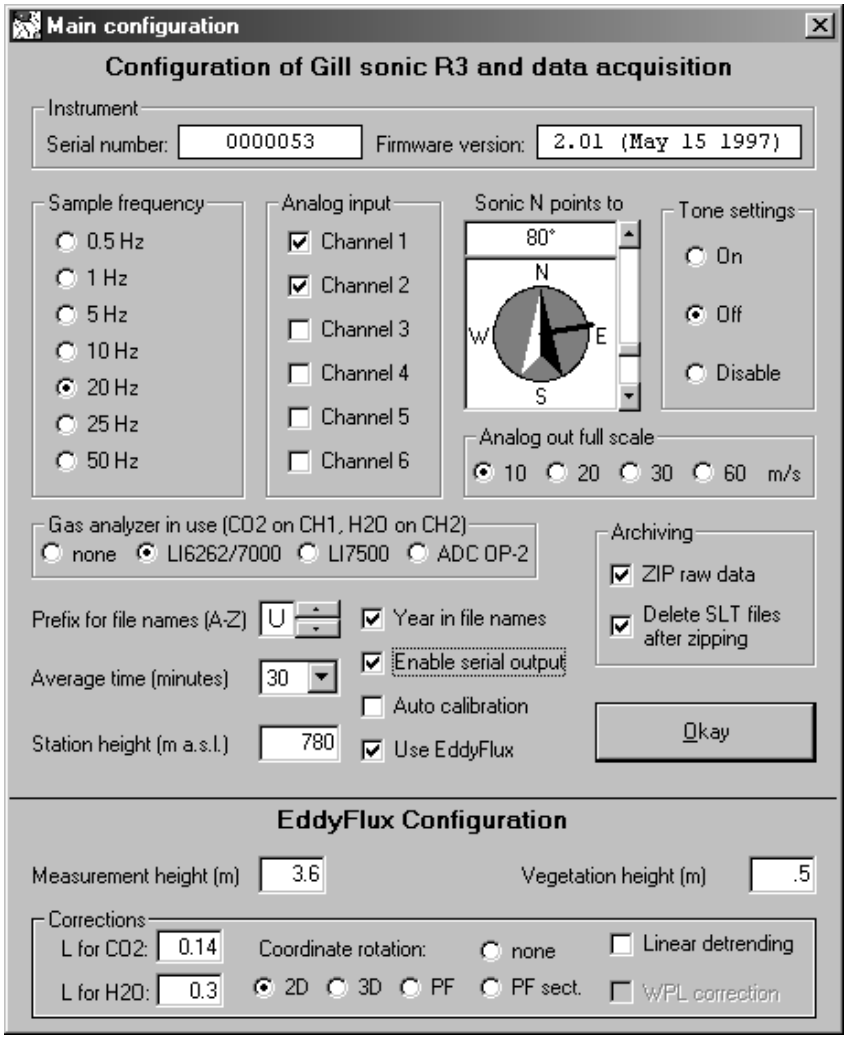


Figure 4: The general configuration dialog window

On top of the dialog window the serial number and the firmware version are shown (only for Gill R3/HS, WindMaster Pro and Metek USA-1). It is possible to select

- the sampling frequency (different options for different sonic types) which usually should be set to 20 hz (not for Gill R2 where it is fixed at 20.8 hz and not for WindMaster Pro where 10 hz is the maximum).

- the additional analog input channels which are sampled by the sonic anemometer. These are usually 6 channels but only 5 channels for the Gill R2 and only 4 channels for the Young 81000V. **For the Gill WindMaster Pro there are supported only 4 differential channels but no single ended channels**.

- the alignment angle of the sonic anemometer should be adjusted here which gives then the correct u- and v-components in the alphanumerical output field of EDDYMEAS. In case an online postprocessing is desired then this angle is handed over to EDDYFLUX for calculating the correct wind direction. For the Gill HS and the Campbell CSAT3 the direction of the arm going from the mast to the sensor head must be selected, for all other sonics the direction where the north mark points at must be adjusted.

- the tone settings where "on" means the tone is always on, "off" means the tone is off until a power failure occured and "disabled" means the tone is always off. The most useful setting is "off" because then it is possible to check whether there was a power failure. This is only available for the Gill R3/HS.

- the heating settings where the heating can be permanentely "on" or "off" or can be set to "auto" where it switches on and off automatically at a temperature a few degrees above zero. This is only available for the Metek USA-1.

- the analog output full scale deflection for the wind components if the communication interface with analog outputs is used. This is only available for the Gill R3/HS.

- whether an ADC or a LiCor gas analyzer is used to measure the CO_2 and the H_2O concentrations. It is possible to use either an ADC OP-2 analyzer or a LI6262 or a LI7000 closed path analyzer or the LI7500 open path analyzer. In all cases the CO_2 signal **must** be connected to analog input channel 1 and the H_2O signal to analog input channel 2 (in case using one of the closed path analyzers the linearized 5 V output **must** be used) at the sensor input unit of the sonic. The post processing programs are nevertheless able to process the non linearized output signals as well. If for a better frequency resolution this feature is going to be used then the non linearized CO_2 output should be connected to channel 3, the non linearized H_2O output should be connected to channel 4, the temperature output should be connected to channel 5 and the pressure output should be connected to channel 6 of the sensor input unit.

- a single character as prefix for the file names. The file names consist of the prefix character, the day of the year (ddd) and the time (hhmm) of creation (the beginning of each averaging period).

- to include the year (4 digits) in the file names. The file names then consist of the prefix character, the year (yyyy), the day of the year (ddd) and the time (hhmm) of creation (the beginning of each averaging period).

- fixed averaging periods between 2 and 60 minutes where 30 minutes is the preferred value.

- archiving options: if ZIP raw data is selected then each raw data file is added to an archive where one archive is created for each day. The names of the archives consist of the prefix character, the year (yyyy) and the day of the year (ddd) with the extension zip. If this option is selected then it is possible to select whether the original raw data files should be deleted after they are added to the archive (both options are recommended). **It is important to configure the console window (DOS-window) on the computer being used in a way that it is closed after the program running in it has terminated. Otherwise more and more windows will be opened and the system will stop after 64 averaging periods.**

- whether a serial output of the averaged values via COM-port is enabled. If the serial output is enabled then an external device can request the data by transition of the CTS (clear to send) line of the computer RS232 port from low to high (this is pin 8 on a 9-pin connector or pin 5 on a 25-pin connector). This may happen at any time during program activity because the handshake signal forces an interrupt. For a short period the program jumps to a subroutine and sends the data as string to the desired COM-port (this is on pin 3 on a 9-pin connector or on pin 2 on a 25-pin connector). The output can have two fixed but different formats depending on a gas analyzer being used or not.
  If only the sonic data are acquired then the serial output may look as follows:
  `DOY=203, TIME=1436, u= -3.45, v= 2.18, w= -0.21, T= -19.72, H= 314.76`
  If the data from a gas analyzer are acquired as well then the serial output may look as follows:
  `DOY=203, TIME=1436, u= -3.45, v= 2.18, w= -0.21, T= -19.72, CC= 358.39, CH= 11.83 H= 314.76, FC= -8.71, LE= 152.44`
  `DOY` is the day of the year, `TIME` is the time of day (hhmm), `u, v, w` are the wind components in $\mathrm{m\,s^{-1}}$ (`u` is positive from West to East, `v` is positive from South to North and `w` is positive if upward. `T` is the sonic temperature in ^{o}C, `H` is the sensible heat flux in $\mathrm{W\,m^{-2}}$. `CC` is the CO_2 concentration in $\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$, `CH` is the H_2O concentration in $\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$, `FC` is the CO_2 flux in $\mu\mathrm{mol\,m^{-2}\,s^{-1}}$ and `LE` is the latent heat flux in $\mathrm{W\,m^{-2}}$. In both cases a carriage return (ASCII 13) is the termination character.
  This feature can be used to transfer the data to a datalogger. If the datalogger can be accessed remotely via modem (GSM or normal telephone line) then it is possible to check if the computer, the sonic and the gas analyzer are working properly. An easy way to do this is using dataloggers from CAMPBELL where a serial input with a three wire connection using two control ports is working fine.

The hardware wiring is described in chapter 2.
If for any reason the data transmission from the sonic anemometer to the computer stops, EDDYMEAS keeps running without any error being reported while just waiting for new data. If in such a case an external device, for instance a datalogger, requests data from the computer, EDDYMEAS will output the same string as shown above but with all values being zero including the day of year and the time. This is important for remote check of the eddy system because in this case it is a clear indicator that the data transmission between the sonic anemometer and the computer has stopped.

- whether an automated calibration is initiated by the program by means of triggering a stand alone external device which lets calibration gases flow through a closed path gas analyzer. This option is only available if a LI6262 or a LI7000 is being used and if the averaging period is greater equal 15 minutes. If this option is activated then the program performs special steps at certain times which can be selected in the Auto Calibration Settings dialog (see figure 6). After reaching the appointed time for auto calibration the first step is to trigger the external device by a sequence of three pulses on the RTS line of the desired COM-port (this is pin 7 on a 9-pin connector or pin 4 on a 25-pin connector). As next the raw data, but only the CO_2- and the H_2O-signals (in units of $\mu\mathrm{mol\,mol}^{-1}$ and $\mathrm{mmol\,mol}^{-1}$) are written to a special file following the same naming convention as the raw data files but with the extension cal. The format of those ASCII files is described later. After **five** minutes the program switches back to normal operation by closing and archiving the calibration file and opening the usual binary raw data file. The calibration files are only archived if the archiving option for raw data files is activated. Of course there are no covariances etc. calculated during the calibration procedure. During the period of these five minutes the external device may do whatever it is designed for but has to switch back to normal inlet of ambient air not later than the time which is required to let the system equilibrate with the ambient air before expiration of this five minute calibration interval.
  The hardware wiring and trigger signal is described in chapter 2.

- whether EDDYFLUX is being used to carry out the final flux calculations.
  If this option is selected, then the dialog box is extended on the bottom showing additional options and input fields:
  - the measurement height in meters above ground and the vegetation height in meters must be typed in, these values are mainly used to calculate the footprint.
  - the values of the inductances for the CO_2- and the H_2O-signals which are used for flux corrections (the correct values must be determined in advance using spectral analysis of the cospectra with EDDYSPEC). If this correction should

not be applied e.g. if using an open path gas analyzer one or both values must be set to zero which forces EDDYFLUX not to perform this correction.

- the type of coordinate rotation which is applied on the turbulence data (standard PF rotation is the default setting which also is recommended for forest sites, for grasland or agricultural site the 2D rotation should be applied). If the PF sect. option is selected, then a sectorwise planar fit rotation is applied. Both PF and PF sect. use data for the rotation angles from a file named pfitmatrix.csv which must reside in the same directory as the program itself. PF performs a rotation using the results of a single planar fit, PF sect. performs a rotation using the results of multiple sectorwise planar fits as they are both calculated by the program EDDYPFIT (see section 14).
- a linear detrending may be activated, it is recommended not to detrend.
- in case of using one of the open path gas analyzers (LI7500 or ADC OP-2) the option of applying the WPL-correction (Webb et al., 1980) in EDDYFLUX may be selected. This option is not available when having selected one of the closed path analyzers. **The rough online calculation of the fluxes performed in EDDYMEAS automatically includes the WPL-correction by default when using an open path analyzer. This cannot be switched off.** Those results are stored in the files with the extension flx.

Important: set the correct configuration using EDDYCONF!

This means to select the correct gas analyzer, the correct positions of the gas analyzer signals within the raw data records and the correct settings for checking limits and rates of change of the raw data. If for example in EDDYMEAS the non linearized signals of the gas analyzer are sampled as well (sensor input unit channels 3 to 6) and these signals are supposed to be used for calculating the fluxes by EDDYFLUX (called from EDDYMEAS) then make sure that the appropriate settings are selected in EDDYCONF.

- Furthermore the station height (tower base) in meters above sea level must be typed in, this value together with the measurement height is used to calculate mean air pressure and air density values. It is important to have specified the correct measurement height as well, even if EDDYFLUX is not used for final flux calculations. In this case the option Use EddyFlux should be switched on to be able to enter the measurement height, and then it might be switched off again.

After leaving the main configuration dialog, a dialog window may appear in case the serial data output has been enabled. Here the desired COM-port and the baud rate can be selected. These settings are not being saved to any configuration file but may be preset by command line options (see later in this chapter).

If the Cancel button is pressed here then the serial data output is completely switched off.

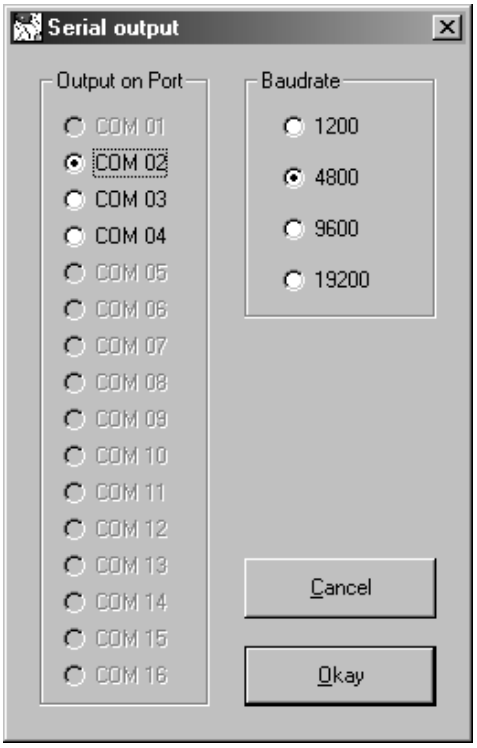


Figure 5: The serial output configuration window

If the auto calibration option was activated the dialog window shown in figure 6 appears. The COM-port for the trigger signal is only selectable if the serial data output was **not** enabled, otherwise the same COM-port as for the data output is automatically selected (see chapter 2 for wiring details).
The time for auto calibration can be selected in different ways:

- regular intervals in steps of 1, 2, 3, 4 or 6 hours where the intervals always start at midnight.
- single fixed hours one during nighttime or one during daytime or both together.

If regular intervals are selected then the single fixed hours are switched of and vice versa. If the Cancel button is pressed then the auto calibration is completely switched off.

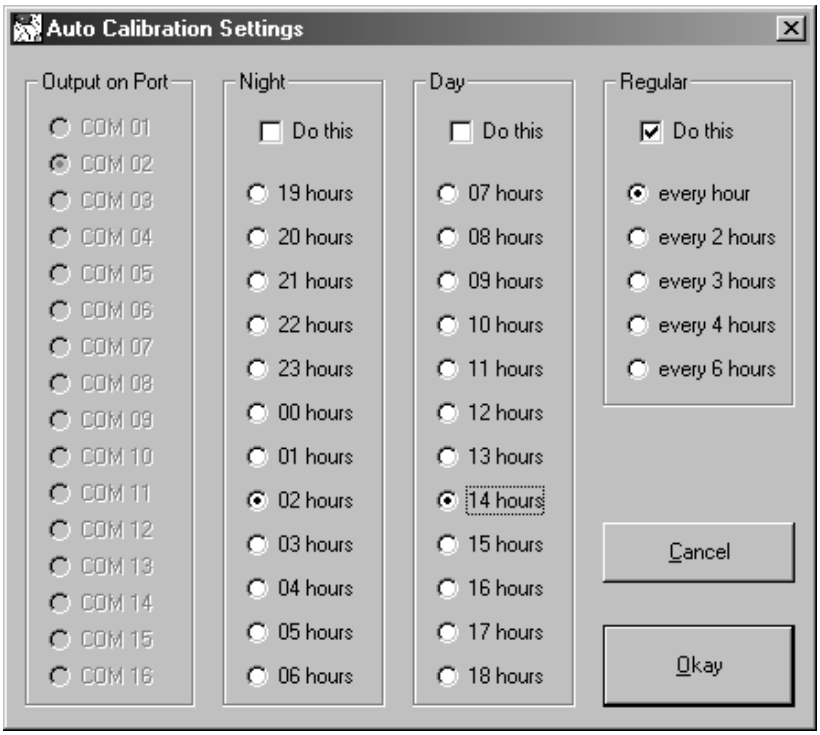


Figure 6: The auto calibration settings window

If any analog input channel is selected then a further configuration dialog appears. In case of the R2 being used it takes again several seconds after pressing the Okay button until the new configuration dialog window opens (see next page).

For each channel the name, the range (value in physical units at 0 V and at 5 V), the units and the time lag between the signal of the analog channel and the anemometer signal in seconds must be filled in. Using a closed path gas analyzer with hoses, then the time lags must be set to calculate the correct fluxes of carbon dioxide and water vapor. Using a LI7500 the time lag must be set according to the configuration of the instrument. For each channel a high resolution option may be set (HiRes). In low resolution the values of the analog channels are stored in the raw data file in a resolution of 1 mV and may range from −5000 mV to +5000 mV. If high resolution is selected, then the data are stored in a resolution of 0.1 mV but may range only from −700 mV to +5000 mV which is the case when using the linearized signals of an ADC or LiCor gas analyzer in absolute mode.

If in addition the non linearized outputs as well as the temperature and the pressure signal of the analyzer are sampled on analog channels 3 to 6 of the sensor input unit then for those channels the high resolution option <u>must not</u> be switched on.

The setting of the second option (DilOff, if checked it means that the dilution correction is switched off or not available in the instrument) determines if the dilution correction must be applied in the post processing programs. This option must be switched on if a LI7000 is used or if the dilution correction is switched off in a LI6262. With EDDYSPLIT

it is possible to modify this setting in the rawdata files (see section 10) in case it was not set correctly here or in case old rawdata files need to be modified.

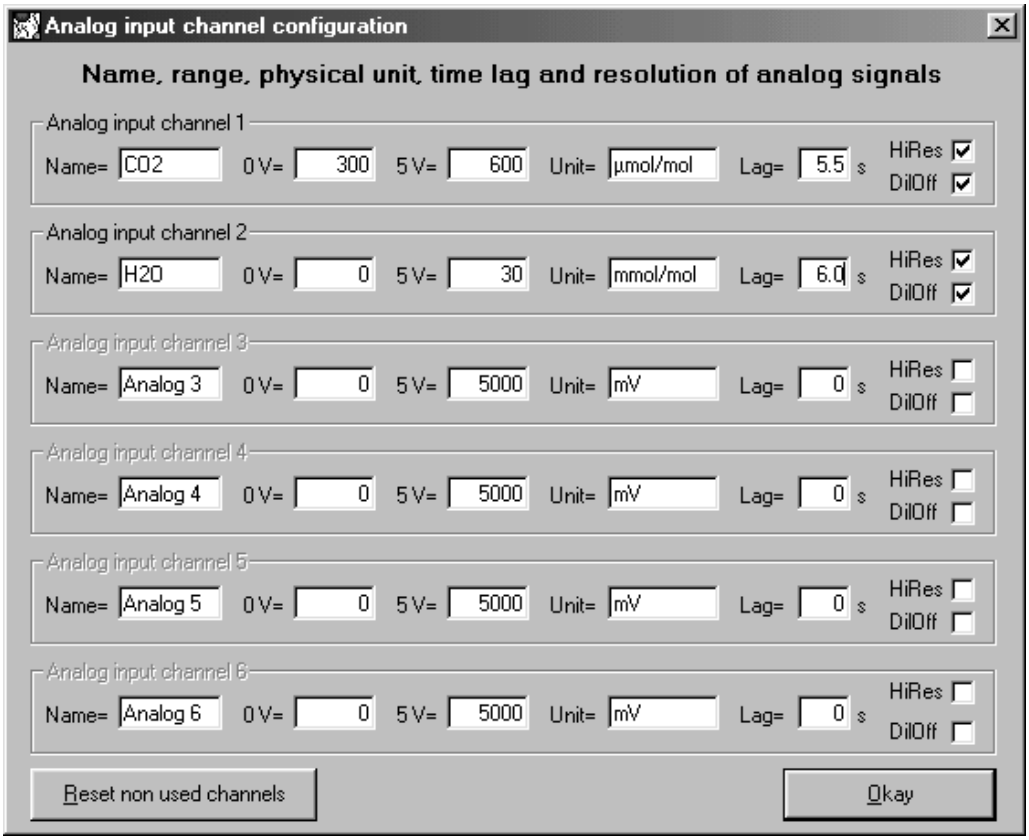


Figure 7: The analog input configuration window

After leaving the configuration dialog(s) the data acquisition can be started by pressing the Start acquisition button. If started the values of the three wind components and the speed of sound are displayed in different text boxes. If additional analog channels were selected then their voltage values are also shown. All these values are updated every second even if the scan and recording rate is higher. The status of the instrument and the quickly (according to the scan rate) changing number of the actual record within the averaging period are shown below. If in the field Display mode the Mean values option is selected then the Sonic temperature is shown instead of the speed of sound and for the analog channels physical values instead of voltages. The data fields then also contain running mean values since start of the averaging period instead of single samples.
Additional text boxes contain the actual raw data file name, the averaging period, the actual date and time and in case of occurance an error number, the procedure where and the time when it happened.
In the frame below, different informations are displayed:

- the COM-port and baud rate at which the data transfer between sonic anemometer and computer is running,

- the number of bytes which are in the communication buffer at the moment. Normally the buffer content is kept at about 50 bytes to avoid a buffer underflow, if there are additional activities on the hard disk or an intensive use of the CPU the number of bytes in the buffer will temporarily increase.
- the maximum number of bytes which have been in the communication buffer since start of the data acquisition. The size of the buffer is normally 32 kByte. If the lower progress bar is totally filled then there may have occured a buffer overflow and thus a loss of data.

Depending on the actual configuration different options for the graph on the right side are available:

- time series of wind velocity ($\mathrm{m\,s^{-1}}$),
- time series of sonic temperature (^{o}C),
- time series of sensible heat flux ($\mathrm{W\,m^{-2}}$),

If a gas analyzer is used then in addition:

- time series of CO_2 concentration ($\mu\mathrm{mol\,mol^{-1}}$ (LI6262, LI7000) or $\mathrm{mmol\,m^{-3}}$ (LI7500 or ADC OP-2)),
- time series of H_2O concentration ($\mathrm{mmol\,mol^{-1}}$ (LI6262, LI7000) or $\mathrm{mmol\,m^{-3}}$ (LI7500 or ADC OP-2)),
- time series of CO_2 flux ($\mu\mathrm{mol\,m^{-2}\,s^{-1}}$),
- time series of latent heat flux ($\mathrm{W\,m^{-2}}$).

The graph always shows 24 hours where the data of the actual day are plotted as dark blue crosses and the data of the previous day as light blue crosses so that the data of the last 24 hours are displayed. If the value of any data point exceeds the default standard y-axis then the axis is redrawn to match the new minimum or maximum. The standard y-axis limits can be restored by clicking on "Standard scale for y-axis".

The list box on the bottom of the window contains the data as tabular list for the last 48 hours. Also depending on the actual configuration different variables are listed:

- date of the data record (e.g. dd.mm.yyyy),
- time of the data record which is the end of the averaging period (e.g. hh:mm:ss),

- u-component of wind velocity in meteorological notation – positiv from east to west ($\mathrm{m\,s^{-1}}$),
- v-component of wind velocity in meteorological notation – positiv from south to north ($\mathrm{m\,s^{-1}}$),
- w-component of wind velocity in meteorological notation – upward positiv ($\mathrm{m\,s^{-1}}$),
- sonic temperature (^{o}C),
- sensible heat flux ($\mathrm{W\,m^{-2}}$),
- number of samples contributing to the mean values.

If a gas analyzer is used then in addition:

- CO_2 concentration ($\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$),
- H_2O concentration ($\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$),
- CO_2 flux ($\mu\mathrm{mol\,m^{-2}\,s^{-1}}$),
- H_2O flux ($\mathrm{mmol\,m^{-2}\,s^{-1}}$),

If the option Use EddyFlux was selected during configuration then EDDYFLUX is called in the online mode after each averaging period. Without opening a window the program starts, reads the raw data file, performes all calculations and writes the results to a file which is named as the flx file but with the extension csv. Two additional files with the extensions csu and csr are created for extra output (see section 15)

If the archiving option is set then 10 seconds later the ZIP-program is called which adds the raw data file to the archive and deletes the raw data file if this option is selected.

On the left side of the EDDYMEAS window above the data fields the program status ('please configure', 'standby' or 'running') is displayed together with the instrumentation which is currently in use.

The EDDYMEAS window can be moved on the screen and can be minimized like normal WINDOWS applications.

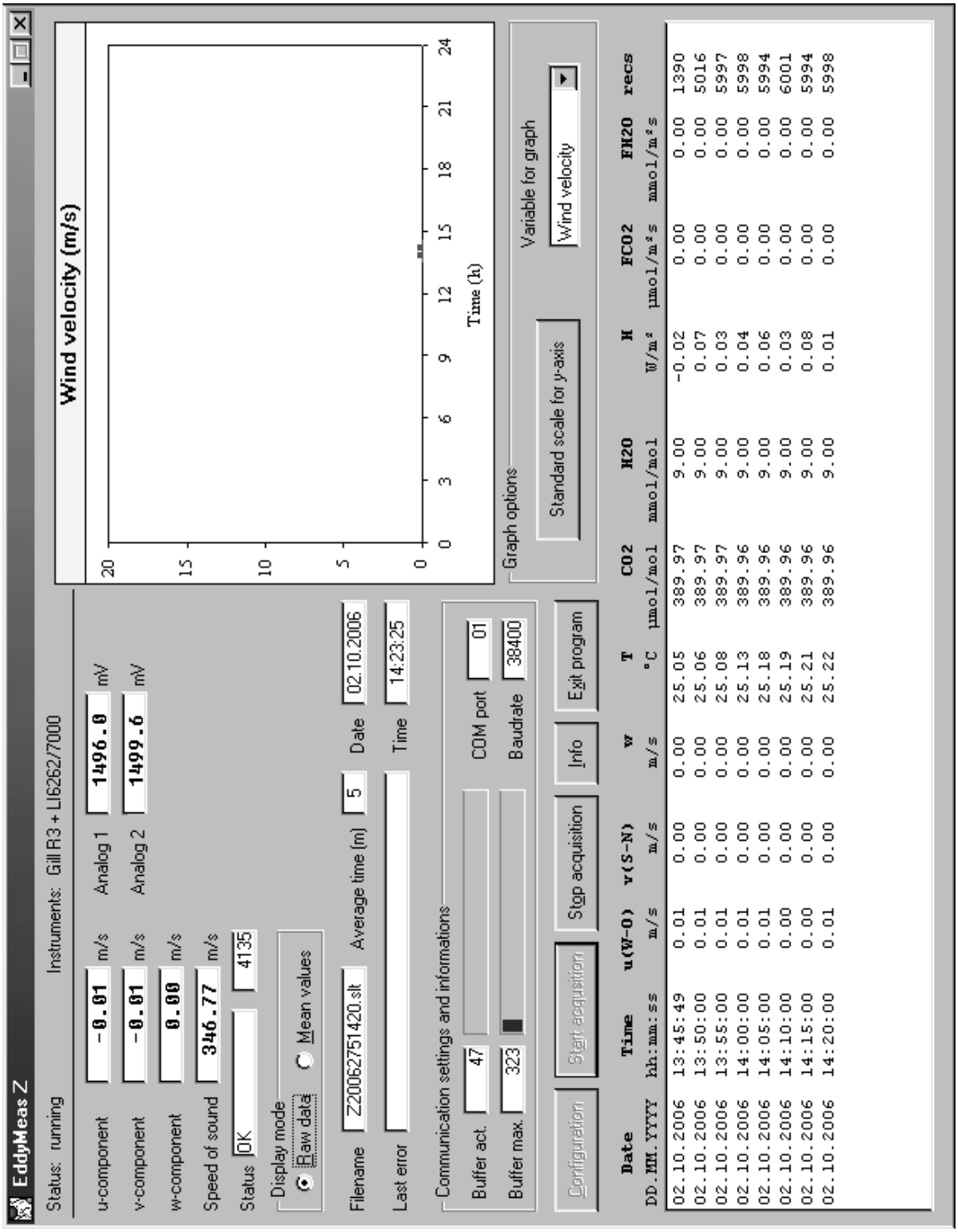


Figure 8: The EDDYMEAS window while running

The following files are created by EDDYMEAS during runtime:

1. the raw data files (extension slt) containing the high speed turbulence data in binary format with 16 bit integer numbers for each data point. Each raw data record consists of minimum 8 byte, 2 byte for each wind component $100 \cdot u$, $100 \cdot v$, $100 \cdot w$

with u, v and w in $\mathrm{m\,s^{-1}}$ and the speed of sound $50 \cdot c$ with c in $\mathrm{m\,s^{-1}}$ plus 2 byte for the voltage in mV of each additional analog channel. There is one header record with the same length containing

number of bytes per record	byte 1
major version number of EDDYMEAS	byte 2
day in month	byte 3
month	byte 4
first two digits of year	byte 5
last two digits of year	byte 6
hour	byte 7
minute	byte 8
if analog channels are being used then	
bit mask for options	byte 9
channel number	byte 10
bit mask for options	byte 11
channel number	byte 12
.	.
.	.
.	.

Bit 0 (LSB) in the options bit mask is set if the high resolution option for the specific analog channel is selected. All post processing programs are checking for that bit to correctly process the data. In case of high resolution the 16 bit integer numbers contain $10 \cdot U - 25000$ where U is the voltage in mV.
Bit 1 in the options bit mask is set if the dilution off option for the specific analog channel is selected. All post processing programs are checking for that bit to correctly process the data. If the dilution correction must be performed in the post processing programs, the following formula is used $[CO_2] = [CO_2]/(1 - [H_2O]/1000)$ where $[H_2O]$ is given in $\mathrm{mmol\,mol^{-1}}$.
All remaining 6 bits are reserved for future use.

2. the calibration data files (extension cal) containing the high speed concentration data in ASCII format in case the auto calibration option was activated. Following are the first few lines of a sample calibration data file:

```
Autocalibration File at Site H
Date (DDMMYYYY): 06082002
Time (HHMMSS): 150000
379.03, 7.91
```

```
379.03, 7.91
379.03, 7.91
379.03, 7.91
379.03, 7.91
379.03, 7.91
379.03, 7.91
379.03, 7.91
379.03, 7.91
   .      .
   .      .
```

The last character of the first line is equal to the prefix character for all files entered in the general configuration dialog representing the site. Date and time are the beginning of the five minute calibration interval. Following are the CO_2- and H_2O concentration data in μmol mol^{-1} and mmol mol^{-1} (6000 lines in case of 20 Hz sampling frequency).

3. a configuration file (extension cfg) containing the sample frequency, the average period and all settings of the analog channel configuration dialog which is important to know in case of postprocessing of the data. The last character of the lines containing the settings of the analog channels can be 'E' (enabled) of 'D' (disabled) which clearly indicates which channels had been measured and which not. The following is an example of a configuration file:

```
[Settings for EddyMeas]
Sonic: Gill R3
Analyzer: LI6262/7000
Sonic alignment:  80 deg
Sample frequency: 20 hz
Average time: 30 min
CO2, 300 , 600 , µmol/mol , 2.8 , E
H2O, 0 , 30 , mmol/mol , 3.55 , E
CO2, 12 , 26 , mmol/m3 , 0.4 , E
H2O, 0 , 1200 , mmol/m3 , 0.4 , E
Analog 5, 0 , 5000 , mV , 0 , D
Analog 6, 0 , 5000 , mV , 0 , D
Station height: 161.2 m
[Settings for EddyFlux]
Measurement height: 6.03 m
Vegetation height: 0.1 m
Inductance for CO2: 0.25
Inductance for H2O: 0.6
Coordinate rotation:  2-dimensional
Webb correction:  no
Linear detrending:  yes
```

4. a flux file (extension flx) containing averages, variances and fluxes as mean values for each averaging period – these online calculated fluxes are determined from the covariances using running means over the whole averaging period with no detrending, no coordinate rotation and no corrections. The following variables are written to the file where the header line contains the symbols on the left side:

Symbol	**Unit**	**Variable**
Date & Time	format settings	date and time of end of record
u	$\mathrm{m\,s^{-1}}$	average of u-component (sonic coordinates)
v	$\mathrm{m\,s^{-1}}$	average of v-component (sonic coordinates)
w	$\mathrm{m\,s^{-1}}$	average of w-component (sonic coordinates)
T	^{o}C	temperature measured by Sonic
$CO2^*$	$\mu\mathrm{mol\,mol^{-1}}$	CO_2-concentration, LI6262, LI7000
	$\mathrm{mmol\,m^{-3}}$	or CO_2-concentration, LI7500, ADC OP-2
$H2O^*$	$\mathrm{mmol\,mol^{-1}}$	H_2O-concentration, LI6262, LI7000
	$\mathrm{mmol\,m^{-3}}$	or H_2O-concentration, LI7500, ADC OP-2
var u	$\mathrm{m^2\,s^{-2}}$	variance of u-component
var v	$\mathrm{m^2\,s^{-2}}$	variance of v-component
var w	$\mathrm{m^2\,s^{-2}}$	variance of w-component
var T	$\mathrm{K^2}$	variance of temperature
var $CO2^*$	$\mu\mathrm{mol^2\,mol^{-2}}$	variance of CO_2-concentration, LI6262, LI7000
	$\mathrm{mmol^2\,m^{-6}}$	or variance of CO_2-concentration, LI7500, ADC OP-2
var $H2O^*$	$\mathrm{mmol^2\,mol^{-2}}$	variance of H_2O-concentration, LI6262, LI7000
	$\mathrm{mmol^2\,m^{-6}}$	or variance of H_2O-concentration, LI7500, ADC OP-2
$u'w'$	$\mathrm{m^2\,s^{-2}}$	covariance of u-component and w-component
$v'w'$	$\mathrm{m^2\,s^{-2}}$	covariance of v-component and w-component
ustar	$\mathrm{m\,s^{-1}}$	friction velocity
H	$\mathrm{W\,m^{-2}}$	sensible heat flux
$FCO2^*$	$\mu\mathrm{mol\,m^{-2}\,s^{-1}}$	CO_2 flux
$FH2O^*$	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	H_2O flux
covar wt	$\mathrm{K\,m\,s^{-1}}$	covariance of T and w-component
covar wc^*	$\mu\mathrm{mol\,m\,s^{-1}\,mol^{-1}}$	covariance of $[CO_2]$ and w, LI6262, LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of $[CO_2]$ and w, LI7500, ADC OP-2
covar wh^*	$\mathrm{mmol\,m\,s^{-1}\,mol^{-1}}$	covariance of $[H_2O]$ and w, LI6262, LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of $[H_2O]$ and w, LI7500, ADC OP-2
rho	$\mathrm{kg\,m^{-3}}$	air density used to calculate fluxes
recs	–	number of records during average period
heated	–	heating status: 0=off, 1=on (only Metek USA-1)

The items marked with an asterisk are only written to the file if a gas analyzer is connected.

5. a data transmission file (extension txd) containing one line of text with data which are supposed to be read by the program Eddy_TxD (see section 3) in case it is

running, to be transmitted to an external device when requested. The name of the file is for instance ?_Eddy.txd where the question mark stands for the station prefix character which was specified in the first configuration dialog of EDDYMEAS. The data transmission file is always generated regardless of any option settings. The format of the file is exactly the same as the format for the direct serial output of EDDYMEAS in case of having activated the Enable serial output option. This format is shown and described on page 6.

6. a log file (extension log) containing messages about errors which may occur during one run – mainly the message "checksum error" is found which indicates errors in the serial data transfer from the sonic to the computer. Each error message is stored together with date and time of occurance. The size of this error log file is limited to 432000 error messages which is enough for 6 hours of persistant errors at 20 hz. After this, errors are not logged anymore but at the end of the log file a message will appear telling that there have been such-and-such many additional errors. The maximum size of the log file is thus limited to approx. 18 MByte. The following example shows some of the possible error messages:

```
16.05.1999 10:12:14 Checksum error
16.05.1999 10:12:16 Memory error
16.05.1999 10:12:18 Transducer failure
16.05.1999 10:12:22 6 in Acquisition
16.05.1999 10:12:23 6 in Acquisition
16.05.1999 10:12:24 6 in WriteData

14.06.2006 14:31:06 invalid data (005)
```

The raw data files are created one for each averaging period and named, depending on the settings, either as Xdddhhmm.slt or Xyyyydddhhmm.slt where X is the prefix character. The latter three files are each created only once for each run where a run starts clicking on the Start acquisition button and ends clicking on the Stop acquisition or Exit program button. They are named as the first raw data file with the different extensions. All these files are created in a subdirectory named EDDYDATA located in the same directory as the program itself. In the program's directory all settings of the configuration dialog are stored in a file named Eddymeas.cfg. The following is an example of the configuration file:

```
[Sonic]
3
[sample frequency]
4
[confidence tone]
1
[analog input channel 1]
1
CO2, 300 , 600 ,µmol/mol, 2.8 , 1
[analog input channel 2]
1
H2O, 0 , 30 ,mmol/mol, 3.55 , 1
[analog input channel 3]
1
CO2, 12 , 26 ,mmol/m3, 0.4 , 1
[analog input channel 4]
1
H2O, 0 , 1200 ,mmol/m3, 0.4 , 1
[analog input channel 5]
0
Analog 5, 0 , 5000 ,mV, 0 , 0
[analog input channel 6]
0
Analog 6, 0 , 5000 ,mV, 0 , 0
[analog output FSD]
2
[prefix for filenames]
U
[year in filenames]
1
[average time (index)]
5
[Analyzer]
1
[Station height]
161.2
[Eddyflux]
1
[Archiving]
1 , 1
[Serial output]
1
[Auto calibration]
1 , 0 , 0 , 1 , 7 , 7 , 0
[Heights]
6.03 , 0.1
[Inductances]
0.2 , 0.6
[Coordinate rotation]
1
[Webb correction]
0
[Linear detrending]
0
[Sonic alignment]
80
```

Clicking on the Info button of the EDDYMEAS window will show some information about the program:

This window disappears after about 10 seconds if it is not closed before.

Figure 9: The EDDYMEAS info window

Using EDDYMEAS in the autostart mode

Sice version 11 EDDYMEAS is capable to run in an autostart mode. This feature may be used to automatically restart the data acquisition after power failure and reboot of the computer. To activate the autostart mode a shortcut for EDDYMEAS must be created in the autostart folder of WINDOWS. The command line option in the second page of the properties dialog of the shortcut must be modified because EDDYMEAS must be started using some command line parameters. The command line parameters may generally be used but are essential for the autostart mode. Between one and four parameters are allowed. The following line shows an example:

Eddymeas.exe 10,1,3,9600

- the 1st parameter determines the start mode. 0 means normal start, a number greater 1 means autostart where the number determines the delay in seconds before the automatic configuration routines will start (10 seconds in the above example). Numbers greater than 60 will be limited to 60. In the autostart mode no activities from the user are necessary.

- the 2nd parameter determines the COM-port number to be used for data input from the sonic. This parameter is not member of the EDDYMEAS configuration file and must always be set as first after program start. By default the program uses the first available COM-port (usually COM1).

- the 3rd parameter determines the COM-port number to be used for data output from the computer. This parameter is not member of the EDDYMEAS configuration file and must be set during configuration if the serial data output is enabled. By default the program uses the second available COM-port (usually COM2).

- the 4th parameter determines the baud rate to be used for data output from the computer. This parameter is not member of the EDDYMEAS configuration file and must be set during configuration if the serial data output is enabled. By default the program uses 4800 baud.

In the example above EDDYMEAS is started in autostart mode using COM1 for data input and COM3 at 9600 baud for data output. Starting EDDYMEAS without any parameter is the same as starting the program with only the first parameter being 0.

After start of EDDYMEAS in the autostart mode firstly the usual window (see fig. 2) appears with a small window on top:

Figure 10: The EDDYMEAS autostart message

During the desired delay period the user is able to cancel the autostart and proceed with the manual configuration. After the delay period a message appears showing which sonic anemometer is selected. After two seconds the first configuration dialog (see fig. 4) automatically appears with all the previous settings. The dialog remains visible for a two second period then the dialog for the serial data output (see fig. 5) appears if this option was selected in the first configuration dialog. This dialog as well remains visible for two seconds. Depending on the settings in the first configuration dialog the second configuration dialog (see fig. 7) appears for another two seconds. After all the configuration dialogs are automatically closed the data acquisition automatically starts.
In case of communication problems during search for the sonic on the desired COM-port at different baud rates an additional message may appear:

Figure 11: The EDDYMEAS instrument search message

If the instrument is not detected in the first phase then it is usually found after one or two more attempts. If for any reason the sonic is down then the program will remain in this loop until it is cancelled by the user.

2 Hardware

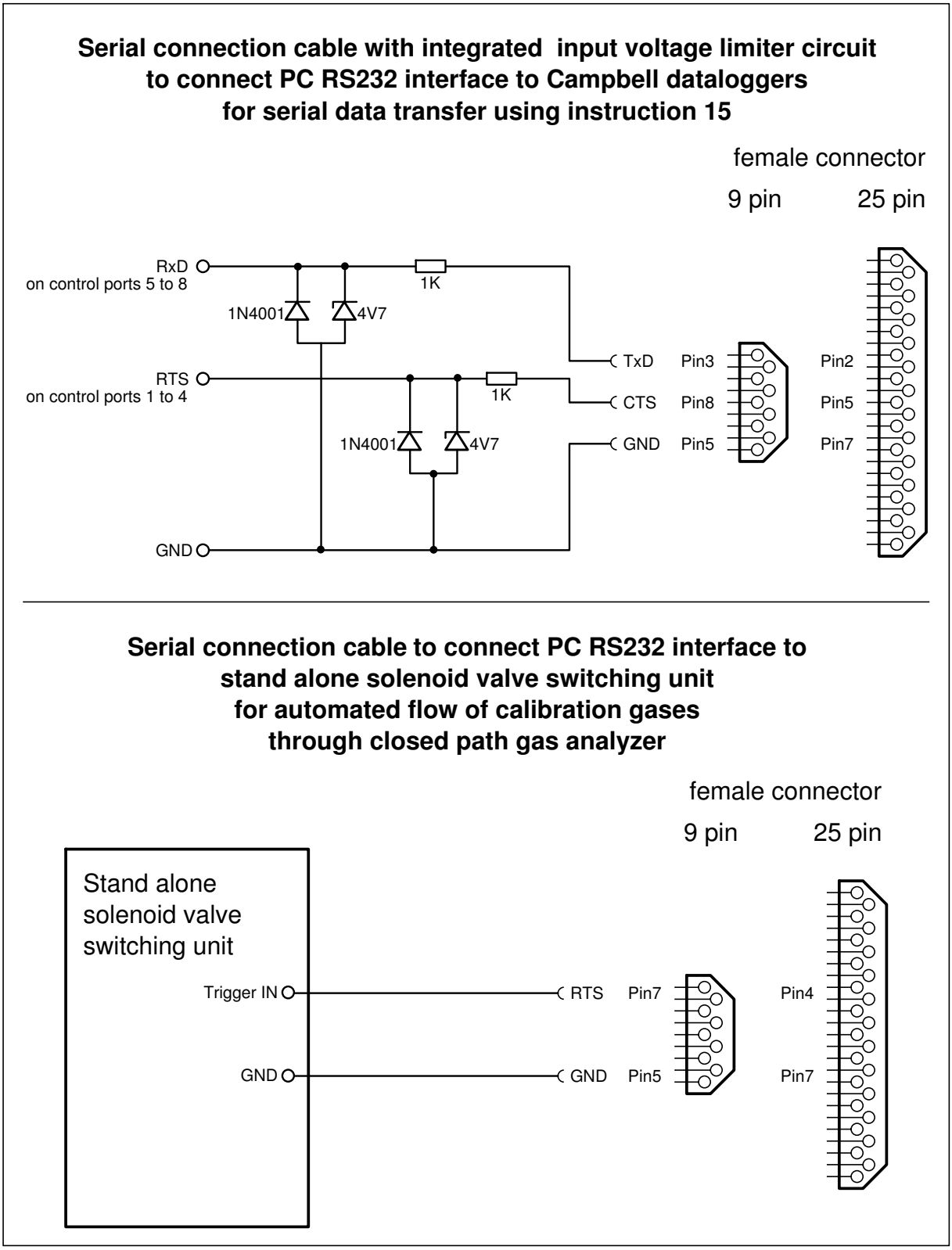
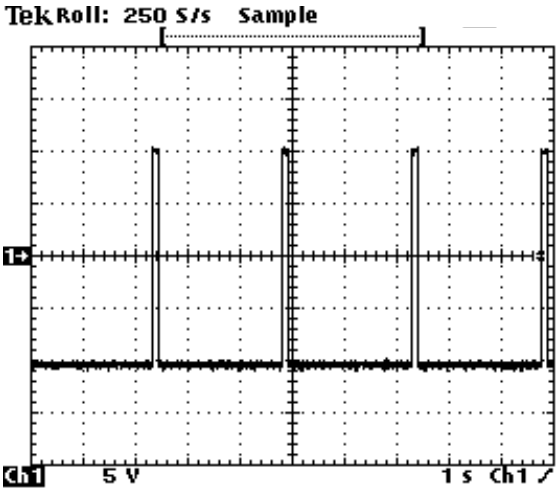
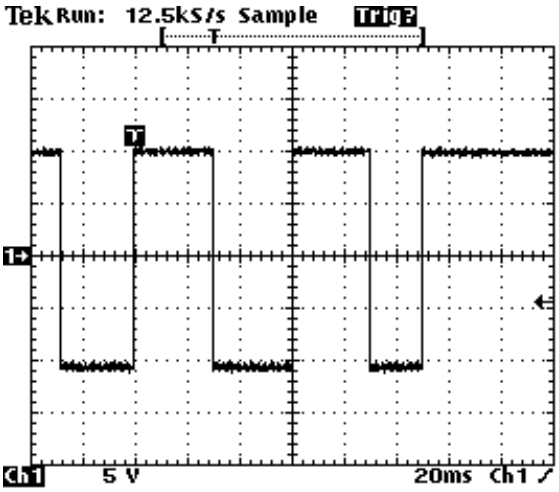


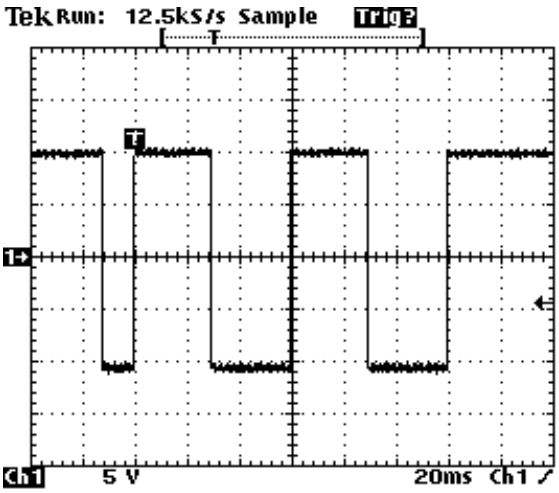
Figure 12: Wiring of the second serial port for data output and/or to trigger an auto calibration device

RTS signal to trigger auto calibration switching unit



RTS signal if computer is switched on, WINDOWS is running but no program is active:
approx. every 2.5s RTS goes from -10V to +10V for 120ms.





If EDDYMEAS is in normal operation then the RTS line is high (+10V).
If trigger signal is generated by the EDDYMEAS program then RTS goes three times from +10V to -10V and back, the pulse width can vary between 10ms and 30ms.
The total time for all three pulses is less than 200ms.

Figure 13: Trigger signal on RTS line of second serial port for auto calibration device

3 EDDY_TXD – data transfer utility

EDDY_TXD is a small utility program which allows monitoring of more than one eddy systems from one computer via a connection to a datalogger which can be accessed through modem. If two or more copies of EDDYMEAS are running on one computer then it is under normal conditions not possible to have a serial data transfer to an external device from more than one instance of the EDDYMEAS program. On the other hand it would be very convenient to be able to remotely check all eddy systems which data are collected by one single computer. This is possible by making use of the program EDDY_TXD. Best is to place a shortcut to this program in the StartUp folder of WINDOWS - there is no need to take any additional action after the program has started. The program simply waits for a request of data as described on page 6. The program reads the content of all files specified in eddytxd.ini and transmits them over the specified COM-port with the specified baud rate. The connected external device can then receive these data to make them available for remote check. eddytxd.ini must look comparable to this:

```
1
9600
C:\Tower1\W_Eddy.txd
C:\Tower2\X_Eddy.txd
    .       .
```

The first line contains the COM-port number, followed by the second line with the baud rate. Each of the next lines contains one complete filename with path in which the data to be transmitted are stored. More information about these files and their format can be found on page 6 and 17.

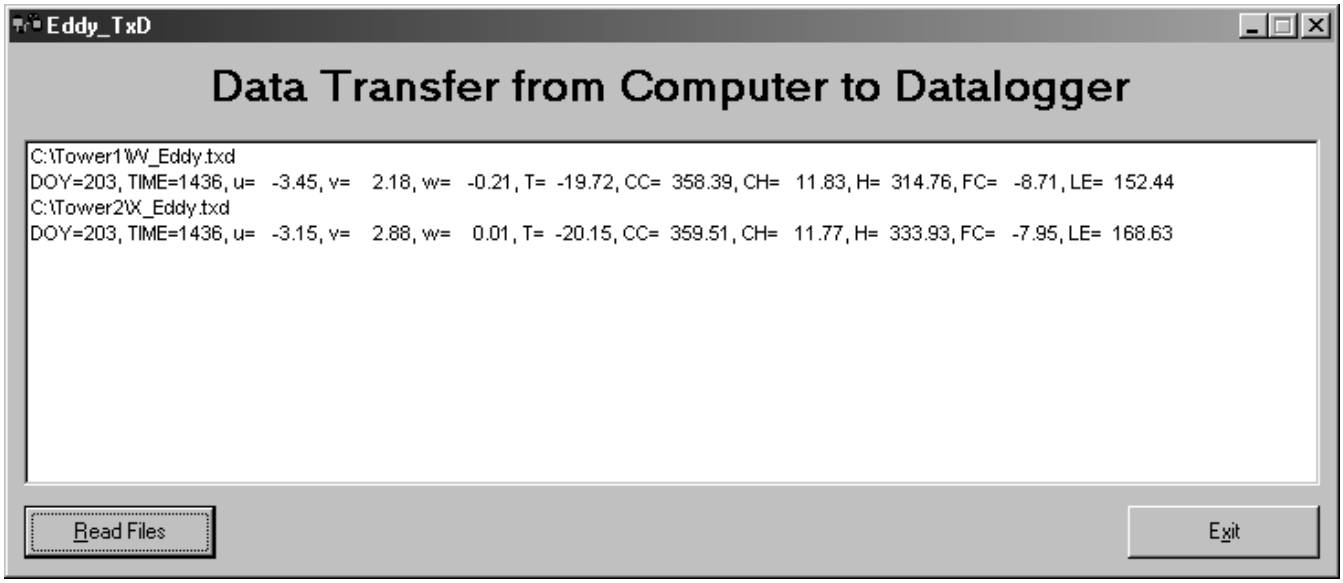


Figure 14: Main window of EDDY_TXD

If the button Read Files is pressed then the content of the files which are specified in eddytxd.ini is read and displayed in the window together with the names of the files. The same information is displayed every time a data transmission is requested by the external device.

If this program is used then the option Enable serial output must be switched of in all running copies of EDDYMEAS.

4 LI7500Log – LI7500 monitoring

This small tool allows to monitor and log several parameters of an LI7500 open path gas analyzer parallel to a running EDDYMEAS data acquisition. The LI7500 must be connected to the computer via a separate RS232-connection. After the program is loaded the main window of LI7500Log appears as shown in figure 15.

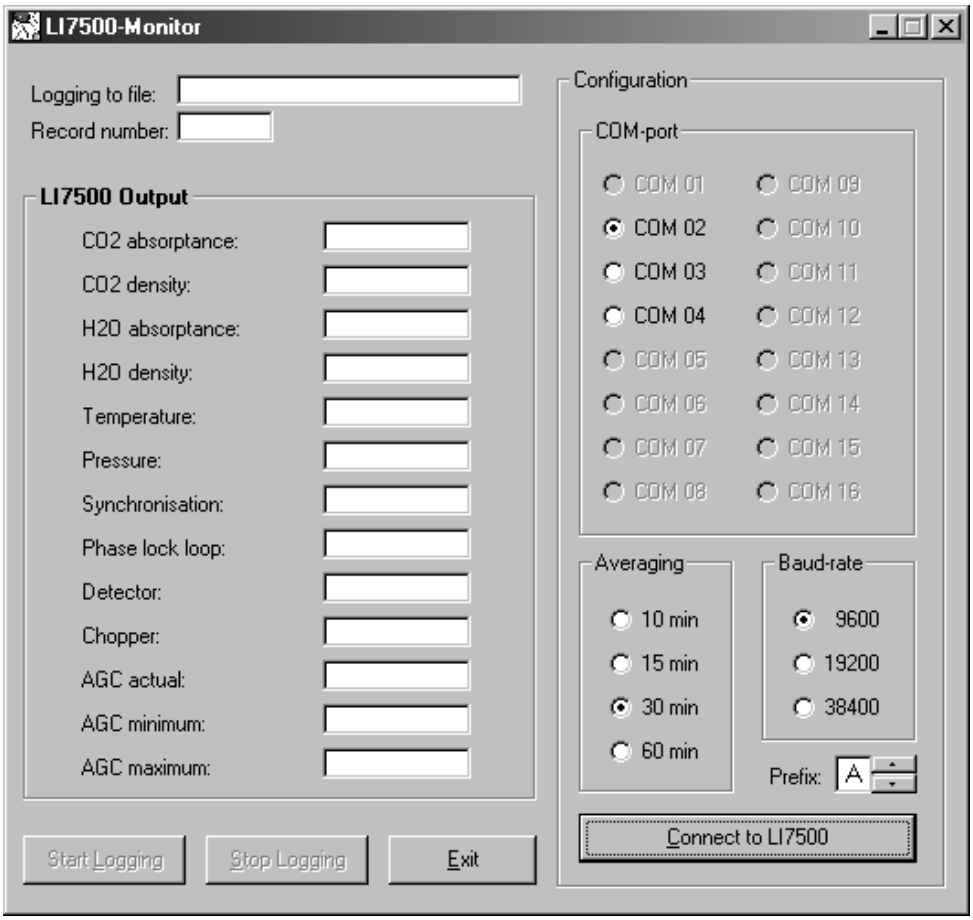


Figure 15: Main window of LI7500Log

The first step is to select the configuration options as needed such as the correct COM-port to which the instrument is connected to and the baud rate. For longer serial cables it is recommended to use only 9600 baud. The averaging period should be set to the same value as it is used in the EDDYMEAS data acquisition so that the data records correspond to each other. As well it is convenient to use the same prefix character for the output file names as it is used in EDDYMEAS for the same site. Having the configuration completed it is necessary to establish the communication between the computer and the LI7500 by pressing the Connect to LI7500 button.
Whenever it is desired logging of the data can be started by pressing the Start Logging button.

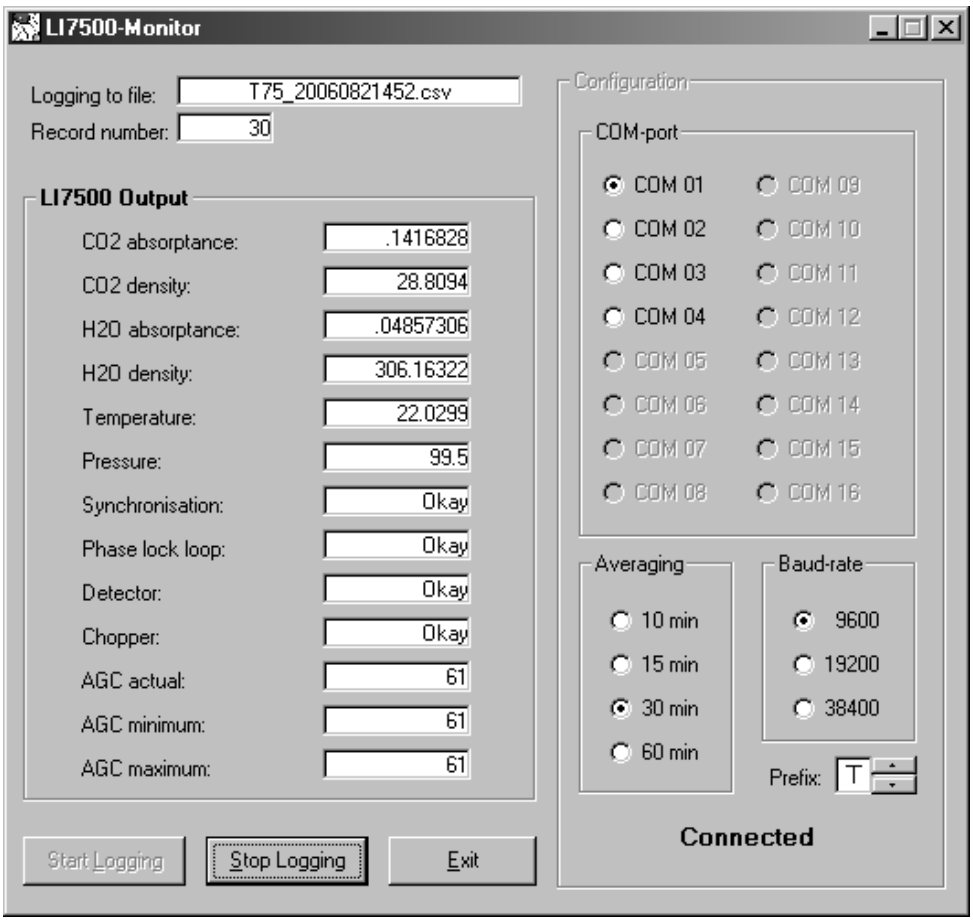


Figure 16: Main window of LI7500Log while logging

The data are sent from the LI7500 to the computer once a second and immediately displayed in the according fields. The fields CO2 absorptance, CO2 density, H2O absorptance, H2O density, Temperature and Pressure show the actual values. The fields Synchronisation, Phase lock loop, Detector and Chopper show either Okay or NOT Okay. The field AGC actual shows the actual value of the AGC (automatic gain control) and the two fileds below show the AGC minimum and maximum value during the averaging period.
The data output files of LI7500Log are named as X75_yyyydddhhmm.csv where X is the desired prefix character. The name of the file to which data are written and the number of records which have been transmitted from the instrument during the actual averaging period are shown in the upper left corner of the window. As long as datalogging has not been stopped, data are continuously appended to the output file. The program does not write each record which was received from the LI7500 to the file, there is only one line of data for each averaging period. For the upper six fields the averages over the averaging period are written to the file. For the four status fields the number of faults during the averaging period are written to the file and for the three AGC fields the average, minimum and maximum during each averaging period are written to the file. Following is an example of the data output file:

```
Date Time,CO2Raw,CO2D,H2ORaw,H2OD,Temp,Press,n1,Sync_f,Pll_f,DetOK_f,Chopper_f,Path_avg,Path_min,Path_max,n2
23.03.2006 15:00, 0.14265, 29.0928, 0.04873, 306.550, 22.32, 99.5,  462, 0, 0, 0, 0, 61, 61, 61,  461
23.03.2006 15:30, 0.14732, 30.5118, 0.04922, 310.419, 23.38, 99.5, 1800, 0, 0, 0, 0, 61, 61, 61, 1800
23.03.2006 16:00, 0.15380, 32.5298, 0.04927, 310.821, 24.18, 99.5, 1800, 0, 0, 0, 0, 61, 61, 61, 1800
   .            .            .            .            .            .            .         .
   .            .            .            .            .            .            .         .
```

where $n1$ is the number of data records received from the LI7500 and $n2$ is the number of status records received from the instrument; they may differ by a few records.

The configuration file for LI7500Log.cfg for this program may look as follows:

```
[Settings]
1 , 3 , 1 ,W
[Auto Minimize]
10
```

where the first parameter of the `[Settings]` section indicates the COM-port, the second parameter is the index of the baud rate (1=9600, 2=19200, 3=38400), the third parameter is the index of the averaging period (1=10 min, 2=15 min, 3=30 min, 4=60 min) and the fourth parameter is the prefix character for the output files.
The first and only parameter in the `[Auto Minimize]` section specifies the time in seconds after which the LI7500Log window is being minimized automatically. It can of course be reopened at any time from the task bar but will then again be minimized automatically. In some cases (especially on WIN95) it may happen that LI7500Log in some way interferes with EDDYMEAS resulting in the serial data buffer of EDDYMEAS being steadily filled which may lead to data loss. This happens only if the LI7500Log window is in the foreground and can be avioded by activating the auto minimize option. By specifying 0 (zero) as auto minimize time this option is disabled and the window will stay open.

The major purpose of this program is to easily detect situations where the LI7500 didn't operate properly due to rain or dew formation or disturbance by insects. Mainly by looking at the AGC values those periods can be identified where the flux data should be discarded or flagged as data of poor quality.

Using LI7500Log in the autostart mode

Sice version 3.3 LI7500Log is capable to run in an autostart mode. This feature may be used to automatically restart the data acquisition after power failure and reboot of the computer. To activate the autostart mode a shortcut for LI7500Log must be created in the autostart folder of WINDOWS. The command line option in the second page of the properties dialog of the shortcut must be modified because LI7500Log must be started using one command line parameter. The following line shows an example:

LI7500Log.exe 5

where the only parameter determines the start mode. 0 means normal start, a number greater 1 means autostart where the number determines the delay in seconds before the automatic configuration routine will start (5 seconds in the above example). Numbers greater than 60 will be limited to 60. In the autostart mode no activities from the user are necessary.

After start of LI7500Log in the autostart mode firstly the usual window (see fig. 15) appears with a small window on top:

Figure 17: The LI7500Log autostart message

During the desired delay period the user is able to cancel the autostart and proceed with the manual configuration. After the delay period the program tries to connect to the instrument, to configure it and to start the data acquisition automatically.
In case of communication problems during search for the instrument an additional message may appear:

Figure 18: The LI7500Log instrument search message

If the instrument is not detected in the first phase then it is usually found after one or two more attempts. If for any reason the instrument is down then the program will remain in this loop until it is cancelled by the user.

5 Postprocessing software – general remarks

All programs are created in a similar way. They consist of a graphical user interface written in VisualBasic and a Fortran90 program which performs the calculations. In the VisualBasic dialogs all configuration parameters and selections are set and are written to two files (the parameter file and the information file). These files are read from the Fortran90 program which is called by pressing the button calculate. After choosing everything appropriately within the VisualBasic dialog one or more raw data files must be selected by clicking on the select files button which forces a file selector to be displayed. This is not the standard WINDOWS file selector.
Directories are opened by a single click, names for new files must be typed into the text box at the top right corner (they appear in red color). By using the SHIFT- or CTRL-key or staying on the left mouse- button it is possible to select more than one file.

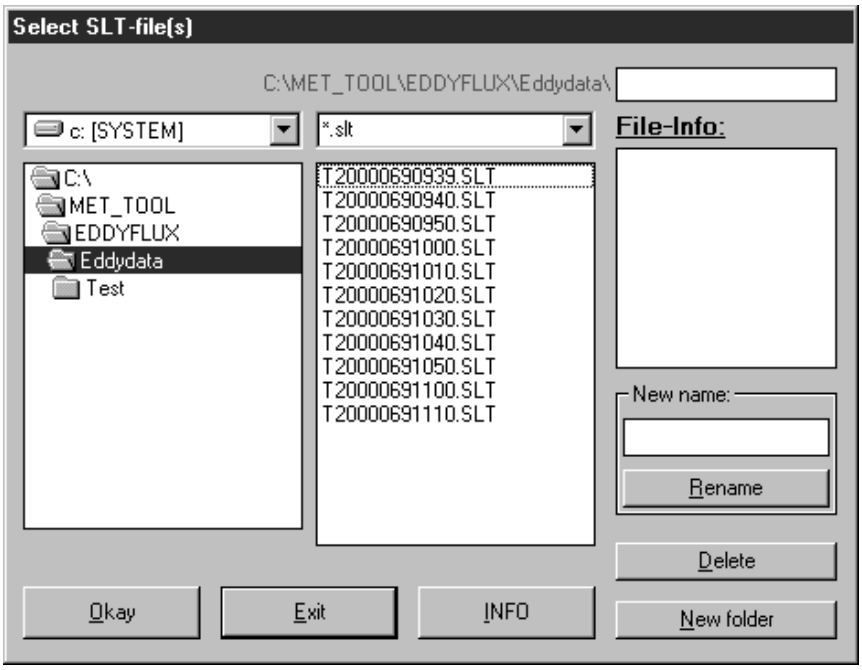


Figure 19: The FILESELECT dialog window

The selected files will appear in the window selected files. The number of files may be smaller here than the initially selected number because files of a size less than 100 byte are rejected. After selecting calculation, the connected Fortran90 program is started coming up with a separate window. Different control outputs for each program will be displayed in that window. Pressing Enter closes the window after the program has finished, the programs may also be interrupted by pressing the Esc key. The resulting csv files (comma separated values) can be imported into any graphic software for visualization.

Eddyread_p.exe, Eddycorr_p.exe, Eddyspec_p.exe, Eddyflux_p.exe and Eddypfit_p, the Fortran90 executable parts, can as well be used independently from the VisualBasic

parts. They may for instance be called from batch files which automatically build the needed parameter files. Usually one must hit the ENTER key to close the processing window of those programs. This can be overcome by calling the programs with the command line option /cw which forces the window being closed after the calculations are finished. Furthermore the command line option /mw can be used which forces the programs to run in the background with minimized window and to terminate without user interaction.

Programs which write the wind components u and v to a file as EDDYMEAS, EDDYREAD and EDDYFLUX do this in different ways. EDDYMEAS and EDDYREAD do **not** rotate the horizontal wind components, they are written to the file as they come from the sonic. **Attention:** due to the fact that the Metek USA-1 uses a left-handed coordinate system EDDYMEAS assigns the y-axis data to the wind vectors u-component and the x-axis data to the wind vectors v-component resulting in a right-handed coordinate system. So already the raw data files contain swapped horizontal wind components!
EDDYFLUX writes the wind components in different ways to the different output files. In the csv files u runs positive from West to East and v runs positive from South to North. The csu files contain unrotated wind components as they come from the sonic and the csr files contain rotated wind components so that u is aligned to the mean wind direction and $\overline{v} = 0$ and $\overline{w} = 0$. If one of the two planar fit rotation procedures was selected then there will be three additional columns at the right end of the csr files containing the three wind components directly after the planar fit rotation. EDDYREAD and EDDYFLUX calculate the wind direction taking into account the adjustment for the alignment of the sonic anemometer. For the Gill HS and the Campbell CSAT3 the direction of the arm going from the mast to the sensor head must be selected in EDDYMEAS, EDDYREAD EDDYPFIT and EDDYFLUX, for all other sonics the direction where the north mark points at must be adjusted.
EDDYSPEC of course rotates the components before calculating the spectra so that u is aligned to the mean wind direction and $\overline{v} = 0$.

In EDDYREAD, EDDYCORR, EDDYSPEC and EDDYFLUX it is possible to combine up to 6 raw data files before the data are being processed. This is done by setting the slider bar within the calculate from frame to the desired number of files. By default the maximum number of records that can be processed in one step is 200000. That means for data sampled at 20 Hz five half hourly files may be combined which gives about 180000 records. This limitation was built in to avoid a memory overflow. If needed and with enough computer memory this limit may be changed in the configuration program EDDYCONF.

6 EDDYCONF – configuration utility

With EDDYCONF some general settings can be configured which are used by all post processing programs as EDDYREAD, EDDYCORR, EDDYSPEC and EDDYFLUX and partly in EDDYMEAS and LI7500Log and only to set the language in EDDYZIP, EDDYSHOW, EDDYSPLIT and EDDYPFIT.

The default language for the above mentioned programs can be selected here.

The maximum number of records determines how many records can be processed in one step and is limited by the memory of the computer. This means that either one raw data file may contain up to this number of records, or if raw data files are combined (see above), they may contain up to this number of records in total. If the number is too big for the computer memory an error message will appear later during run time of any of the post processing programs.

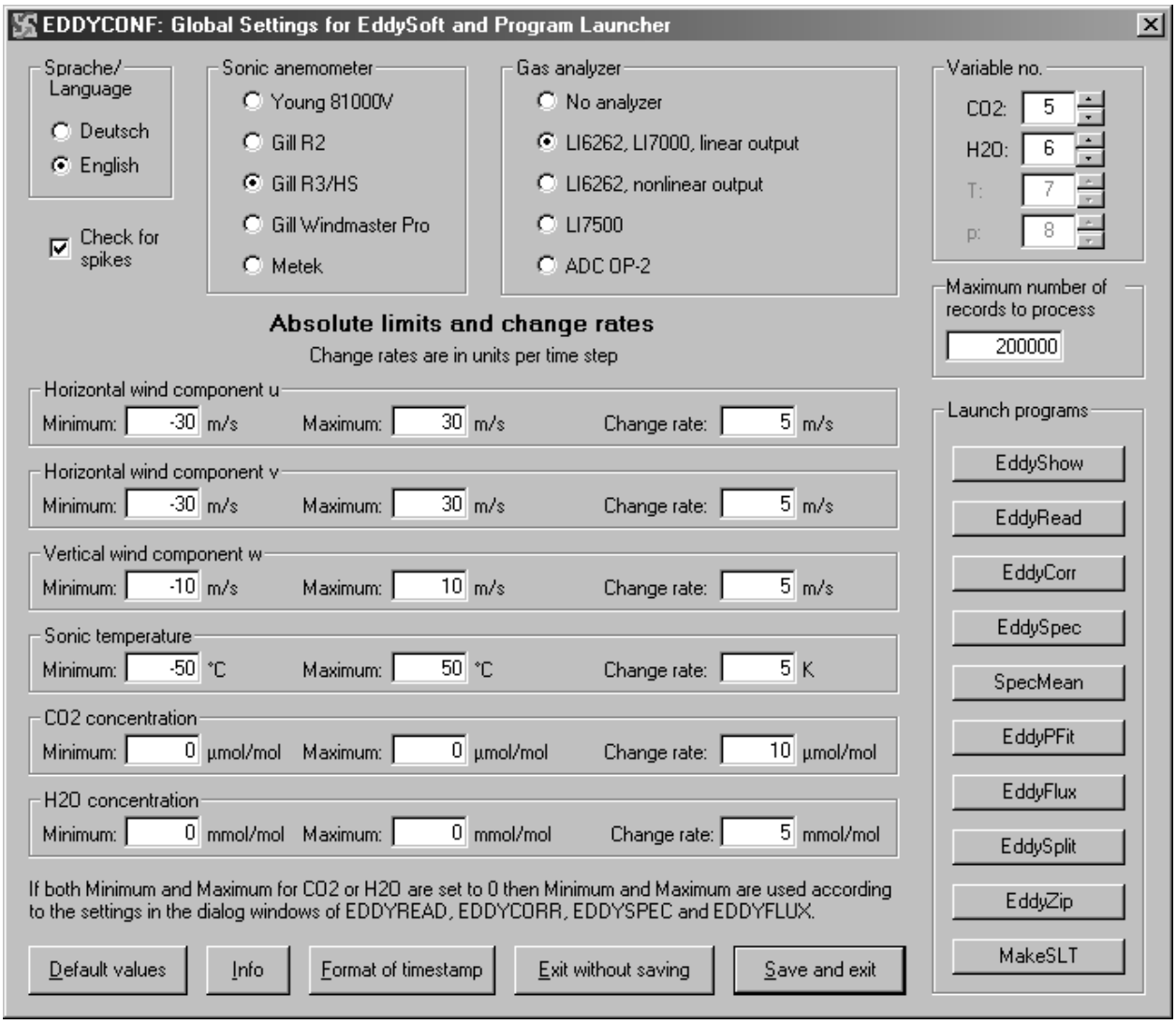


Figure 20: The EDDYCONF dialog window

If the option Check for spikes is selected then EDDYREAD, EDDYCORR, EDDYSPEC and EDDYFLUX are checking the raw data for spikes defined as peaks above or below certain values and for change rates exceeding given numbers (both are values which can be defined in the lower part of this dialog window). In EDDYREAD those spikes can be processed in different ways (see later), EDDYCORR and EDDYSPEC reject files containing spikes for further processing. These three programs check for spikes only if the option transform to meteorological data is selected. EDDYFLUX checks for spikes by default and interpolates automatically linearly between the last and the first good value before and after the spike(s). All spike treatment within the post processing programs is disabled if the Check for spikes option is switched off here. **If EDDYFLUX is used for on site flux calculation it is recommended to have this option being switched on.**

The type of sonic anemometer must be set in this configuration dialog. Six options are available: the Young 81000V sonic or the Gill R2 or the Gill R3/HS or the Gill WindMaster Pro or the Metek USA-1 sonic or the Campbell CSAT3.

As well the type of gas analyzer must be selected here. Five options are available: no analyzer at all is used but only a sonic anemometer, one of the closed path analyzers LI6262 or LI7000 using the linearized output signals, or one of the same analyzers using the non linearized output signals along with the temperature and pressure signals, or the open path analyzer LI7500, or the open path analyzer ADC OP-2. The major differences which must be accounted for during post processing are the different units for the CO_2 and the H_2O signals and the additional processing steps if using the non linearized outputs. The closed path analyzers give CO_2 in $\mu\mathrm{mol\,mol^{-1}}$ and H_2O in $\mathrm{mmol\,mol^{-1}}$ while the open path analyzers LI7500 and ADC OP-2 give CO_2 and H_2O in $\mathrm{mmol\,m^{-3}}$. If the non linearized outputs are used then the CO_2 and H_2O concentrations are calculated according to the formulas listed in the LI6262 manual.

As soon as the LI6262 or LI7000 analyzer using the non linearized output signals is selected a small window is automatically opened (see figure 21) showing the content of the file LI6262.CAL which must exist in this case in the same directory as the programs. This file must contain the serial number and all the calibration coefficients of the gas analyzer in use.

It is very important that the file format matches the format shown below in the example. The first line must not contain any blank character and all the following lines must contain one and only one blank character between the '=' and the number.

```
IRG3-698
C2T= 31.1
C2K= 17888
C2A= .1422
C2B= 6.951E-06
```

```
C2C= 7.923E-09
C2D= -1.022E-12
C2E= 6.661E-17
H2T= 44.4
H2K= 14918
H2A= 6.394E-03
H2B= 2.990E-06
H2C= 6.295E-11
FCT71= 57.01
FCT72= 0.01526
```

This file is read in by all the FORTRAN executables during post processing to calculate the correct CO_2 and H_2O concentration values. Don't forget to make the appropriate changes to that file when replacing the gas analyzer.

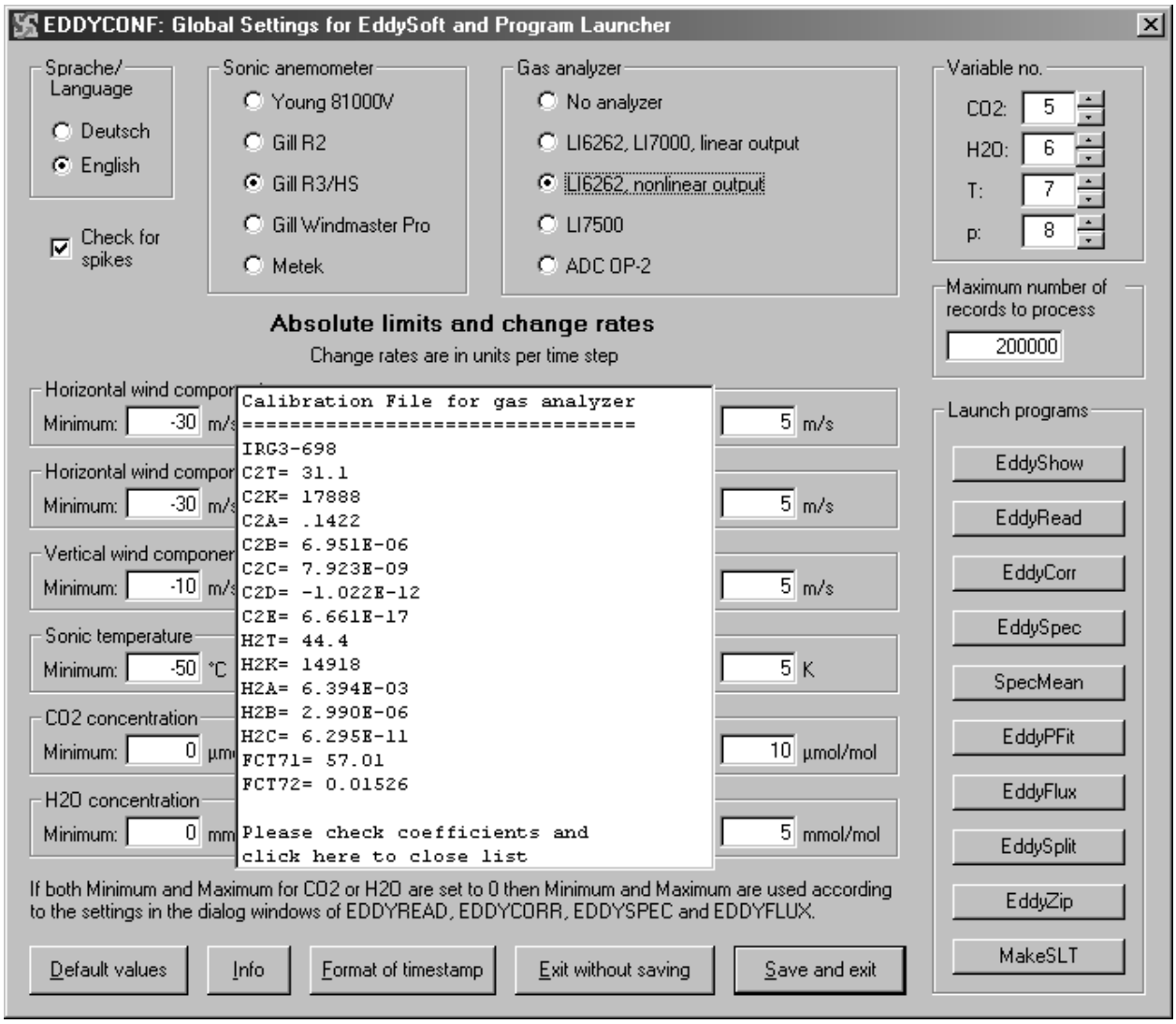


Figure 21: The EDDYCONF dialog window showing the content of the LI6262.CAL file

As soon as the list is closed by clicking on it, a small dialog window appears allowing to enter the internal offsets for CO_2 and H_2O which may have been set using function 8 of the LI6262 gas analyzer. The file LIOffset.CAL contains these values but needs not necessarily exist in which case the offsets are set to 0. When exiting EDDYCONF using the option to save all new settings this file is created anyway. All FORTRAN90 executables read the offsets from this file and correct the CO_2 and H_2O raw data to obtain the real concentration values.

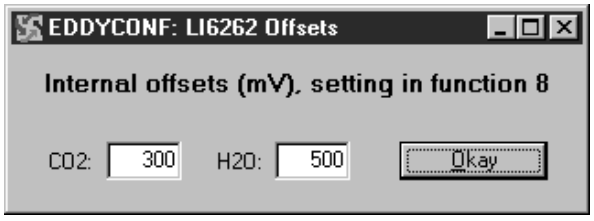


Figure 22: The EDDYCONF offsets dialog window

The number or position of the variables within one record of rawdata containing the CO_2 and the H_2O values can be set as well. This is useful if for example two gas analyzers are used in parallel both connected to the sensor input unit of the sonic. The data of one instrument are processed online while the data from the second analyzer have to be processed offline by selecting the next two positions in the raw data stream here. If the non linearized output signals of the analyzer are sampled as well and should be used during online calculations with EDDYFLUX then the positions of the variables within the raw data records must be set to 7 for CO_2, 8 for H_2O, 9 for temperature and 10 for pressure if these signals are connected in the same order to the input channels 3 to 6 on the sensor input unit. The selectable numbers are limited between 5 and 10 because the first four positions contain always the sonic data u, v, w, and T.
The limits and the change rates are used for quality check of the raw data. All raw data are checked whether their values are in between the defined absolute limits and whether their rates of change from one sample to the next exceed the given limits. If the entries are 0 for both the minimum and maximum in case of CO_2 or H_2O concentration the settings are taken according to the entries in the dialog boxes of any of the post processing programs. Figure 20 shows the default values for all entries used in case of a closed path gas analyzer. EDDYREAD checks for the limits and change rates and it is possible to force the program to interpolate values which do not match those settings. EDDYCORR and EDDYSPEC check for the limits as well and reject files where any value does not match the settings. In EDDYFLUX all values which do not match the settings are interpolated and as in EDDYREAD a log file is generated reporting the number of exceeded limits and change rates before and after the interpolation.

The settings of EDDYCONF are saved to a file named Eddysoft.cfg which may look as shown below (default values for the open path gas analyzer).

200000	maximum number of records
3, 2 , 1	type of sonic anemometer, type of gas analyzer , check for spikes (0=no, 1=yes)
7 , 8 , 9 , 10	position of CO_2, H_2O, temperature and pressure in raw data records
-30 , 30 , 5	absolute limits and change rate for u
-30 , 30 , 5	absolute limits and change rate for v
-10 , 10 , 5	absolute limits and change rate for w
-50 , 50 , 5	absolute limits and change rate for T
0 , 0 , 0.5	absolute limits and change rate for CO_2
0 , 0 , 200	absolute limits and change rate for H_2O
0	language (0=German, 1=English)

Type of sonic anemometer:
1 = Young 81000V
2 = Gill R2
3 = Gill R3/HS
4 = Gill WindMaster Pro
5 = Metek USA-1
6 = Campbell CSAT3

Type of gas analyzer:
−1 = LI6262 or LI7000, non linear outputs with temperature and pressure
0 = no gas analyzer
1 = LI6262 or LI7000, linear outputs
2 = LI7500
3 = ADC OP-2

When changing the type of gas analyzer in the dialog some units and some numbers in the part containing the absolute limits and change rates are automatically updated.

It is very important to set the correct configuration using this program if EDDYFLUX is called online from EDDYMEAS for the final flux calculations!

All postprocessing programs show after start the most important settings of EDDYCONF in the box where later the selected files for processing are displayed.

When clicking on the button Format of timestamp a small dialog will appear (see figure 23) which allows to set different formats for date and time. These settings are used in EDDYMEAS, LI7500Log and the FORTRAN executable of EDDYFLUX whenever they write records including a timestamp to any of their output files. The settings are stored in form of two lines with each two numbers in a file named Timestamp.cfg inside the program folder, e.g.

1, 1
1, 0

where in the first line the date format is set to MM DD YYYY and the delimiter for the date is set to /. In the second line the time format is set to HH MM SS and the delimiter for the time is set to :. Thus the time stamp in the output files will be formatted as MM/DD/YYYY HH:MM:SS.

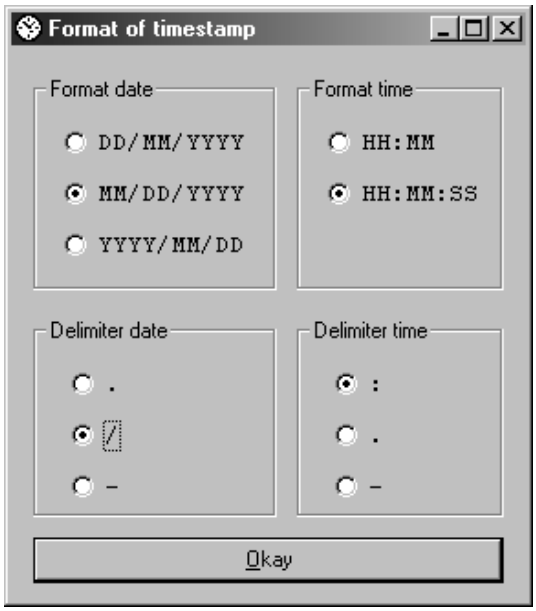


Figure 23: The EDDYCONF timestamp dialog window

Some graphic programs or spread sheet software do not accept the default timestamp information (DD.MM.YYYY HH:MM) as a valid format for date and time. In this case the proper formats must be set with EDDYCONF.

When working with the EddySoft program suite it is usually necessary to firstly execute EddyConf to ensure the correct settings. For this reason EddyConf allows to launch all post processing programs from its dialog window which makes it unnecessary to start the programs from the start menue or from the desktop. Of course **all the settings are being saved to the configuration files as soon as one of the post processing programs is launched** from EDDYCONF.

7 MAKE_SLT – conversion tool for raw data files

This tool allows to convert raw data files from other sources than EddyMeas into the raw data file format used by this software suite (slt-files). With the standard installation Make_SLT is delivered with the option to convert ASCII-files only. Special customized versions for conversion of specific other raw data file formats are already available or can be generated on individual order. Customers of such special versions will receive their individual copy of Make_SLT with a second option for raw data input files allowing to convert their specific raw data.

Important: the raw data input files must be named according to the naming convention for raw data files as described in section 1. That means that they must be named for instance as Xyyyydddhhmm.asc where X is any single prefix character, yyyy is the year, ddd is the day in the year and hhmm are hours and minutes of the start time of raw data contained in this file. The three character file extension is not necessarily asc , it can be simply any extension. The time information from the file names is used by Make_SLT to put the time stamp in the header record of the resulting slt-files.

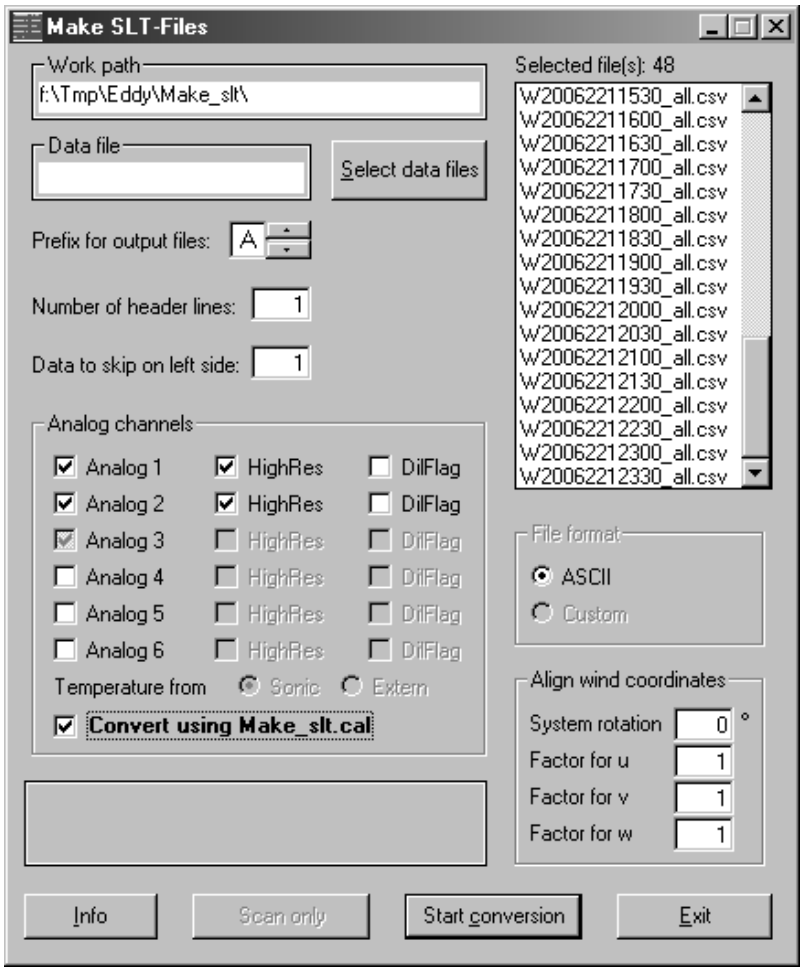


Figure 24: The MAKE_SLT dialog window

In this manual only the standard version of Make_SLT is described, additional information on customized versions will be given on delivery.

Firstly the format of the input files must be choosen, only after that it is possible to select the input files themselves. The prefix character for the output files can be choosen differently from the ones that are being used for the input files. If the raw data ASCII input files contain header lines in front of the lines with data then these lines must be skipped by defining the number of header lines in the dialog window. As well the input files may contain other data at the beginning of each record as e.g. a time information which must be skipped as well by defining the number of data to skip on left side of each record. With the exception of the header lines and additional data at the beginning of each record, all the records must have an identical format with u, v, w, Ts and optional analog channels from left to right separated by commas (,). The wind components u, v and w must be given in $\mathrm{m\,s^{-1}}$ and the sonic temperature must be given in ^{o}C. The records may contain up to six analog channel data which can be given in mV or their physical units. Since in the slt raw data files all data from analog input channels are stored in mV the data must be converted if they are given in their physical units. For this Make_SLT uses the file Make_SLT.cal which may look as follows

```
[analog input channel 1]
0 , 5 , 300 , 600
[analog input channel 2]
0 , 5 , 0 , 30
[analog input channel 3]
0 , 5 , 0 , 5
[analog input channel 4]
0 , 5 , 0 , 5
[analog input channel 5]
0 , 5 , 0 , 5
[analog input channel 6]
0 , 5 , 0 , 5
```

The text inside the brackets is mandatory, the lines below must contain four numbers separated by commas. The first two numbers are minimum and maximum voltages in V to which the second two numbers are being scaled. They can for instance be concentration values which should not be exceeded by any value of the raw data files being converted. For the voltage values it is always the best to use 0 as minimum and 5 as maximum. The numbers for the physical units should be choosen in a way that all values from the raw data files are well within these limits. For a good resolution the limits should not be too far away from the range of all the raw data files.

Since the program must know the total number of analog channels stored in each record it is obligatory to switch on as many analog channels as there are stored in the input files. There must be no gaps in ticking the channel numbers but it is possible to exclude some channels from being written to the slt output files by holding the Shift-key when clicking on the check box. The tick will be gray and this particular channel will be read from the input file but will not be written to the output file.

Example:

```
time in s,u,v,w,T,CO2,H2O,extra 1
0.05000, -2.97, -1.47, -0.80, 15.14, 402.14, 15.20, 4496.00
0.10000, -3.01, -1.41, -0.79, 15.14, 402.14, 15.20, 4495.00
0.15000, -3.00, -1.34, -0.95, 15.18, 402.06, 15.20, 4495.00
0.20000, -3.17, -1.27, -1.05, 15.11, 402.06, 15.20, 4495.00
0.25000, -3.26, -1.32, -1.03, 15.11, 402.06, 15.20, 4495.00
0.30000, -3.14, -1.35, -1.12, 15.18, 402.14, 15.20, 4495.00
0.35000, -3.14, -1.32, -1.00, 15.18, 402.06, 15.20, 4494.00
```

This example raw data ASCII file contains one header line and a time information at the beginning of each record. The three wind components and the sonic temperature are following and there are three analog channels, the first is a CO_2 concentration in ppm, the second is the H_2O concentration in $\mathrm{mmol\,mol^{-1}}$ and the third is a synchronization signal in mV. In this case the settings must be made as shown in figure 24 if the third analog channel should not be written to the output file. The other two analog channels will be converted to voltages in mV by making use of the informtion of the file Make_SLT.cal as shown in the example above.

For the high resolution option (HiRes) and the dilution option (DilFlag) please refer to the description related to figure 7 in chapter 1.

In some cases it might be necessary to scale the wind components by a factor and/or to rotate the coordinate system to align the wind components to geographic coordinates. This can be done by setting individual factors for u, v and w and by defining a rotation angle for the coordinate system (a negative angle will turn the sonic coordinates clockwise).

8 EDDYZIP – archiving utility

Raw data archives created by EDDYMEAS can be tested or unpacked by EDDYZIP. If no archives have been created then this program may be used to pack the raw data files to save disk space. The extension of the files which should be zipped may be different from slt, as long as the file name itself follows the rules described in paragraph 1. The program is easy to use and self explaining. After selecting the desired action (pack, unpack or test archive) and the files to process, the program builds and then executes a batch file (Eddyzip.bat). Either Zip.exe or Unzip.exe are called by the batch file with the appropriate parameters. Although these programs are running in a DOS box, long file names can be used.

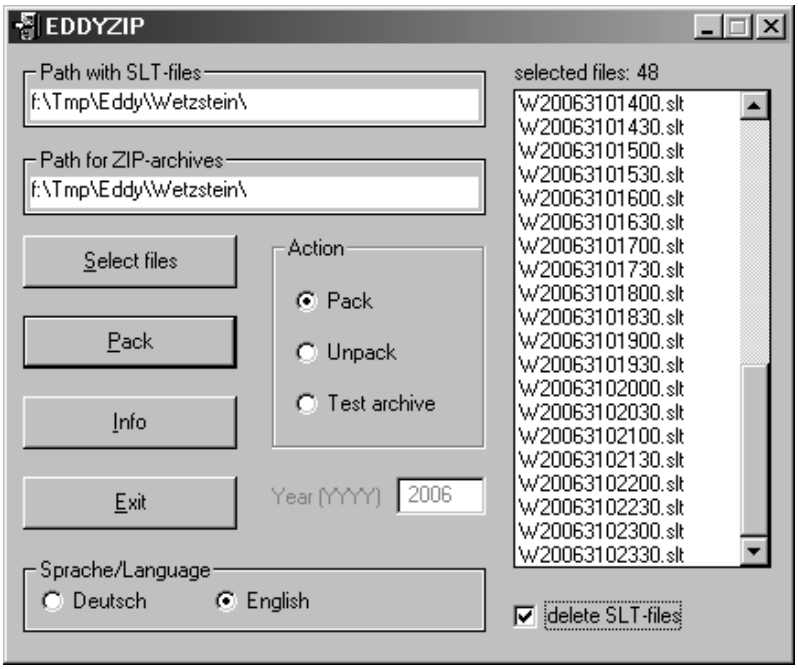


Figure 25: The EDDYZIP dialog window

9 EDDYSHOW – visualization of raw data

EDDYSHOW is used to quickly show the contents of raw data files (extension slt) including the available header information and time series of single variables in a graphical representation.

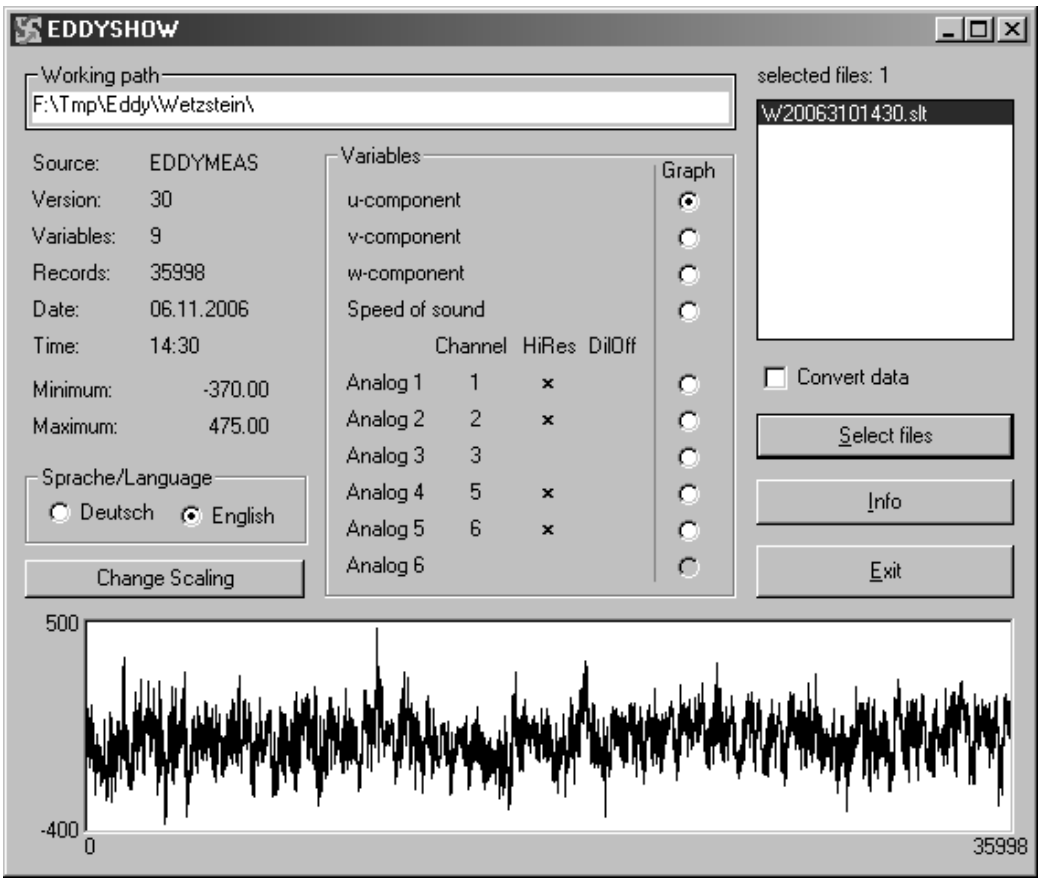


Figure 26: The EDDYSHOW window

After selecting the desired raw data files their names appear in the list box at the top right corner of the window and the first file is automatically selected and its content is read in. In case EDDYMEAS was used for data acquisition this is displayed as Source together with the Version and the Date and Time of the first record in the raw data file. In any case the number of variables per record and the number of records in the file are shown. If EDDYMEAS was used to collect the data then for each additional analog input variable connected to the sensor input unit of the sonic the input channel is shown together with the information whether those data are stored in high resolution format. After selecting one of the Graph option buttons the time series of the desired variable is displayed in the graph window and the minimum and maximum value are shown on the left side of the main window. The axes are only labeled with their minimum and maximum. As long as the Convert data option is not checked the data are shown as they are stored in the file. This means for the three wind components the unit is $\mathrm{cm\,s^{-1}}$, the forth value is either the

temperature in $1/100^{th}$ degree centigrade or a value representing the speed of sound. The additional analog channels are given either directly in mV or in a transformed number representing the voltage in $1/10^{th}$ mV in case of the high resolution format. If the Convert data option is checked then the wind velocity is in $\mathrm{m\,s^{-1}}$ and the temperature is in ^{o}C. All additional data are shown in mV.
The size of the main window may be changed to enlarge the graph. The scaling of the graph can be modified in several ways: using the Change scaling button a small dialog window opens to enter new minima and maxima of both axes.

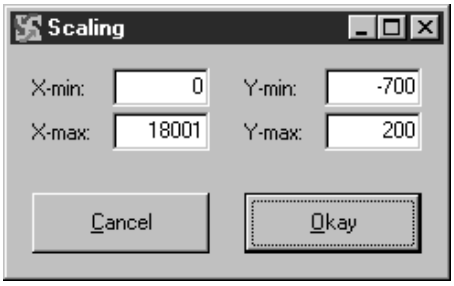


Figure 27: The EDDYSHOW axes scaling window

Any desired part of the time series can be zoomed in by pressing the left mouse button within the graph window and dragging to enlarge a frame around the area of interest. A single left click into the graph window zooms the x-axis by a factor of approx. two. A single right click into the graph window leads back to the original scaling.
At any time it is possible to switch between the pure raw data graph or the graph showing the converted data. If a new file is selected from the file list box or a completely new set of files is selected with the file selector then immediately the same variable is plotted as was chosen for the previous file.
At present only one variable can be plotted at the same time.

10 EDDYSPLIT – split and modify raw data files

EDDYSPLIT is used to split large raw data files (extension slt) into smaller files of certain length and/or to correct the header record of raw data files created by the EDISOL software. As well the analog channels option byte of the header records can be modified and data from individual analog channels may be removed from raw data files. The general philosophy of the software package was to create small raw data files of 10 to 30 minutes during data acquisition which may later be combined to longer periods in all of the post processing programs. If for any reason raw data files of longer periods have been created then this split program may be used to generate raw data files of shorter periods.

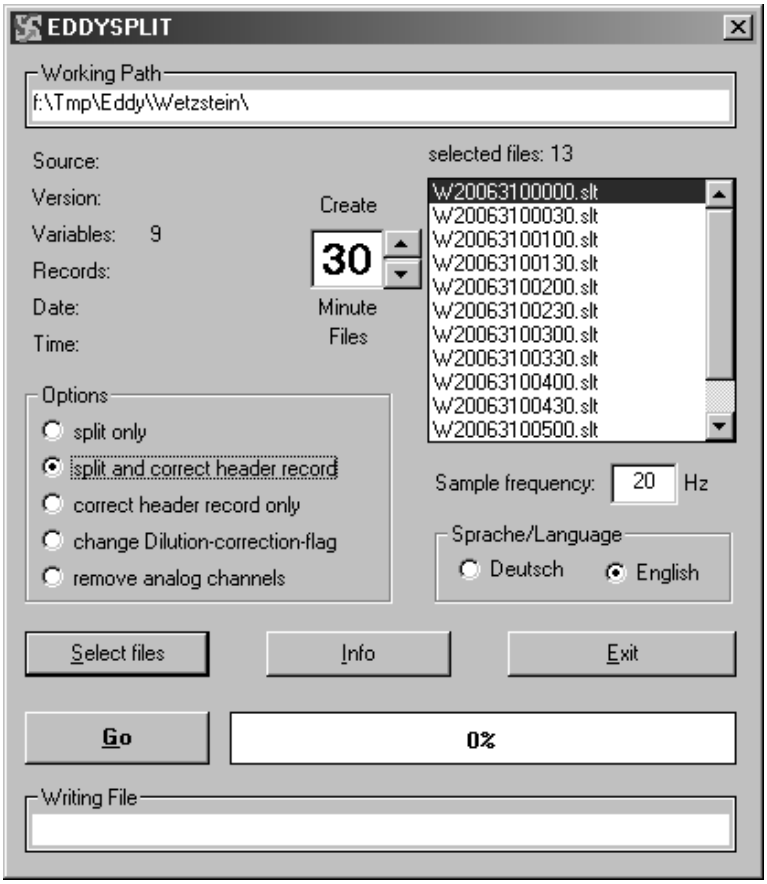


Figure 28: The main EDDYSPLIT window

After selecting raw data files the desired option to treat these files can be chosen. The files may be splitted only in case the raw data have been collected by EDDYMEAS. If the files have been written by EDISOL then it might be the case that the header records are not fully compatible with this software package and thus need to be corrected. The second option allows to split the raw data files and to correct the header records simultaneously. The third option can be used to correct the header records only and to keep the entire length of the raw data files. Treating files with the third option is very quick because only

the header record is modified and no further read/write operations are necessary.
Splitting the files requires to set the desired length of the new raw data files in minutes and the correct sampling frequency; these input fields are meaningless if the header records are being corrected only.
As soon as the second or third option is selected an additional dialog window opens:

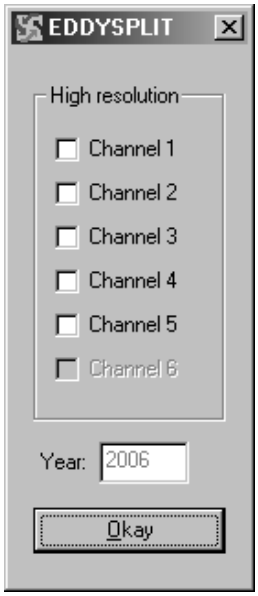


Figure 29: The EDDYSPLIT dialog for correcting the header records

Here the high resolution option for each analog channel can be activated or deactivated; in case of EDISOL data they usually must be deactivated. If the file names do not include the year then the field for the year must be filled correctly with a four digit number.
If the fourth option is selected the following dialog window opens:

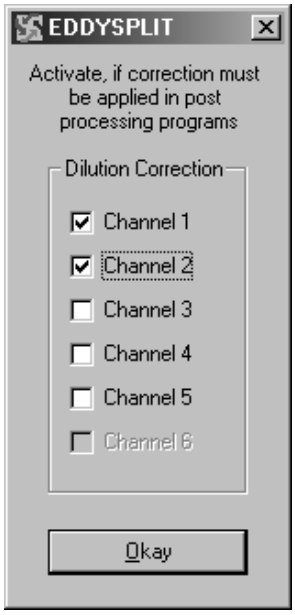


Figure 30: The EDDYSPLIT dialog for changing the dilution correction flag

If this option is checked it means that the dilution correction is switched off or is not available in the instrument itself and that the dilution correction must be applied in the post processing programs. This option must be switched on if a LI7000 was used or if the dilution correction was switched off in a LI6262. With EDDYSPLIT it is possible to switch on or off this setting in the rawdata files in case it was not set correctly in EDDYMEAS or in case old rawdata files need to be modified. If the last option is selected the following dialog window opens:

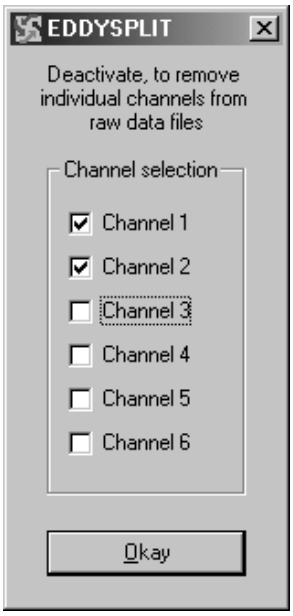


Figure 31: The EDDYSPLIT dialog for removing analog channel data from raw files

This option can be used to remove data from the raw files which had been collected by mistake or which turned out to be useless due to instrument failure for instance. The major effect is to receive smaller raw data files and to get rid of obsolete data. The small dialog shows which additional analog channels had been sampeled. By deselecting individual channels and starting the conversion process, the original raw data files are read in and then replaced by the modified ones, which do not anymore contain those channels. The hole operation takes of course longer than only modifying the header records as in case of options 3 and 4 because all raw data need to be read and partly be written to new files.

Clicking on the Go button forces a dialog to be shown to select the output path for the new raw data files in case one of the first two options was chosen. The output path **must** be different from the input path because some output file names will be identical to the input file names. As well the input files may come from a CD where the output files can not be written to. The path selector is not activated in case of option three where the header records are modified only. But in this case the raw data files **must** reside on a write enabled mass storage device and **must not** be write protected. Immediately after

clicking on the Go button (option 3) or after selecting the output path (option 1 or 2) the read/write operation starts whilst the progress is displayed by the blue bar. The names of the output files and their header information is automatically generated properly. The program may be interrupted at any time by selecting Exit.
If the header record was modified (option 2 or 3) then EDDYSPLIT puts 255 as version number as second byte of each raw data file. This is to identify raw data files which were not generated by EDDYMEAS but which header records have been modified by EDDYSPLIT to be compatible with the other programs of this package. EDDYMEAS puts its own major version number as second byte of the raw data files. EDDYSHOW displays the source of the raw data and can thus distinguish between EDDYMEAS and EDDYSPLIT.

The EDDYSPLIT program makes use of a path selector similar to the file selector (not WINDOWS standard). The handling is more or less identical to the file selector: using the drive pull down menu and the directory list box (single click) on the left side the desired path can be selected. The file list box on the right side is just for information of the content of the current directory.

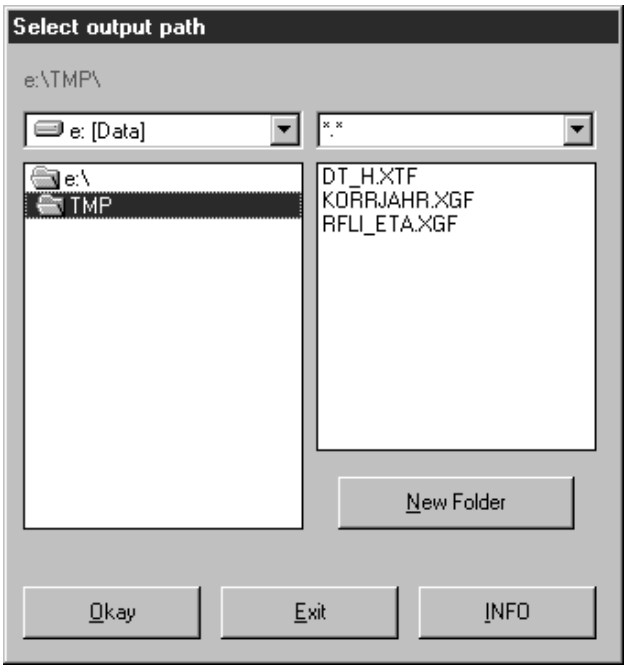


Figure 32: The PATHSELECT dialog window

11 EDDYREAD – reading and conversion of raw data

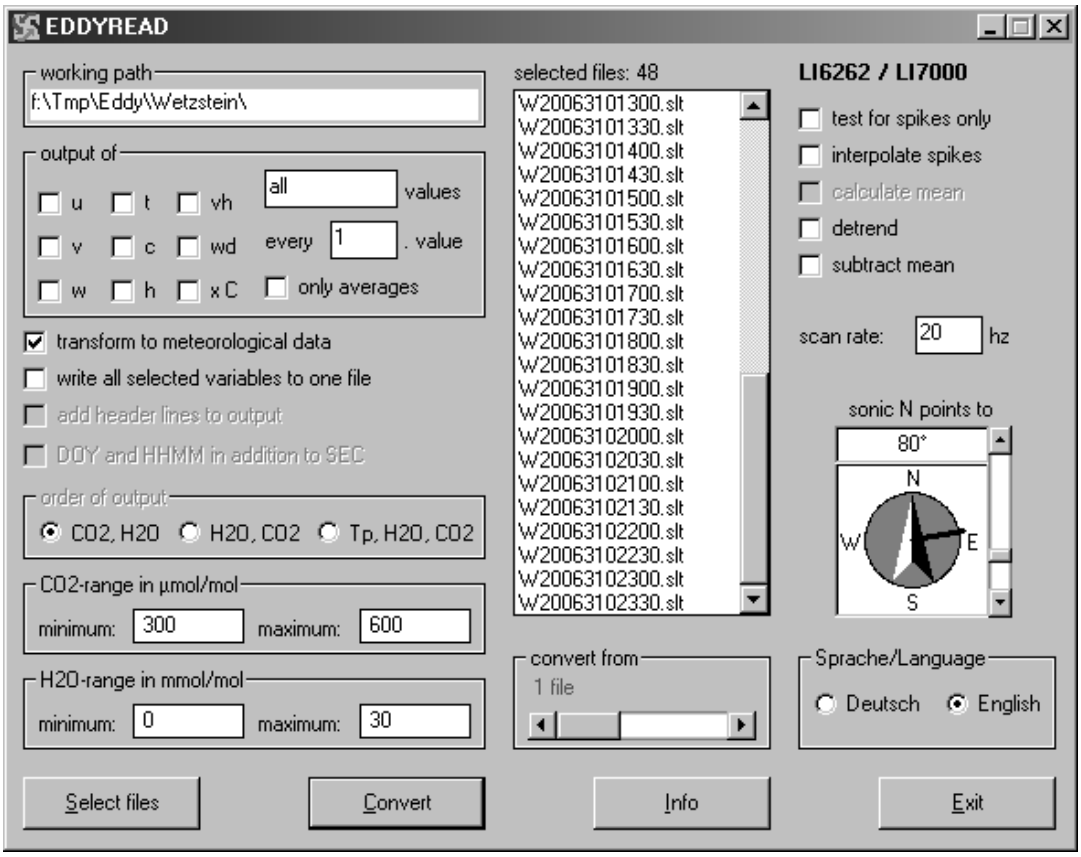


Figure 33: The EDDYREAD dialog window

The following possibilities may be choosen as output of the high-frequency data:

- sonic anemometer wind components as raw values in $\mathrm{cm\,s^{-1}}$ or in $\mathrm{m\,s^{-1}}$.
  If conversion to meteorological data is selected, horizontal wind velocity and wind direction may be output as well.
- sonic anemometer (speed of sound)$\times$50 or temperature T_s in ^{o}C.
- CO_2-concentration in mV or $\mu\mathrm{mol\,mol^{-1}}$ (LI6262, LI7000) or $\mathrm{mmol\,m^{-3}}$ (LI7500, ADC OP-2)
- H_2O-concentration in mV or $\mathrm{mmol\,mol^{-1}}$ (LI6262, LI7000) or $\mathrm{mmol\,m^{-3}}$ (LI7500, ADC OP-2)
- additional analog channels (xC) if any have been logged

If needed, data can be output detrended (linear) and/or with subtracted mean. It is possible to select more than one file, output files will be named as the original raw data

file plus an underscore plus the variable name (for example H20022081200_v.csv for wind component v or H20022081200_x1.csv for the first additional analog input channel. The first column in the output file is time in s, the second column contains the values of the selected variable. If the option Write all selected variables to one file is used then only one output file is written for each raw data file containing all the selected variables in subsequent columns. As an example the name could be H20022081200_all.csv. If this option is selected then three more options are available:

- add header lines to output: if checked then a file should be selected from the file-selector as soon as the Calculate button is pressed. All lines of this particular file are then written on top of each output file.
- DOY and HHMM in addition to SEC: if checked then the standard time information of each record (seconds) is extended by the day of year (first colum) and hourminute (second column). This option is also available if only averages within the output of frame above is chosen.
- three possibilities in order of output: here it is possible to set the output order to u, v, w, t, [CO_2], [H_2O] or to u, v, w, t, [H_2O], [CO_2] or to u, v, w, t, Tp, [H_2O], [CO_2] where Tp stands for temperature of an additional fast PT100-temperature sensor. **This value will be written as** -9999.9 **in any case just to fulfil the CarboEurope raw data exchange file format**. This option is also available if only averages within the output of frame above is chosen.

For reducing the size of the output files, it is possible to select data either by taking only values from the first part of the file or by writing not each sample but for example every second or third sample or the mean of each two or three.
If no gas analyzer was connected and thus the raw data records do not contain any CO_2 or H_2O values, the option No analyzer in EDDYCONF should be switched on, in particular if additional analog channels have been used during data acquisition.
It is also possible to write averages of each channel for each selected file into one output file instead of raw data by selecting the option only averages. The output file in this case is named Eddyread.csv and contains the averages of all available channels.
The option check for spikes only allows to check the data without converting them to ASCII files. The result of the check is written to a file named Eddyread.log.
As already described in section 1, the alignment angle of the sonic anemometer can be adjusted here as well and influences only the output of the wind direction. For the Gill HS and the Campbell CSAT3 the direction of the arm going from the mast to the sensor head must be selected, for all other sonics the direction where the north mark points at must be adjusted.

The calibration parameters and the selections are written to and read from the following files:

Parameter file

EDDYREAD.CAL:
$[CO_2]_{min}$, $[CO_2]_{max}$
$[H_2O]_{min}$, $[H_2O]_{max}$
f_s
s_a
where

$[CO_2]_{min}$ = lower limit of analyzer $[CO_2]$ range in μmol mol^{-1} or mmol m^{-3}
$[CO_2]_{max}$ = upper limit of analyzer $[CO_2]$ range in μmol mol^{-1} or mmol m^{-3}
$[H_2O]_{min}$ = lower limit of analyzer $[H_2O]$ range in mmol mol^{-1} or mmol m^{-3}
$[H_2O]_{max}$ = upper limit of analyzer $[H_2O]$ range in mmol mol^{-1} or mmol m^{-3}
f_s = sample frequency in hz
s_a = sonic alignment in whole-numbered degrees

time t of sample in s:

$$t = n/f_s \tag{1}$$

where:

n = number of sample
f_s= sample frequency in hz

Information file

SLTFILES.LST:
n_{files}, i_{files}
i_u, i_v, i_w, i_T, i_c, i_h, i_{vh}, i_{wd}, i_{ex}
$i_{addhead}$, $i_{adddattim}$, $i_{outorder}$
n_g, n_r, i_{met}, i_{mean}, $i_{detrend}$, i_{subm}, i_{spike}, i_{wmean}, i_{check}, i_{wrall}
file1
file2
.

.

.

where

n_{files} = number of selected files
i_{files} = number of combined files
i_{u} = flag for output of u (0=no, 1=yes)
i_{v} = flag for output of v (0=no, 1=yes)
i_{w} = flag for output of w (0=no, 1=yes)
i_{T} = flag for output of T_s (0=no, 1=yes)
i_{c} = flag for output of [CO_2] (0=no, 1=yes)
i_{h} = flag for output of [H_2O] (0=no, 1=yes)
i_{vh} = flag for output of vh (0=no, 1=yes)
i_{wd} = flag for output of wd (0=no, 1=yes)
i_{ex} = flag for output of extra channels (0=no, 1=yes)
i_{addhead} = flag for additional output of header lines (0=no, 1=yes)
$i_{\text{adddattim}}$ = flag for output of additional time information (0=no, 1=yes)
i_{outorder} = flag for output order (1, 2 or 3)
1 = u, v, w, t, [CO_2], [H_2O]
2 = u, v, w, t, [H_2O], [CO_2]
3 = u, v, w, t, Tp, [H_2O], [CO_2], where $Tp = -9999.9$
n_{g} = number of values to write
n_{r} = write every n_r^{th} value (reduces data)
i_{met} = flag for conversion into meteorological units (0=no, 1=yes)
i_{mean} = flag for calculating mean values, only selectable if $n_r > 1$ (0=no, 1=yes)
i_{detrend} = flag for detrending time series (0=no, 1=yes)
i_{subm} = flag for subtracting mean value from time series (0=no, 1=yes)
i_{spike} = flag for interpolating spikes (0=no, 1=yes)
i_{wmean} = flag for output of only averages (0=no, 1=yes)
i_{check} = flag for check for spikes only (0=no, 1=yes)
i_{wrall} = flag for writing all selected variables to one file (0=no, 1=yes)
name of 1st SLT-file
name of 2nd SLT-file

.

.

.

Conversions into meteorological units are done as follows:

sonic anemometer wind components in $\mathrm{m\,s^{-1}}$

$$u = u_{\mathrm{raw}}/100 \tag{2}$$

$$v = v_{\mathrm{raw}}/100 \tag{3}$$

$$w = w_{\mathrm{raw}}/100 \tag{4}$$

where:

$u_{\mathrm{raw}}, v_{\mathrm{raw}}, w_{\mathrm{raw}}$ = integer values after internal sonic anemometer conversion

sonic anemometer temperature ϑ_s in ^{o}C or T_s in K

$$T_s = \frac{(c_{\mathrm{raw}}/50)^2}{403} \tag{5}$$

$$\vartheta_s = T_s - 273.16 \tag{6}$$

where:

c_{raw} = sonic anemometer integer speed of sound in $\mathrm{m\,s^{-1}}$

Analyzer CO_2-concentration $[CO_2]$ in $\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$

$$[CO_2] = [CO_2]_{\mathrm{min}} + \frac{[CO_2]_{\mathrm{max}} - [CO_2]_{\mathrm{min}}}{5000} \cdot [CO_2]_{\mathrm{raw}} \tag{7}$$

where:

$[CO_2]_{\mathrm{raw}}$ = raw voltage signal for $[CO_2]$ of analyzer in mV

Analyzer H_2O-concentration $[H_2O]$ in $\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$

$$[H_2O] = [H_2O]_{\mathrm{min}} + \frac{[H_2O]_{\mathrm{max}} - [H_2O]_{\mathrm{min}}}{5000} \cdot [H_2O]_{\mathrm{raw}} \tag{8}$$

where:

$[H_2O]_{\mathrm{raw}}$ = raw voltage signal for $[H_2O]$ of analyzer in mV

12 EDDYCORR – calculation of time lags for CO_2 and H_2O

If a closed-path gas analyzer in connection with a tubing is used for the determination of CO_2- and H_2O-fluxes, time delays between the vertical wind component and the concentrations arise. The resulting time lags have to be determined before calculating the fluxes. This can be done with the program EDDYCORR separately. EDDYCORR calculates the cross-correlation function of two time series.
During one run only one combination of variables can be selected. The maximum lag which has to be entered (in samples) in the dialog form should be in a reasonable range, about 2 to 3 times the value determined from a rough estimate with tube length, inner diameter of tube and flow rate.

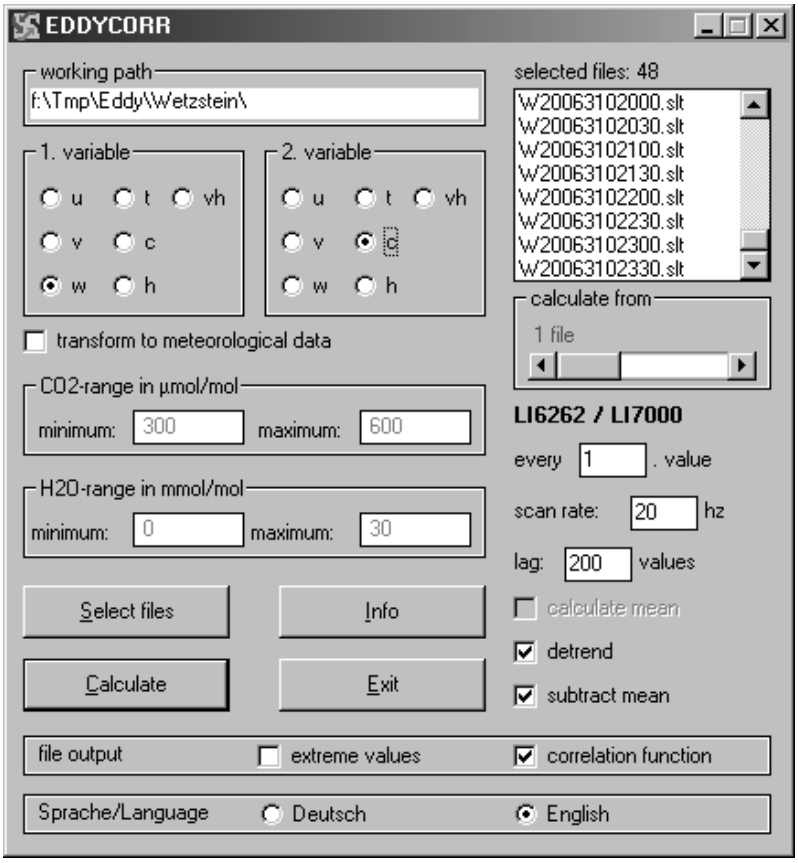


Figure 34: The EDDYCORR dialog window

The calibration parameters and the selections are read from the following files:

Parameter file

EDDYCORR.CAL:

$[CO_2]_{min}$, $[CO_2]_{max}$

$[H_2O]_{min}$, $[H_2O]_{max}$

f_s

where

$[CO_2]_{min}$ = lower limit of analyzer $[CO_2]$ range in μmol mol^{-1} or mmol m^{-3}

$[CO_2]_{max}$ = upper limit of analyzer $[CO_2]$ range in μmol mol^{-1} or mmol m^{-3}

$[H_2O]_{min}$ = lower limit of analyzer $[H_2O]$ range in mmol mol^{-1} or mmol m^{-3}

$[H_2O]_{max}$ = upper limit of analyzer $[H_2O]$ range in mmol mol^{-1} or mmol m^{-3}

f_s = sample frequency in hz

Information file

SLTFILES.LST:

n_{files}, i_{files}

i_{v1}, i_{v2}

n_{lag}, n_r, i_{met}, i_{mean}, $i_{detrend}$, i_{subm}, iop_{lag}, iop_{cor}

file1

file2

.

.

.

.

where

n_{files} = number of selected files

i_{files} = number of combined files

i_{v1} = number of first variable

i_{v2} = number of second variable

n_{lag} = maximum lag in samples (strong influence on computation time)

n_r = take every n_r^{th} value (reduces computation time)

i_{met} = flag for conversion into meteorological units (0=no, 1=yes)

i_{mean} = flag for calculating mean values, only selectable if $n_r > 1$ (0=no, 1=yes)

$i_{detrend}$ = flag for detrending time series (0=no, 1=yes)

i_{subm} = flag for subtracting mean value from time series (0=no, 1=yes)

iop_{lag} = flag for output of extreme values (0=no, 1=yes)

iop_{cor} = flag for output of correlation functions (0=no, 1=yes)
name of 1st SLT-file
name of 2nd SLT-file
.
.
.
.

Transformation into meteorological data, detrending and subtracting of mean should be applied.
The output files for correlation functions are named as the original raw data files plus a two digit number representing the combination of the variables ($u = 1$, $v = 2$, $w = 3$, $t = 4$, $c = 5$, $h = 6$ or $v_{hor} = 7$) plus an underscore plus the letters corr (for example: H20022081200_36_corr.csv for calculation of the correlation function of w (variable #3) and [H_2O] (variable #6)). The files contain the time in samples as first column, the time in seconds as second column and the correlation between the two time series as third column.
The output file for the extreme values is named according to a two digit number representing the combination of the variables plus an underscore plus the letters corr (for example: 36_corr.csv for calculation of the extreme values of the correlation functions of w (variable #3) and [H_2O] (variable #6)). The file contains the raw data filenames in the first column, the time as day of year in column 2, the value of the minimum of the correlation function in column 3, the time lag of the minimum in samples in column 4 , the time lag of the minimum in seconds in column 5, the value of the maximum of the correlation function in column 6, the time lag of the maximum in samples in column 7 , the time lag of the maximum in seconds in column 8.

The sign of the resulting lag times depends of course on which variable was selected as 1. variable and which one was selected as 2. variable. When processing data from a closed path system where the concentration data clearly lag behind the data from the sonic anemometer the resulting lag time will be negative if for instance w is selcted as 1. variable and CO_2 as 2. variable. If both are exchanged then the resulting lag time will be positive. If an open path system is being used then the lag times may have both signs but are very small anyway. In EDDYMEAS , EDDYFLUX and EDDYSPEC lag times must always be defined as positive numbers when using a closed path system. For open path sytems it is recommended to use 0 as lag time in EDDYFLUX because the accurate lag time is determined automatically. In EDDYSPEC always the most accurate lag time must be used because it is not automatically optimised, it must be positive if the concentration data lag behind the sonic data and vice versa which might be the case in special situations when data from an open path system are being processed.

13 EDDYSPEC – calculation of spectra

The spectra program offers the following possibilities in the main dialog:

- single spectra
- cross spectra
- co- and quadrature spectra
- coherence and phase spectra
- covariance spectra

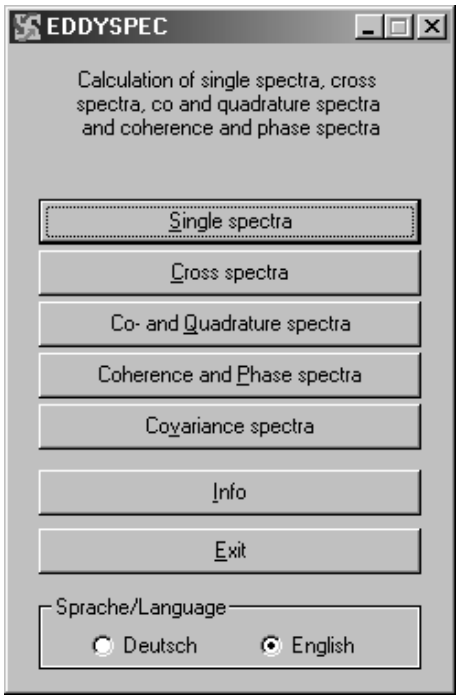


Figure 35: The EDDYSPEC main dialog window

According to the selection two different dialogs may appear, one for single spectra, the other for all other types of spectra.

13.1 Single spectra

Calculation of spectra for a single variable u, v, w, t, $[CO_2]$, $[H_2O]$ or v_{hor} (horizontal wind velocity).

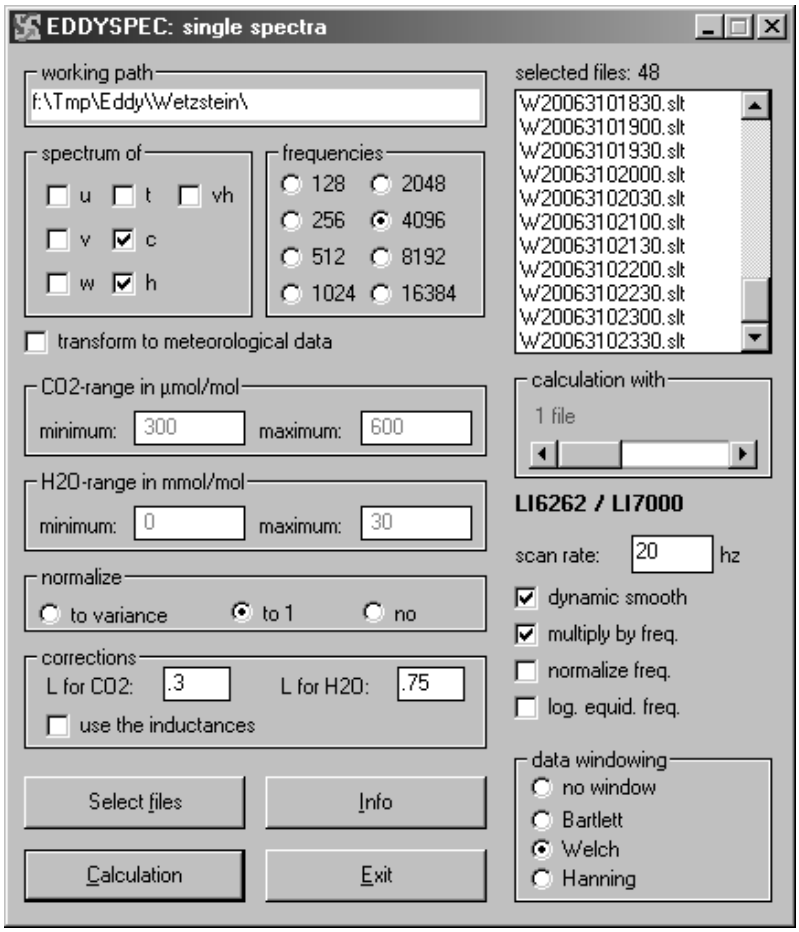


Figure 36: The EDDYSPEC dialog window for single spectra

The following selections may be done:

spectrum of: choice for which variable spectra will be calculated. (more than one variable may be selected)

frequencies: number of frequencies spectra are calculated for. 4096 frequencies are appropriate for half-hourly runs, 8192 frequencies for one hour data.

transform to meteorological data: for transformation into meteorological data the limits for [CO_2] and [H_2O] of the analyzer (minimum and maximum) must be entered. The advantage of the transformation is the output of the correct units, but it is not necessary for a qualitative interpretation of the spectra.

normalize: normalization can be done either to variance (the sum of all spectral densities will be equal to the variance) or to 1 (the sum of all spectral densities will be equal to 1) or may be omitted.

scan rate: <u>must</u> be set to the value with which data were sampled (usually 20 Hz).

dynamic smooth: appropriate for the logarithmic representation of the frequencies because in the high frequency range the density of values is much higher and thus the number of values for averaging should increase with frequency.

multiply by frequency: the spectral density values may be multiplied by the corresponding frequencies (usually this is done for double-logarithmic presentation to clearly recognize the $-5/3$-law (slope is in this case $-2/3$) in the inertial subrange).

normalize freq.: the frequency may be normalized to $n = f*(z-d)/u$ for comparison of spectra from different sites at different wind velocities (for normalization additional input of z-d is required).

log. eq. freq.: this should be selected to get mean values of spectral densities in logarithmic equidistant distances (appropriate for logarithmic representation of frequency axis); an additional input of the number of frequencies per decade (e.g. 5 or 10) is required.

data windowing: different data windows may be applied to the time series before calculation of spectra (see statistic references).

The control output in the processing window shows:
- the path and file name(s) from which spectra are calculated
- number of records read
- um: mean horizontal wind velocity (u rotated into mean wind direction)
- vm: mean v-component, for check if rotation was okay, should always be zero
- spectrum of choosen variable (u, v, w, T, [CO_2], [H_2O] or v_{hor})
- variance of variable

The output files for spectra of single variables are named as the original raw data files plus one or two letters reperesenting the variable plus an underscore plus the letters spec (for example: H20022081200_u_spec.csv for calculation of the spectrum of u. The first column of the output files contain the frequency values (true or normalized depending on your choice) the second column contains the corresponding spectral densities.

13.2 Spectra of combined variables

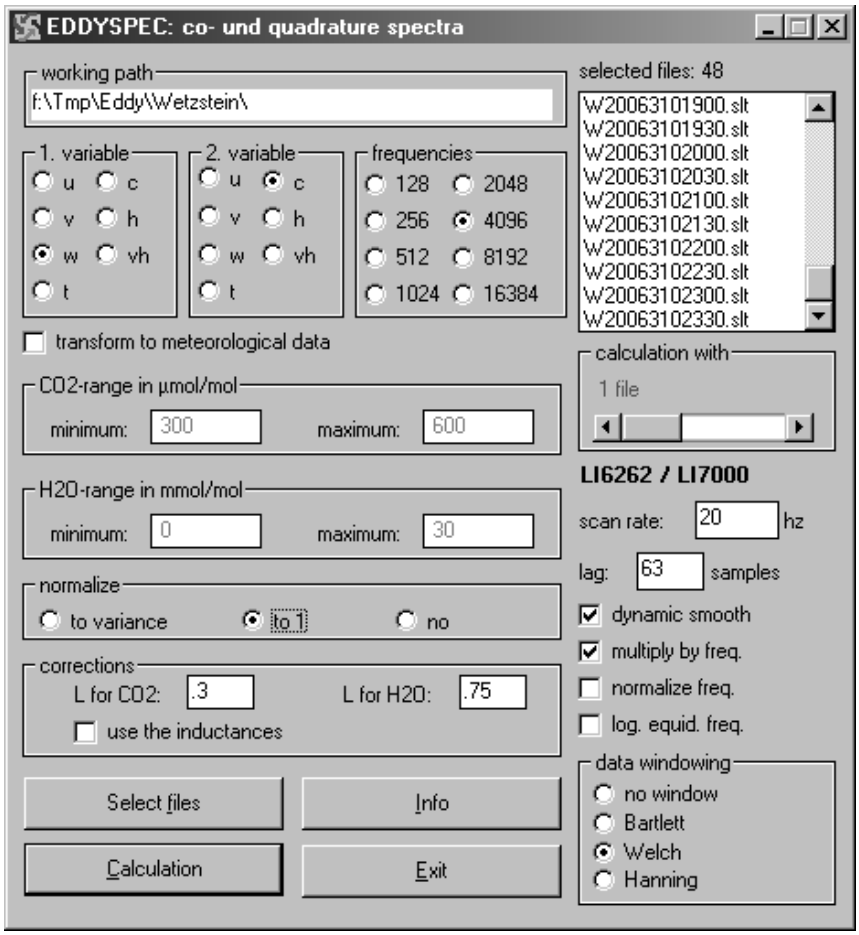


Figure 37: The EDDYSPEC dialog window for spectra of combined variables

13.2.1 Cross spectra

The complex cross spectrum is defined as:

$$Cr(a,b) = Co(a,b) + i\,Qu(a,b) \tag{9}$$

where a, b are the time series, Co is the cospectrum and Qu the quadrature spectrum (see 13.2.2). i is the imaginary unit. The result of the calculation is the absolute value of the cross spectrum:

$$|Cr(a,b)| = \sqrt{Co^2(a,b) + Qu^2(a,b)} \tag{10}$$

which is an estimate of the common spectrum of the amplitudes (i. e. a spectral representation of the amplitudes of both time series).

The output files for spectra of combined variables are named as the original raw data files plus a two digit number representing the combination of the variables ($u = 1$, $v = 2$, $w = 3$,

$t = 4$, $c = 5$, $h = 6$ or $v_{hor} = 7$) plus an underscore plus the letters spec (for example: H20022081200_36_spec.csv for calculation of the cross spectrum of w (variable #3) and [H_2O] (variable #6)). The files will contain the frequency (or normalized frequency, depending on the choice) in the first column and spectral density (possibly multiplied by frequency) in the second column.

13.2.2 Co- and quadrature spectra

The cospectrum represents the equally-phased (positive values, zero shift) and anti-phased (negative values, π-shift) common spectral variance of both analyzed time-series. The integrated values of the non-normalized cospectrum sum up to the covariance $\overline{a'b'}$ which is proportional to the flux.

In contrast the quadrature spectrum represents the common spectral variance (which does not contribute to the flux) of both analyzed time-series for the phase shifts of $\pi/2$ and $3\pi/2$.

The file names are created in the same way as for cross spectra. The files will contain frequency (or normalized frequency, depending on the choice) in the first column, the values of the cospectrum (possibly multiplied by frequency) in the second column, and the values of the quadrature spectrum in the third column.

13.2.3 Coherence and phase spectra

Four different spectral distributions are calculated:

1. correlation coefficient for phase shifts 0 and π

$$Cor(0,\pi)(a,b) = \frac{Co(a,b)}{\sqrt{Sp(a) \cdot Sp(b)}} \tag{11}$$

   with $Sp(a)$ and $Sp(b)$ being the spectral densities of the single time series.

2. correlation coefficient for phase shifts $\pi/2$ and $3\pi/2$

$$Cor(\frac{\pi}{2}, \frac{3\pi}{2})(a,b) = \frac{Qu(a,b)}{\sqrt{Sp(a) \cdot Sp(b)}} \tag{12}$$

3. overall spectral correlation coefficient (coherence)

$$Coh(a,b) = \sqrt{\frac{Co^2(a,b) + Qu^2(a,b)}{Sp(a) + Sp(b)}} \tag{13}$$

4. spectral phase shift between a and b

$$Pha(a,b) = \arctan\left(\frac{Qu(a,b)}{Co(a,b)}\right) \tag{14}$$

The file names are created in the same way as for cross spectra. The files will contain frequency (or normalized frequency, depending on the choice) in the first column and the different spectral distributions in the columns 2 to 5.

13.2.4 Covariance spectra

The calculation of spectra of a covariance time series is done in this routine, for example $w't'$-spectra.

General

For any of the combined spectra it is recommended to select the analyzer values in the right of the two windows (2nd variable). For example using the w-component and $[CO_2]$, w should be selected in the left window (1st variable) and $[CO_2]$ in the right window (2nd variable). The appropriate time-lag has then to be entered as positive number in samples.

Parameter file

EDDYSPEC.CAL:
$[CO_2]_{\mathrm{min}}$, $[CO_2]_{\mathrm{max}}$
$[H_2O]_{\mathrm{min}}$, $[H_2O]_{\mathrm{max}}$
f_s, $co2_l$, $h2o_l$

where

$[CO_2]_{\mathrm{min}}$ = lower limit of analyzer $[CO_2]$ range in $\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
$[CO_2]_{\mathrm{max}}$ = upper limit of analyzer $[CO_2]$ range in $\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
$[H_2O]_{\mathrm{min}}$ = lower limit of analyzer $[H_2O]$ range in $\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
$[H_2O]_{\mathrm{max}}$ = upper limit of analyzer $[H_2O]$ range in $\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
f_s = sample frequency in hz
$co2_l$ = inductance for $[CO_2]$
$h2o_l$ = inductance for $[H_2O]$

Information file

SLTFILES.LST:

n_{files}, i_{files}

i_{u}, i_{v}, i_{w}, i_{T}, i_{c}, i_{h}, i_{vh}

i_1, i_2, n_{lag}, m

n_{freq}, i_{smooth}, i_{norm}, i_{mult}, i_{korrf}, i_{win}, i_{met}, i_{fnorm}, z_m, l_{freq}

file1

file2

.

.

.

.

.

where

n_{files}	= number of selected files
i_{files}	= number of combined files
i_u	= flag for u-component (0=no, 1=yes) in case of spectra of single variables
i_v	= flag for v-component (0=no, 1=yes) in case of spectra of single variables
i_w	= flag for w-component (0=no, 1=yes) in case of spectra of single variables
i_t	= flag for temperature (0=no, 1=yes) in case of spectra of single variables
i_c	= flag for [CO_2] (0=no, 1=yes) in case of spectra of single variables
i_h	= flag for [H_2O] (0=no, 1=yes) in case of spectra of single variables
i_{vh}	= flag for horizontal wind velocity (0=no, 1=yes) in case of spectra of single variables
i_1	= number of first variable in case of combined spectra
i_2	= number of second variable in case of combined spectra
n_{lag}	= lag in samples if only one variable is from the analyzer
m	= mode of calculation (0=Cr, 1=Co and Qu, 2=Coh and Pha,3=Cov) in case of spectra of combined variables
n_{freq}	= number of frequencies for which spectral densities are calculated
i_{smooth}	= flag for dynamic smoothing (0=no, 1=yes)
i_{norm}	= flag for normalizing the spectral densities (0=no, 1=to 1, 2=to variance)
i_{mult}	= flag for multiplying spectral densities by frequencies (0=no, 1=yes)
i_{korrf}	= flag for spectral correction (0=no, 1=yes)
i_{win}	= window to be applied to data (0=no, 1=Bartlett, 2=Welch, 3=Hanning)
i_{met}	= flag for conversion to meteorological data (0=no, 1=yes)
i_{fnorm}	= flag for normalizing the frequencies (0=no, 1=yes)
z_m	= measuring height above displacement height $z_m = z - d$

l_{freq} = number of decades for logarithmic equidistant frequencies
name of 1st SLT-file
name of 2nd SLT-file
.
.
.
.
.

13.3 SPECMEAN – calculation of mean spectra

This program is used to calculate mean spectra of any kind from the output files of the spectra programs. As input files the files with the extension csv are accepted, the output file name of one program run consits of the characters following the first underscore (_) of the original input file names plus mean.csv.

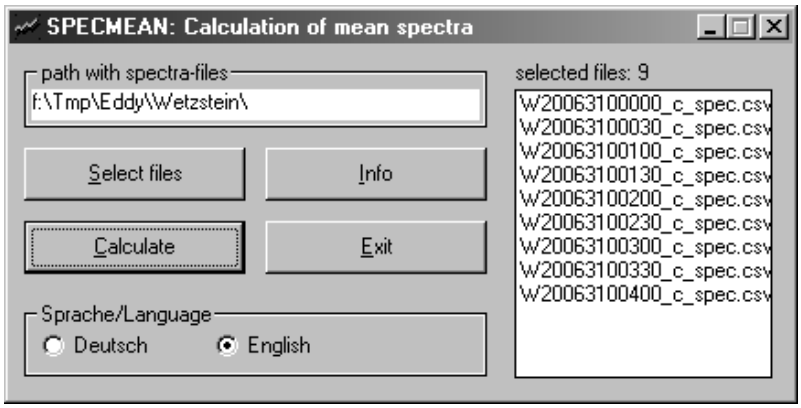


Figure 38: The SPECMEAN dialog window

Because the results of single spectrum calculations contain a lot of scatter it is recommended to process several spectra of a continuous period and then to calculate a mean spectrum.

14 EDDYPFIT – fit wind components to a plane

This program is used to generate the coeffcients and angles for the planar fit rotation of the wind components measured (Wilczak et al., 2001). This tool again consists of two programs, a dialog window and a processing program. The processing program is able to read data from two different file formats. Most convenient would be to use directly the files with the extension flx which are generated by EDDYMEAS and which contain the three wind components as they are measured by the sonic anemometer. As well csv files may be used as input (but not the ones generated by EDDYFLUX) which must contain the three wind components u, v and w seperated by commas and with one header line. The format in use must be selected in the dialog.

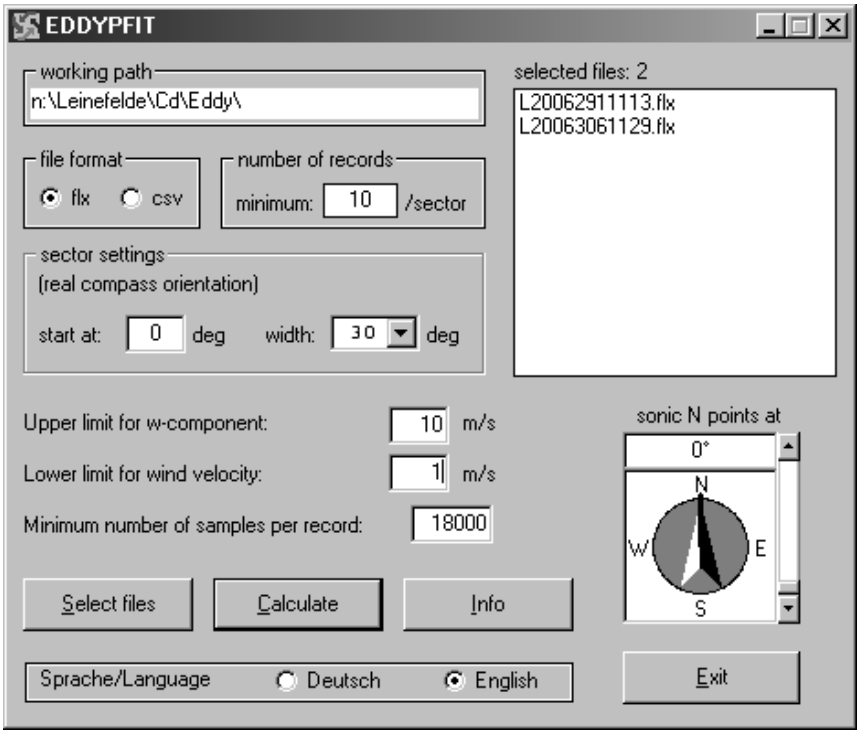


Figure 39: The EDDYPFIT dialog window

Independent from the sector settings in the dialog, the processing program calculates in a first step the planar fit for all data in the input file(s). In addition it is possible to divide the input data into sectors (from 2 of 180° to 72 of 5°). A sector is equal to a range of real wind directions or compass orientations, respectively. Depending on the type of sonic anemometer and depending on the adjustment of the sonic orientation the program calculates the real wind direction from the u- and v- componets and sorts them into the corresponding arrays for the desired sectors. From these arrays of u- and v-couples planar fits are calculated for each sector.

It is very important to set the correct alignment angle of the sonic anemometer here and

later in EDDYFLUX as well if a sectorwise planar fit is desired. Otherwise the calculations of wind direction will be wrong and thus also the assignment to the sectors. For the Gill HS and the Campbell CSAT3 the direction of the arm going from the mast to the sensor head must be selected, for all other sonics the direction where the north mark points at must be adjusted.

If sector width is set to 0 (zero) then no additional sector-wise calculations are being performed and the result is the best fit for the entire dataset only. If sector-wise calculations are performed, then it is checked if the number of data triples for each sector is greater than what is entered in the dialog window. If there are less records available in one sector, then this sector is skipped and the results for the entire dataset are placed in the result file instead.

An absolute limit for the vertical wind component w can be entered in the dialog window. If in any record w is greater than this threshold then it is discarded and not used for the calculation of the planar fit. A lower limit for the horizontal wind velocity wv can also be set. If in any record wv is lower than this threshold then this record is discarded and not used for the calculation of the planar fit. It is recommended to create a histogram of w and the wind velocity wv before using EDDYPFIT to decide how to set these threshold values.

If the flx-file format is selected for the input files then it is possible to enter a minimum number of samples which must have been collected for each record of the input files. Records consisting of less samples than the desired number are being rejected and not used for calculating the planar fit. It is recommended to enter at least half of the number of samples which is normally collected during a complete averaging period.

It is possible to select more than one input file, because those may contain data of short periods only. During the calculations the data of all input files are combined and there is only one result generated for all input files. The final result consists of 3 or 4 files:

1. pfitmatrix.csv contains the sector limits in the first two columns, then the coefficients $b0$, $b1$ and $b2$ (see Wilczak et al., 2001) which fit the best plane, then the rotation angles α and β first in radian and then in degree and as last column the number of records in each sector. If sector width was set to zero then this file contains only one line apart from the header line. Otherwise it will contain this line (for the entire dataset) and one more line for each sector. The smallest number of a sector limit is equal to zero or to the start value for the first sector (sector offest).

   In the following example the first sector starts at 0 degree and the sector width was set to 90 degrees:

```
Secl,Sech,   b0    ,    b1     ,     b2    , alpha_r  ,  beta_r ,alpha_d,beta_d,recs
000, 360,0.52267E-1,-0.30993E-1,-0.36239E-1,0.30963E-1,-0.36223E-1,1.77,-2.08,1339
000, 090,0.18283E-1,-0.50398E-1,-0.45333E-1,0.50304E-1,-0.45302E-1,2.88,-2.60, 141
090, 180,0.14633E-1,-0.12078E-2,-0.35538E-1,0.12070E-2,-0.35523E-1,0.07,-2.04, 211
180, 270,0.10898E-1,-0.40460E-3,-0.57644E-1,0.40393E-3,-0.57581E-1,0.02,-3.30, 157
270, 360,0.17191E-1,-0.49457E-1,-0.20313E-1,0.49407E-1,-0.20311E-1,2.83,-1.16, 830
```

In the second example the first sector starts at 15 degrees and the sector width was set to 180 degrees:

```
Secl,Sech,   b0    ,    b1     ,     b2    , alpha_r  ,  beta_r ,alpha_d,beta_d,recs
000, 360, 0.8696E-01,-0.1037E-01, 0.2132E-01, 0.1037E-01, 0.2131E-01, 0.59, 1.22,1404
015, 195,-0.1153E-01, 0.9835E-02, 0.5352E-01,-0.9821E-02, 0.5347E-01,-0.56, 3.06,638
195, 015, 0.1189E-01,-0.3804E-01,-0.9900E-02, 0.3802E-01,-0.9900E-02, 2.18,-0.57,766
```

2. pfitdata0.csv contains three columns with the original wind components u, v ($-v$ in case of an R2) and w, comma separated with one header line.

3. pfitdata1.csv contains three columns with the planar fit rotated wind components u, v and w, comma separated with one header line. This rotation is performed with only one plane fitted from the entire dataset.

4. If sector-wise planar fit was performed then pfitdata2.csv contains three columns with the planar fit rotated wind components u, v and w, comma separated with one header line. This rotation is performed with several planes fitted from the sector-wise selected data.

The sector where both, u and v are negative represents wind directions between 240° and 330°. The terrain at the site where the data, presented in figure 40, is sloping down from East to West and as well from North to South. This is clearly reflected in the graph of unrotated data where upslope winds result in a positive w at the sonic anemometer which is levelled against a horizontal plane.
After calculating the planar fit there is more or less only random scatter of w found for all range of u and v. $\overline{w}$ reduces from 0.1 $\mathrm{m\,s^{-1}}$ for the original data to $7.5 \cdot 10^{-6}\,\mathrm{m\,s^{-1}}$ for the simple planar fit rotated dataset. Performing a 4-sector planar fit reduces the scatter of w and gives an average value of $\overline{w} = 4.3 \cdot 10^{-19}\,\mathrm{m\,s^{-1}}$.

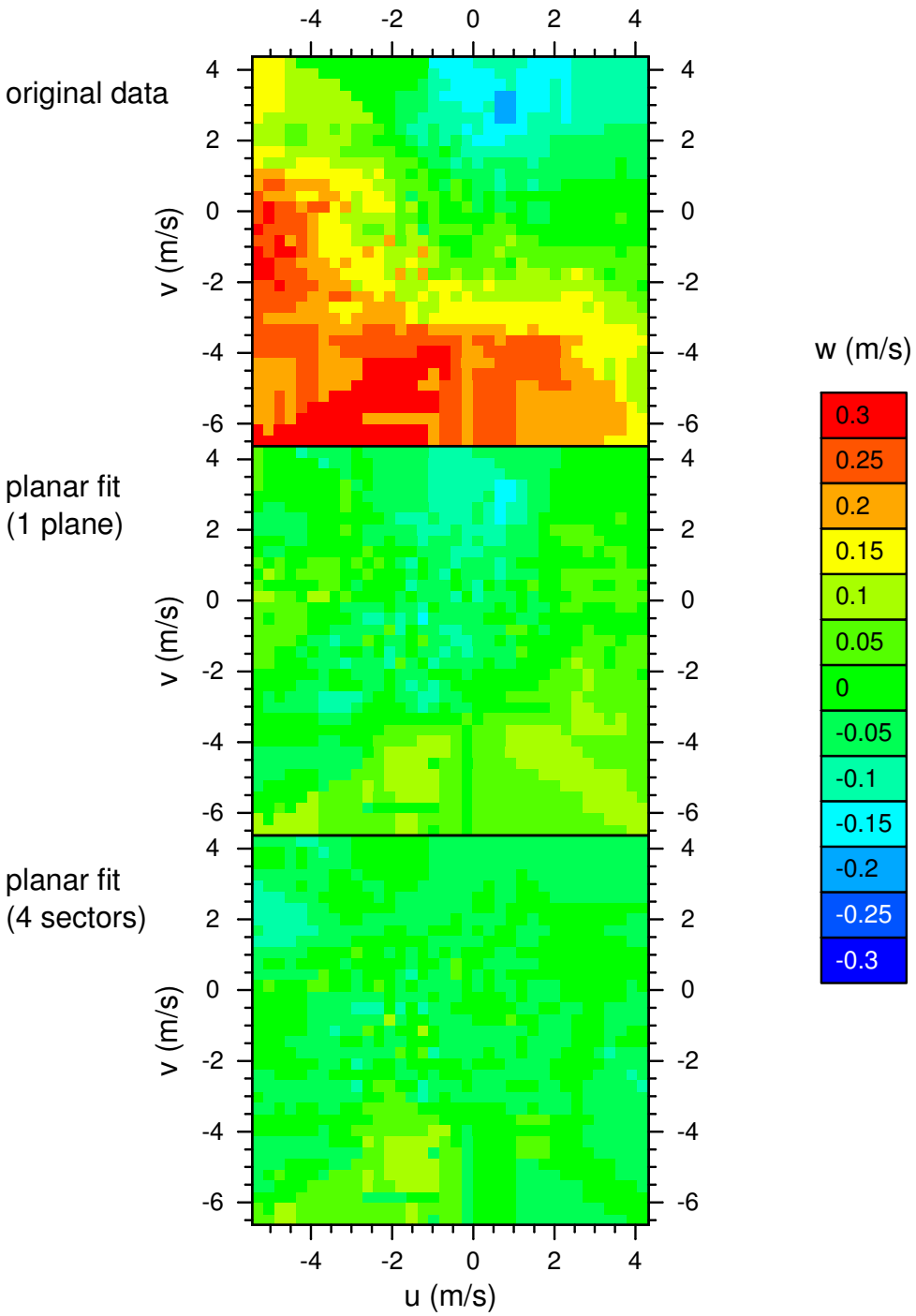


Figure 40: Results from Planar Fit (w over u and v)

All the settings in the dialog window are saved to a file named eddypfit.ini containing 8 numbers in 7 separate lines:
$file\_format$
min_recs
$sector\_start$
$sector\_width$
$sonic\_angle$
w_limit, wv_limit
min_samp

where $file\_format$ is 0 for flx and 1 for csv files, min_recs is the minimum required number of records (u, v, w triples) to calculate a planar fit in one sector. This number should not be choosen too small, otherwise the error defining the planes will increase. Data records containing vertical wind velocities w with $|w| > w\_limit$ are discarded and not used for the calculation of the planar fit as well as records containing horizontal wind velocities wv with $wv < wv\_limit$ and as well as data records with less than min_samp samples (the latter is possible for flx-files only).
The file named pfitfiles.lst is used to pass the settings and names of input files to the processing program:
$file\_format$
min_recs
$sector\_start$
$sector\_width$
$sonic\_angle$
w_limit, wv_limit
min_samp
nf
file1
file2
.
.
.
.

The first seven lines are identical to the content of the eddypfit.ini file. nf represents the number of input files selected and from line 9 on each line contains the name of one input file (flx or csv files, which must not be mixed for one run!).

The file pfitmatrix.csv (or its renamed copies) containing the results of the planar fits is in a later stage used by EDDYFLUX to perform the wind vector rotation.

15 EDDYFLUX – data analysis

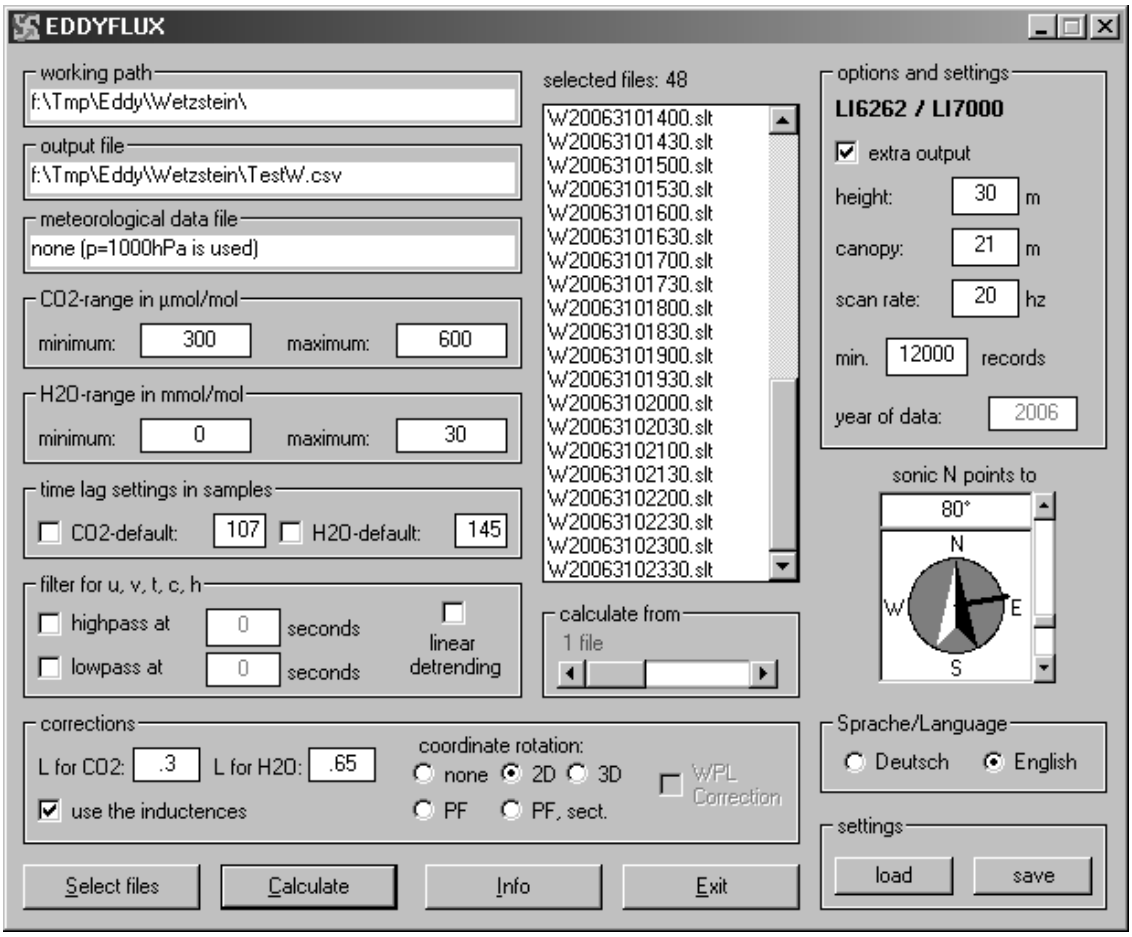


Figure 41: The EDDYFLUX dialog window

As already described in sections 1 and 11, the alignment angle of the sonic anemometer can be adjusted here as well and influences only the output of the u- and v-components and the wind direction in the standard output file (extension csv).

Besides other already known or described input fields or buttons some must be explained separately here: Within the frame for filtering u, v, t, c and h the option for linear detrending those variables can be switched on or off. It is recommended to have this option switched off.

The value which is filled in the min. [ ] records box determines how many records a raw data file must contain at least to be accepted. Files containing less records are rejected and not being processed. The field for the year is disabled if the raw data file names contain the year. If the year is not included in the filenames the year of acquiring the data must be filled in to create the correct time stamp within the output file.

Using the load and save buttons within the settings frame the most important settings may be saved to or loaded from site specific files which have the same format as the EDDYFLUX.CAL file (the standard settings file which is read after program start).

Having selected the raw data files, one is asked if meteorological data are available from an additional input file:

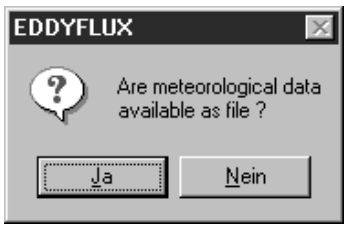


Figure 42: Meteorological data available?

If meteorological data are available it is recommended to create such a file for more precise calculations of air density, the fluxes and their corrections. This file **must** then contain air pressure (hPa), air temperature (^{o}C) and relative humidity (%) separated by comma (,) line by line for each corresponding raw data file without any headerline.
Each line **may** contain as well individual default values (in samples) for the time lags of [CO_2] (first) and [H_2O] (second). The lag of [H_2O] turned out to highly correlate with ambient air water vapour deficit and could thus be modelled. Those modelled values may be used in this file to define much better the value around which the optimum lag is being searched by the EDDYFLUX program. As well individual measurement (first) and vegetation (second) height values (in m) **may** be set in each line as rightmost numbers. This is useful for agricultural sites where for instance corn is growing and where a telescopic tower is used which is modified in height during the growing season.
The file must look as follows where values within brackets [ ] may be omitted in which case the values for the lags and heights are taken from the parameter file (see below) and are equal for all raw data input files. Either only the heights can be omitted or both, the heights and the lags.

```
964.73, 12.34, 97.27[, 110, 118[, 6.0, 0.40]]
964.59, 12.47, 97.60[, 110, 118[, 6.0, 0.40]]
964.30, 12.76, 96.93[, 110, 118[, 6.0, 0.40]]
964.09, 12.38, 97.70[, 110, 118[, 6.0, 0.40]]
963.88, 12.06, 98.20[, 110, 118[, 6.0, 0.41]]
963.85, 11.78, 98.40[, 110, 120[, 6.0, 0.41]]
963.95, 11.63, 98.50[, 110, 120[, 6.0, 0.41]]
964.12, 11.54, 98.50[, 110, 120[, 6.0, 0.41]]
964.20, 11.70, 97.60[, 110, 125[, 6.0, 0.41]]
964.20, 11.61, 96.43[, 110, 125[, 6.0, 0.41]]
   .      .      .      .    .    .    .
   .      .      .      .    .    .    .
```

If such a file is available one is asked to select this file from the file selector dialog, otherwise one is asked to enter an average pressure value being valid for all the selected raw data files:

Figure 43: Pressure value to use?

If data from a file are available then the air density is calculated using these data, missing numbers have to be replaced by −9999.00. If a fixed pressure value was selected then the air density is calculated using this pressure, the air temperature from the sonic and the humidity from the gas analyzer. If the sonic temperature is bad then 15 ^{o}C is used and if the humidity from the analyzer is bad then a value of 50 % relative humidity is used.
If EDDYFLUX is called by EDDYMEAS then the pressure is calculated from the height above sea level with a temperature correction using the sonic temperature.
The standard csv output file of EDDYFLUX contains columns with the actually used meteorological data.

If the coordinate rotation option is set to PF or PF sect. then in the next step it is necessary to select the file containing the parameters for the planar fit calculations (the file can be stored at any directory and may have any name). The file must exactly look as it was generated by EDDYPFIT. It is recommended to run EDDYPFIT for each site for different periods (e.g summer and winter in case of deciduous forest or whenever the position of the sonic anemometer was changed etc.) and generate several parameter files by giving each pfitmatrix.csv file a meaningful new name. It would be important to archive all these parameter files for future use. If EDDYFLUX is called by EDDYMEAS online at the site and if one of the planar fit options is selected, then the parameter file must be named pfitmatrix.csv and must reside in the same directory as the programs (see also section 14).

In the following section the processing steps of the FORTRAN90 program are summarized where the rest of the buttons and settings are described.

15.1 Reading parameter and information file

Parameter file

EDDYFLUX.CAL:
$[CO_2]_{min}$, $[CO_2]_{max}$

$[H_2O]_{\min}$, $[H_2O]_{\max}$
lag_c, lag_h
z_g, h_c, f_s, L_{CO_2}, L_{H_2O}, y
s_a
$minrecs$

where

$[CO_2]_{\min}$ = lower limit of analyzer $[CO_2]$ range in $\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
$[CO_2]_{\max}$ = upper limit of analyzer $[CO_2]$ range in $\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
$[H_2O]_{\min}$ = lower limit of analyzer $[H_2O]$ range in $\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
$[H_2O]_{\max}$ = upper limit of analyzer $[H_2O]$ range in $\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$
lag_c = default value for time lag calculation in samples for CO_2 signal
lag_h = default value for time lag calculation in samples for H_2O signal
z_g = measuring height in m above ground
h_c = canopy height in m
f_s = sample frequency in hz
L_{CO_2} = correction factor (inductance) for CO_2
L_{H_2O} = correction factor (inductance) for H_2O
y = year of dataset
s_a = sonic alignment in whole-numbered degrees
$minrecs$ = minimum required number of records to process the data file

Calculation of roughness length z_0

$$z_0 = 0.01 \qquad \text{if } h_c < 0.1\,\mathrm{m} \tag{15}$$

$$z_0 = 0.1 \cdot h_c \qquad \text{if } h_c \geq 0.1\,\mathrm{m} \tag{16}$$

Measuring height z_m above zero plane displacement:

$$z_m = z_g - \frac{2}{3} \cdot h_c \tag{17}$$

Information file

SLTFILES.LST:

n_{files}, i_{files}
i_{online}
t_{high}, t_{low}
i_{rot}, i_{exout}, i_{fixlagc}, i_{fixlagh}, i_{corfreq}, i_{wpl}, i_{detrend}

[pfitfile]
outputfile
file1, $p1,\ T1,\ rh1\,[,\ lag1_c,\ lag1_h\,[,\ z1_m,\ z1_v]]$
file2, $p2,\ T2,\ rh2\,[,\ lag2_c,\ lag2_h\,[,\ z2_m,\ z2_v]]$
. . . .
. . . .
. . . .

where

n_{files} = number of selected files
i_{files} = number of combined files
i_{online} = called from EDDYMEAS (0=no, 1=yes, 2=yes with archiving)
t_{high} = high pass filter period in s
t_{low} = low pass filter period in s
i_{rot} = flag for coordinate rotation (0=none, 1=planar fit, 2=2D, 3=3D, 4=planar fit sectors)
i_{exout} = flag for additional output (0=no, 1=yes)
i_{fixlagc} = flag for default lag for CO_2 signal (0=calculate, 1=take default)
i_{fixlagh} = flag for default lag for H_2O signal (0=calculate, 1=take default)
i_{corfreq} = flag for CO_2 and H_2O flux correction (0=no correction, 1=correction)
i_{wpl} = flag for WPL-correction (0=no correction, 1=correction)
i_{detrend}= flag for linear detrending (0=no detrending, 1=detrending)
name of parameter file for planar fit (appears only or may only appear if $i_{\text{rot}} = 1$ or $i_{\text{rot}} = 4$)
name of output file
name of 1st SLT-file, air press. (hPa), air temp. (^{o}C), rel. hum. (%)[, CO_2 lag, H_2O lag[, h_{meas}, h_{veg}]]
name of 2nd SLT-file, air press. (hPa), air temp. (^{o}C), rel. hum. (%)[, CO_2 lag, H_2O lag[, h_{meas}, h_{veg}]]
. . . . o p t i o n a l
. . . . o p t i o n a l
. . . . o p t i o n a l

Measurement height h_{meas} and vegetation height h_{veg} must be given in meters but may be omitted. CO_2 lag and H_2O lag must be in samples but may be omitted, if also h_{meas} and h_{veg} are omitted.

If the option extra output is selected then two additional output files are created. They are named in the same way as the standard output file but with different extensions. The file with the extension csu contains averages, variances and covariances (not fluxes) calculated with unrotated wind components. The file with the extension csr contains averages, variances and covariances (not fluxes) calculated with rotated wind components together with the three rotation angles. If EDDYFLUX is running in the online mode called from EDDYMEAS the two additional output files are created by default.

15.2 Conversion of raw data into physical data (see **EDDYREAD**)

time t of sample in s:

$$t = n/f_s \tag{18}$$

where:

n = number of sample
f_s= sample frequency in hz

sonic anemometer wind-components u, v, w in $\mathrm{m\,s^{-1}}$:

$$u = u_{raw}/100 \tag{19}$$
$$v = v_{raw}/100 \tag{20}$$
$$w = w_{raw}/100 \tag{21}$$

where:

$u_{raw}, v_{raw}, w_{raw}$ = integer values after internal sonic anemometer conversion

sonic anemometer temperature ϑ_s in ^{o}C or T_s in K

$$T_s = \frac{(c_{raw}/50)^2}{403} \tag{22}$$

$$\vartheta_s = T_s - 273.16 \tag{23}$$

where:

c_{raw} = sonic anemometer integer speed of sound in $\mathrm{m\,s^{-1}}$

Analyzer CO_2-concentration $[CO_2]$ in $\mu\mathrm{mol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$

$$[CO_2] = [CO_2]_{\mathrm{min}} + \frac{[CO_2]_{\mathrm{max}} - [CO_2]_{\mathrm{min}}}{5000} \cdot [CO_2]_{\mathrm{raw}} \tag{24}$$

where:

$[CO_2]_{\mathrm{raw}}$ = raw voltage signal for $[CO_2]$ of analyzer in mV

Analyzer H_2O-concentration $[H_2O]$ in $\mathrm{mmol\,mol^{-1}}$ or $\mathrm{mmol\,m^{-3}}$

$$[H_2O] = [H_2O]_{\min} + \frac{[H_2O]_{\max} - [H_2O]_{\min}}{5000} \cdot [H_2O]_{\mathrm{raw}} \tag{25}$$

where:

$[H_2O]_{\mathrm{raw}}$ = raw voltage signal for $[H_2O]$ of analyzer in mV

In the following c is used instead of $[CO_2]$ for CO_2-concentration, and h instead of $[H_2O]$ for H_2O-concentration.

15.3 Calculation of means $\overline{x}$ and variances $\overline{x'^2}$

$$\overline{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i \tag{26}$$

$$\overline{x'^2} = \frac{1}{n-1} \cdot \sum_{i=1}^{n} (x_i - \overline{x}) \tag{27}$$

where:

n = number of samples
x_i= sample of u, v, w, T_s, c, h

15.4 Coordinate rotations

15.4.1 The first two rotations

The first two rotations force u into the mean wind direction and $\overline{w} = 0$.
In the first rotation the streamwise component is rotated in the direction of the mean horizontal wind vector.

$$u_1 = u \cdot \cos\alpha_r + v \cdot \sin\alpha_r \tag{28}$$

$$v_{1/2} = -u \cdot \sin\alpha_r + v \cdot \cos\alpha_r \tag{29}$$

$$w_1 = w \tag{30}$$

with:

$$\cos\alpha_r = \frac{u}{v_{\mathrm{hor}}}, \quad \sin\alpha_r = \frac{v}{v_{\mathrm{hor}}} \tag{31}$$

where:

$$v_{\text{hor}} = \sqrt{u^2 + v^2} \tag{32}$$

In the second rotation the coordinate system is tilted so that $\overline{w} = 0$. Both rotations ensure that the streamwise velocity component is aligned with the direction of the mean 3D flow vector.

$$\begin{aligned} u_2 &= u \cdot \cos\alpha_r \cdot \cos\beta_r + v \cdot \sin\alpha_r \cdot \cos\beta_r + w \cdot \sin\beta_r && (33) \\ v_{1/2} &= v_{1/2} && (34) \\ w_2 &= -u \cdot \cos\alpha_r \cdot \sin\beta_r \; - v \cdot \sin\alpha_r \cdot \sin\beta_r + w \cdot \cos\beta_r && (35) \end{aligned}$$

with:

$$\cos\beta_r = \frac{v_{\text{hor}}}{v_{\text{3D}}}, \quad \sin\beta_r = \frac{w}{v_{\text{3D}}} \tag{36}$$

where:

$$v_{\text{3D}} = \sqrt{u^2 + v^2 + w^2} \tag{37}$$

In matrix form:

$$\begin{pmatrix} u_2 \\ v_{1/2} \\ w_2 \end{pmatrix} = \begin{pmatrix} \cos\alpha_r \cos\beta_r & \sin\alpha_r \cos\beta_r & \sin\beta_r \\ -\sin\alpha_r & \cos\alpha_r & 0 \\ -\cos\alpha_r \sin\beta_r & -\sin\alpha_r \sin\beta_r & \cos\beta_r \end{pmatrix} \begin{pmatrix} u \\ v \\ w \end{pmatrix} \tag{38}$$

15.4.2 The third rotation

This rotation minimizes the $\overline{v'w'}$ momentum flux by performing a rotation of angle γ_r about axis x_2.

$$\begin{aligned} u_3 &= u_2 && (39) \\ v_3 &= v_{1/2} \cdot \cos\gamma_r + w_2 \cdot \sin\gamma_r && (40) \\ w_3 &= -v_{1/2} \cdot \sin\gamma_r + w_2 \cdot \cos\gamma_r && (41) \end{aligned}$$

or in matrix form:

$$\begin{pmatrix} u_3 \\ v_3 \\ w_3 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\gamma_r & \sin\gamma_r \\ 0 & -\sin\gamma_r & \cos\gamma_r \end{pmatrix} \begin{pmatrix} u_2 \\ v_{1/2} \\ w_2 \end{pmatrix} \tag{42}$$

These rotations apply also to fluctuating quantities. Thus, the calculation of the covariance $\overline{v_3'w_3'}$ is:

$$\overline{v_3'w_3'} = -\sin\gamma_r \cdot \cos\gamma_r \cdot \left(\overline{v_{1/2}'^2} + \overline{w_2'^2}\right) + \left(1 - 2 \cdot \sin^2\gamma_r\right) \cdot \overline{v_{1/2}'w_2'} \tag{43}$$

With K defined as $\frac{\overline{v_{1/2}'w_2'}}{\left(\overline{v_{1/2}'^2} + \overline{w_2'^2}\right)}$, the covariance will be equal to zero provided that $\sin\gamma_r$ is the positive solution of the quadratic equation:

$$2 \cdot K \cdot \sin^2\gamma_r + \sin\gamma_r \cdot \cos\gamma_r - K = 0 \tag{44}$$

that is when

$$\sin\gamma_r = \frac{-\cos\gamma_r \pm \sqrt{\cos^2\gamma_r + 8 \cdot K^2}}{4 \cdot K} \tag{45}$$

Solving for γ_r requires an iterative process: starting with $\cos\gamma_r = 1$, $\sin\gamma_r$ is computed using equation 45; then, a new $\cos\gamma_r$ is computed using the identity $\cos\gamma_r = \sqrt{1 - \sin^2\gamma_r}$. the iteration is concluded when both $\sin\gamma_r$ and $\cos\gamma_r$ differ by less then 10^{-12} from their previous values.
Mc Millen (1988) recommends to apply this last rotation with care as it is not always well defined, especially in low wind conditions. In EDDYFLUX, the rotation is limited to 10 degrees.

15.4.3 Planar Fit

The planar fit rotation is computed exactly according to the paper of Wilczak et al. (2001), thus the formula are not shown here in detail. The planar fit rotation can be applied by using only one plane or by using individual planes for different wind direction sectors (see also section 14). For forest sites the planar fit rotation is recommended, but for agricultural sites or grassland in flat terrain the 2D-rotation should be applied.

15.5 Filtering or detrending of the time series

15.5.1 Filtering

For test purposes a high or low pass filter can be applied on the data in the frequency domain. The cut-off frequencies have to be entered as corresponding periods in seconds. Low pass filtering may be necessary if noise is present, high pass filtering may be used instead of linear detrending. Under normal conditions filtering is not applied.

15.5.2 Detrending

It may be necessary to detrend eddy covariance data because of instationarities (trends) of the mean values. Different philosophies do exist, as usual. This can be done by different methods: running mean detrending is mostly used if fluxes are calculated on-line. The disadvantage of the runnning mean procedure may be that low frequency eddies which contribute to the flux are underestimated. In EDDYFLUX a linear detrending algorithm or block averaging is used to avoid low frequency losses (GASH & GULF, 1996). The algorithm consists of calculating a linear regression between the time values and the specific data values in the first step. Then the linear trend represented by the slope of the regression line is subtracted from the time series. In a third step a constant value is added to all data points of the time series, so that the new mean matches the former one. If it seems to be necessary to detrend the time series this option can be selected separately, then a linear detrending as explained above is applied to the data.

15.5.3 Subtraction of the means

For determining the fluctuations of a time series the mean value of each variable $\overline{x}$ has to be calculated first and then subtracted from the single values

$$x' = x - \overline{x} \tag{46}$$

If the coordinate rotations are already done the algorithm has only to be applied on u, T_s, c and h.

15.6 Calculation of time lags for [CO_2] and [H_2O]

For the case that a closed path sensor for measuring c and h as the LI6262 is used, the sampled air needs some time to travel down from the inlet of the tubing to the analyzer. This time shift is calculated by determining the maximum correlation between the concentrations and the vertical wind component w'.

A first estimate of the time lag can be done by calculating it from the tube length and diameter and the flow rate. A second possibility is to use the program EDDYCORR for some selected files and then use these values as default lag_c or lag_h, respectively.
Under some circumstances (especially at low fluxes) no lag can be found and the default value is used. For test purposes a fix lag value can be used by checking the check boxes left of CO2-default and H2O-default respectively.

15.7 Calculation of fluxes

friction velocity u_* and **momentum flux** τ:

$$u_* = -\sqrt{\overline{u'w'}} \quad \mathrm{m\,s^{-1}} \tag{47}$$

$$\tau = -\rho \cdot \overline{u'w'} \quad \mathrm{kg\,m^{-1}\,s^{-2}} \tag{48}$$

where ρ is air density, calculated with pressure p (entered as mean value or as file) and T_s with the gas law.

sensible heat flux :

$$H = \rho \cdot c_p \cdot \overline{w'T_s'} \quad \mathrm{W\,m^{-2}} \tag{49}$$

where c_p is specific heat of air at constant pressure.

CO_2-flux:

$$F_{CO_2} = \frac{\rho}{m_a} \cdot \overline{w'c'} \quad \mu\mathrm{mol\,m^{-2}\,s^{-1}} \tag{50}$$

where $m_a = 0.02896\,\mathrm{kg\,mol^{-1}}$ is the molecular weight of air.

H_2O-flux:

$$F_{H_2O} = \frac{\rho}{m_a} \cdot \overline{w'h'} \quad \mathrm{mmol\,m^{-2}\,s^{-1}} \tag{51}$$

or expressed as **latent heat flux**:

$$\lambda E = F_{H_2O} \cdot 18.016 \cdot (2.5008 - 0.002372 \cdot \vartheta_s) \quad \mathrm{W\,m^{-2}} \tag{52}$$

where $\lambda = 2.45 \cdot 10^6\,\mathrm{J\,kg^{-1}}$ is specific heat of vapourization.

Bowen-ratio :

$$\beta = \frac{H}{\lambda E} \tag{53}$$

Calculation of **wind components** in meteorological notation:

The wind components are output by the Sonic aligned to the Sonic axis. EDDYFLUX converts the direction into the meteorological definitions: u aligned from W to E, v aligned from S to N, w positive in upward direction.

Calculation of Monin-Obukhov-parameters:

Monin-Obukhov-length :

$$L = -\frac{u_*^3}{\kappa \cdot (g/T_s) \cdot \overline{w'T_s'}} \tag{54}$$

where $\kappa = 0.4$ von Karman constant, $g = 9.81\,m\,s^{-2}$ acceleration due to gravity

Monin-Obukhov stability parameter :

$$\zeta = \frac{z_m}{L} \tag{55}$$

15.8 Additional calculations and corrections

applied on raw-data:

- Stationarity tests according to FOKEN & WICHURA (1996) (included in EDDYFLUX)

applied on averages:

- WPL correction: considers the influences of density fluctuations (WEBB ET AL., 1980). This option is selectable in case of using an open path gas analyzer (LI7500). If data of one of the closed path analyzers LI6262 or LI7000 are being processed this correction is not available. Remember that the WPL correction is automatically applied in the online flux calculations of EDDYMEAS if a LI7500 is used.
- Schotanus/Liu correction for sonic temperature: humidity correction for all sonic anemometers, crosswind correction for Gill R2, Gill Windmaster Pro, Metek USA-1 and Campbell CSAT3 only
- Schotanus/Liu correction for sensible heat flux: buoyancy flux to sensible heat flux for all sonic anemometers, crosswind correction for Gill R2, Gill Windmaster Pro, Metek USA-1 and Campbell CSAT3 only
- Calculation of foot-print according to SCHUEPP ET AL. (1990)
- Correction of CO_2- and H_20-fluxes according to EUGSTER & SENN (1995)
- integral turbulence characteristics according to FOKEN & WICHURA (1996)

15.9 Data output and management

15.9.1 Data output by EDDYFLUX to *.csv files

Symbol	Unit	Variable
H	$\mathrm{W\,m^{-2}}$	sensible heat flux
LE	$\mathrm{W\,m^{-2}}$	latent heat flux
E	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	water vapor flux
C	$\mu\mathrm{mol\,m^{-2}\,s^{-1}}$	CO_2 flux
u_*	$\mathrm{m\,s^{-1}}$	friction velocity
tau	$\mathrm{kg\,m^{-1}\,s^{-2}}$	momentum flux
var u	$\mathrm{m^2\,s^{-2}}$	variance of u-component
var v	$\mathrm{m^2\,s^{-2}}$	variance of v-component

var w	$m^2\,s^{-2}$	variance of w-component
var t	K^2	variance of temperature
var c	$\mu mol^2\,mol^{-2}$	variance of CO_2-concentration, LI6262 or LI7000
	$mmol^2\,m^{-6}$	or variance of CO_2-concentration, LI7500, ADC OP-2
var h	$mmol^2\,mol^{-2}$	variance of H_2O-concentration, LI6262 or LI7000
	$mmol^2\,m^{-6}$	or variance of H_2O-concentration, LI7500, ADC OP-2
avg u	$m\,s^{-1}$	average of u-component (positive from West to East)
avg v	$m\,s^{-1}$	average of v-component (positive from South to North)
avg w	$m\,s^{-1}$	average of w-component (positive if upward)
avg t	^oC	temperature measured by Sonic
avg c	$\mu mol\,mol^{-1}$	average CO_2-concentration, LI6262 or LI7000
	$mmol\,m^{-3}$	or average CO_2-concentration, LI7500, ADC OP-2
avg h	$mmol\,mol^{-1}$	average H_2O-concentration, LI6262 or LI7000
	$mmol\,m^{-3}$	or average H_2O-concentration, LI7500, ADC OP-2
wv_hor	$m\,s^{-1}$	average of horizontal wind velocity
wd_hor	deg	average of horizontal wind direction
alpha	deg	angle of first coordinate rotation (see section 15.4.1)
	deg	or rotation angle around y-axis (see Wilczak et al.,2001)
beta	deg	angle of second coordinate rotation (see section 15.4.1)
	deg	or rotation angle around x-axis (see Wilczak et al.,2001)
gamma	deg	angle of third coordinate rotation (see section 15.4.2)
	deg	or rotation angle around z-axis (see Wilczak et al.,2001)
c lag	samples	lag of CO_2 signal
h lag	samples	lag of H_2O signal
L	m	Monin-Obukhov length
zeta	–	Monin-Obukhov stability parameter (z/L)
corr. avg t	^oC	corrected sonic temperature (Schotanus/Liu)
corr. H	$W\,m^{-2}$	corrected sensible heat flux (Schotanus/Liu)
corr. LE^*	$W\,m^{-2}$	corrected latent heat flux (inductance, WPL)
corr. E^*	$mmol\,m^{-2}\,s^{-1}$	corrected water vapor flux (inductance, WPL)
corr. C^*	$\mu mol\,m^{-2}\,s^{-1}$	corrected CO_2 flux (inductance, WPL)
foot-peak	m	foot-peak distance for flux (Schuepp et al., 1990)
50%-fetch	m	50%-fetch distance for flux (Schuepp et al., 1990)
90%-fetch	m	90%-fetch distance for flux (Schuepp et al., 1990)
H/LE	–	Bowen ratio (from uncorrected fluxes)
stest1	–	Stationarity test (30% difference allowed)
stest2	–	Stationarity test (50% difference allowed)

itchu	–	Integral turbulence characteristic test for u-component
itchw	–	Integral turbulence characteristic test for w-component
itcht	–	Integral turbulence characteristic test for temperature
var u (rot)	$m^2\,s^{-2}$	variance of rotated u-component
var v (rot)	$m^2\,s^{-2}$	variance of rotated v-component
var $v\,hor$	$m^2\,s^{-2}$	variance of horizontal wind velocity
var wd	–	variance of wind direction using YAMARTINO algorithm
u_c	samples	number of exceeded change rates for u-component
v_c	samples	number of exceeded change rates for v-component
w_c	samples	number of exceeded change rates for w-component
t_c	samples	number of exceeded change rates for temperature
c_c	samples	number of exceeded change rates for CO_2-concentration
h_c	samples	number of exceeded change rates for H_2O-concentration
u_l	samples	number of exceeded limits for u-component
v_l	samples	number of exceeded limits for v-component
w_l	samples	number of exceeded limits for w-component
t_l	samples	number of exceeded limits for temperature
c_l	samples	number of exceeded limits for CO_2-concentration
h_l	samples	number of exceeded limits for H_2O-concentration
recs	samples	total number of records in the data file
p_air	hPa	air pressure used for calculations
		(from station height or manual input or met. file)
t_air	^{o}C	air temperature used for calculations
		(from sonic temperature measurement or met. file)
rh_air	%	relative humidity used for calculations
		(from gas analyzer humidity measurement or met. file)
e_air	hPa	water vapour pressure used for calculations
		(from gas analyzer humidity measurement or met. file)
rho	$kg\,m^{-3}$	air density used to calculate fluxes
cl_set	samples	set point for time lag of CO_2-signal
		(from dialog window input or met. file)
hl_set	samples	set point for time lag of H_2O-signal
		(from dialog window input or met. file)
z_meas	m	measurement height (from dialog window input or met. file)
z_veg	m	vegetation height (from dialog window input or met. file)

The items marked with an asterisk (corrected fluxes) include the following corrections if those options have been selected in the dialog (see figure 41):

- spectral correction according to Eugster & Senn (1995) using the inductances
- WPL correction according to Webb et al. (1980)

The results for the stationarity tests are binary coded where the bits are set if the test fails (no stationary conditions). Bit 5 is not coding for stationarity but for the sign of $u'w'$ which should be negative. Bit 5 is set if $u'w'$ is positive.

Bit#	**decimal value**	**coding for**
1 (LSB)	1	*tau* (stationarity)
2	2	CO_2-flux (stationarity)
3	4	H_2O-flux (stationarity)
4	8	H (stationarity)
5 (MSB)	16	$u'w'$ (sign)

As an example the output of 7 (binary `00111`) means that the stationarity test failed for *tau*, CO_2-flux and H_2O-flux, the output of 25 (binary `11001`) means that the stationarity test failed for *tau* and H and that $u'w'$ was positive.

15.9.2 Data output by EDDYFLUX to *.csu and *.csr files

Symbol	**Unit**	**Variable**
avg u	$\mathrm{m\,s^{-1}}$	average of u-component
avg v	$\mathrm{m\,s^{-1}}$	average of v-component
avg w	$\mathrm{m\,s^{-1}}$	average of w-component (positive if upward)
var u	$\mathrm{m^2\,s^{-2}}$	variance of u-component
var v	$\mathrm{m^2\,s^{-2}}$	variance of v-component
var w	$\mathrm{m^2\,s^{-2}}$	variance of w-component
covar uw	$\mathrm{m^2\,s^{-2}}$	covariance of u- and w-component
covar vw	$\mathrm{m^2\,s^{-2}}$	covariance of v- and w-component
covar uv	$\mathrm{m^2\,s^{-2}}$	covariance of u- and v-component
covar tu	$\mathrm{K\,m\,s^{-1}}$	covariance of T and u-component
covar tv	$\mathrm{K\,m\,s^{-1}}$	covariance of T and v-component
covar tw	$\mathrm{K\,m\,s^{-1}}$	covariance of T and w-component
covar hu	$\mathrm{mmol\,m\,s^{-1}\,mol^{-1}}$	covariance of $[H_2O]$ and u-component, LI6262 or LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of $[H_2O]$ and u-component, LI7500, ADC OP-2
covar hv	$\mathrm{mmol\,m\,s^{-1}\,mol^{-1}}$	covariance of $[H_2O]$ and v-component, LI6262 or LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of $[H_2O]$ and v-component, LI7500, ADC OP-2

covar *hw*	$\mathrm{mmol\,m\,s^{-1}\,mol^{-1}}$	covariance of [H_2O] and w-component, LI6262 or LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of [H_2O] and w-component, LI7500, ADC OP-2
covar *cu*	$\mu\mathrm{mol\,m\,s^{-1}\,mol^{-1}}$	covariance of [CO_2] and u-component, LI6262 or LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of [CO_2] and u-component, LI7500, ADC OP-2
covar *cv*	$\mu\mathrm{mol\,m\,s^{-1}\,mol^{-1}}$	covariance of [CO_2] and v-component, LI6262 or LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of [CO_2] and v-component, LI7500, ADC OP-2
covar *cw*	$\mu\mathrm{mol\,m\,s^{-1}\,mol^{-1}}$	covariance of [CO_2] and w-component, LI6262 or LI7000
	$\mathrm{mmol\,m^{-2}\,s^{-1}}$	or covariance of [CO_2] and w-component, LI7500, ADC OP-2
rho	$\mathrm{kg\,m^{-3}}$	air density used to calculate fluxes
only in *.csr files		
alpha	deg	angle of first coordinate rotation
beta	deg	angle of second coordinate rotation
gamma	deg	angle of third coordinate rotation
only in *.csr files if planar fit rotation was used		
avg u pf	$\mathrm{m\,s^{-1}}$	average of u-component after planar fit
avg v pf	$\mathrm{m\,s^{-1}}$	average of v-component after planar fit
avg w pf	$\mathrm{m\,s^{-1}}$	average of w-component after planar fit

15.9.3 Data management

Data from the acquisition computer should be read out at least every few days, even though there should be enough space for some weeks raw data on the hard drive. This is best to be done during the calibration procedure.
All *.zip and/or *.slt files and the *.flx, *.cfg and *.log files as well as the *.csv, *.csu and *.csr files (if final calculations with EDDYFLUX were carried out) should be copied from the \EDDYDATA directory onto an external drive.

16 References

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