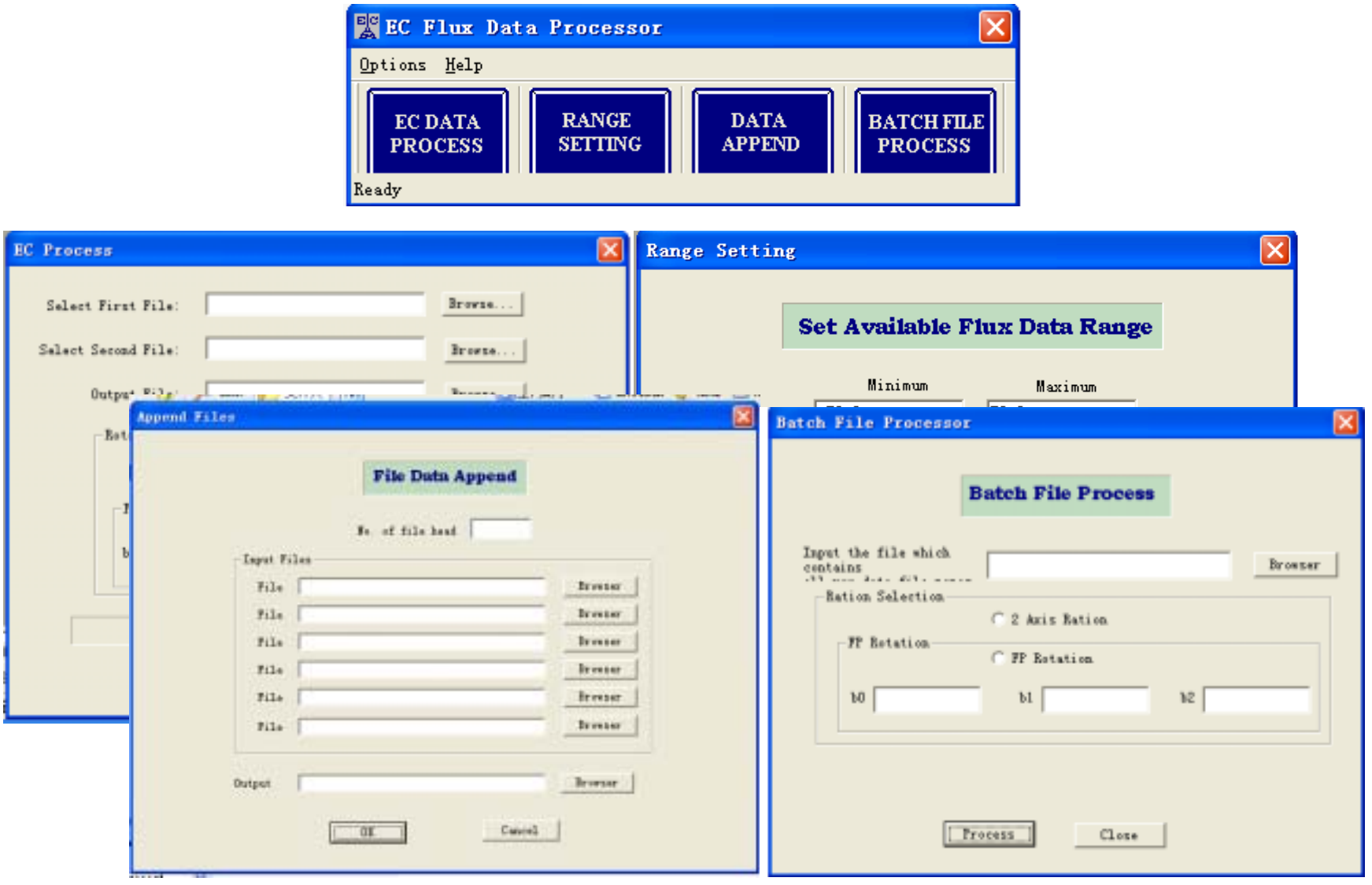
LEES-EC software

Rui Zhou & Asko Noormets

LEES lab,EEES department, The University of Toledo, Ohio, USA

LEES-EC software



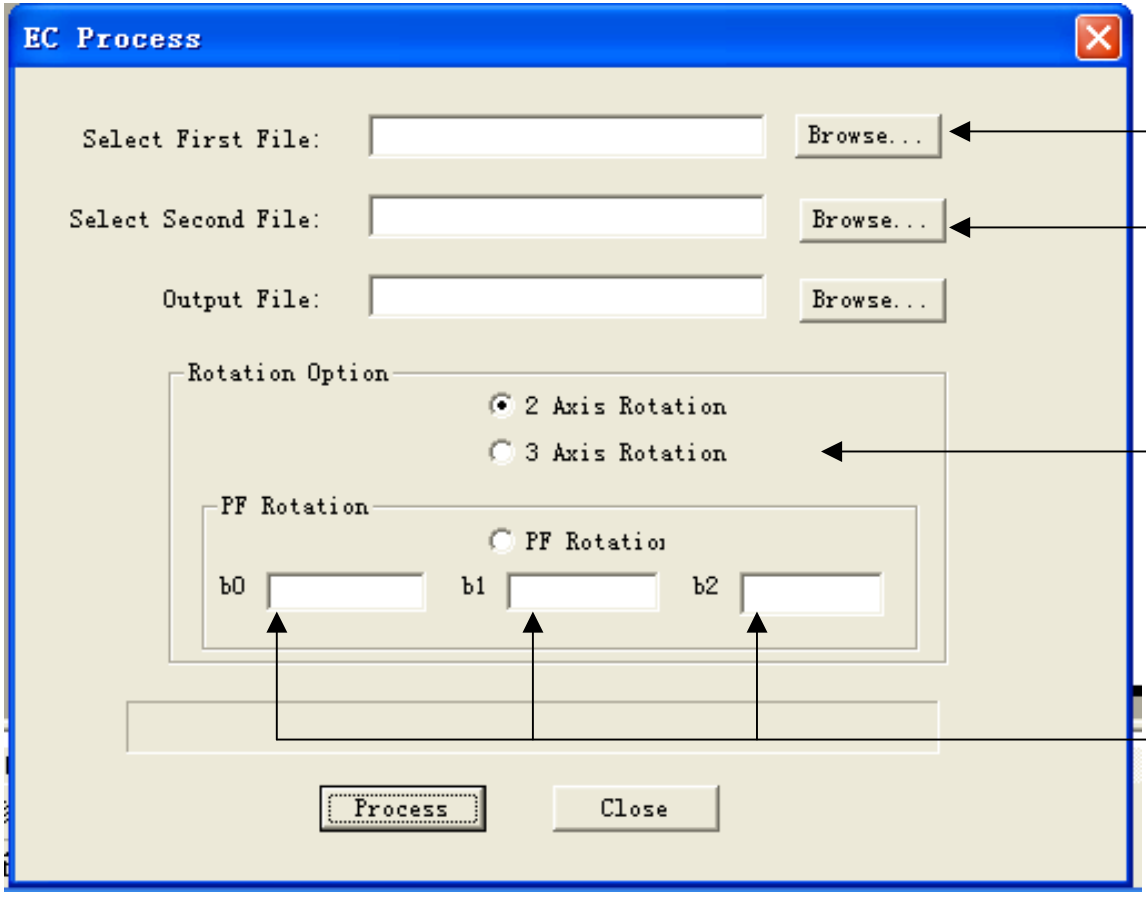
Files

- EC_setup.exe – install LEES-EC Processor
- EC_Processor.exe – start EC Processor with the main menu

- Data files
- Output files
- Readme.txt – input and output information

EC DATA PROCESS

•Provide windows interface for easily selecting input and output data files



The main file

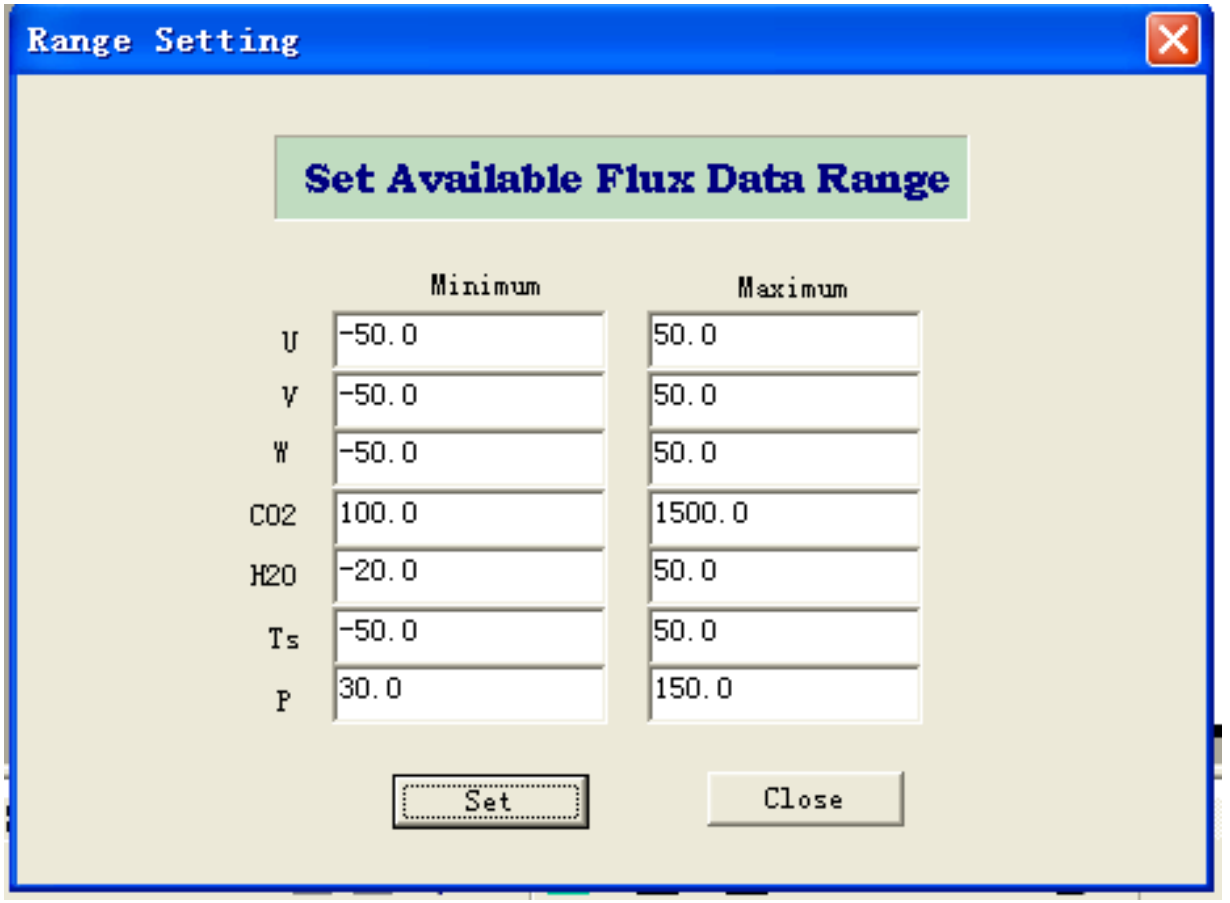
Provide rest data of the last half-hour to the main file

2- or 3-Dimension Rotation

b0,b1 and b2 are regression parameters of PF Rotation

RANGE SETTING

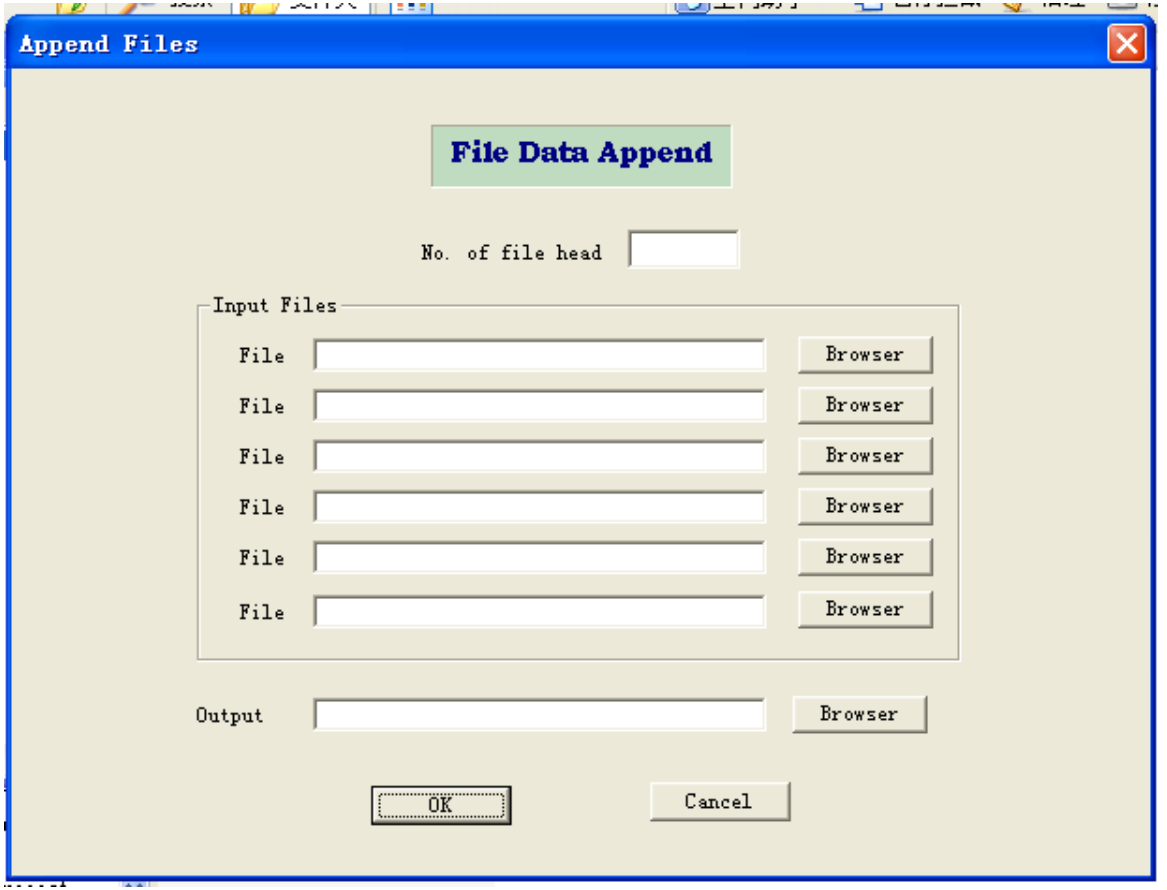
- **Default**
- **Changeable**

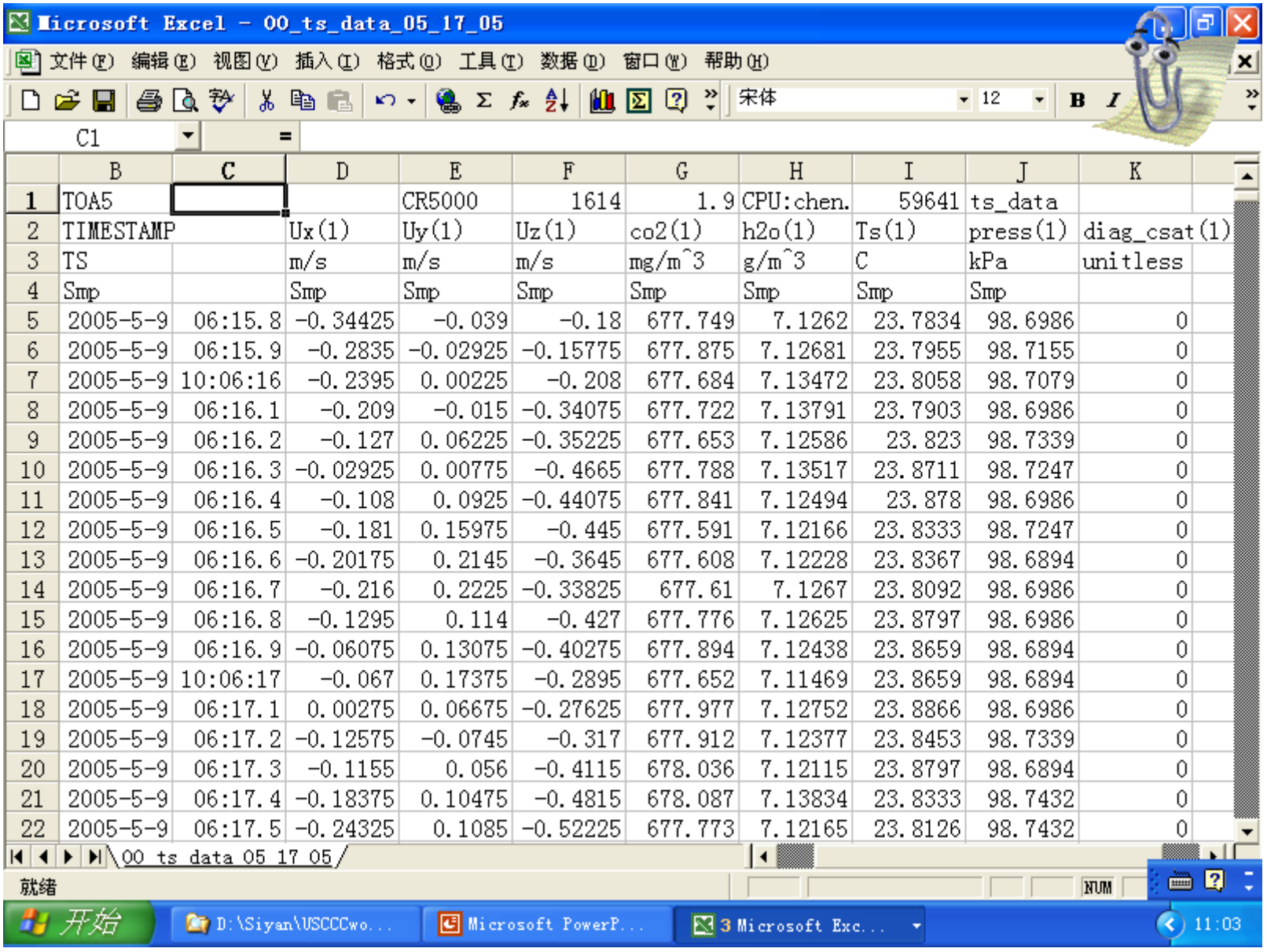


- **Data within ranges are used to calculate means.**
- **Data out of ranges are replaced by the means.**

DATA APEND

- a useful tool
- read six separated files into one big file
- good for txt file

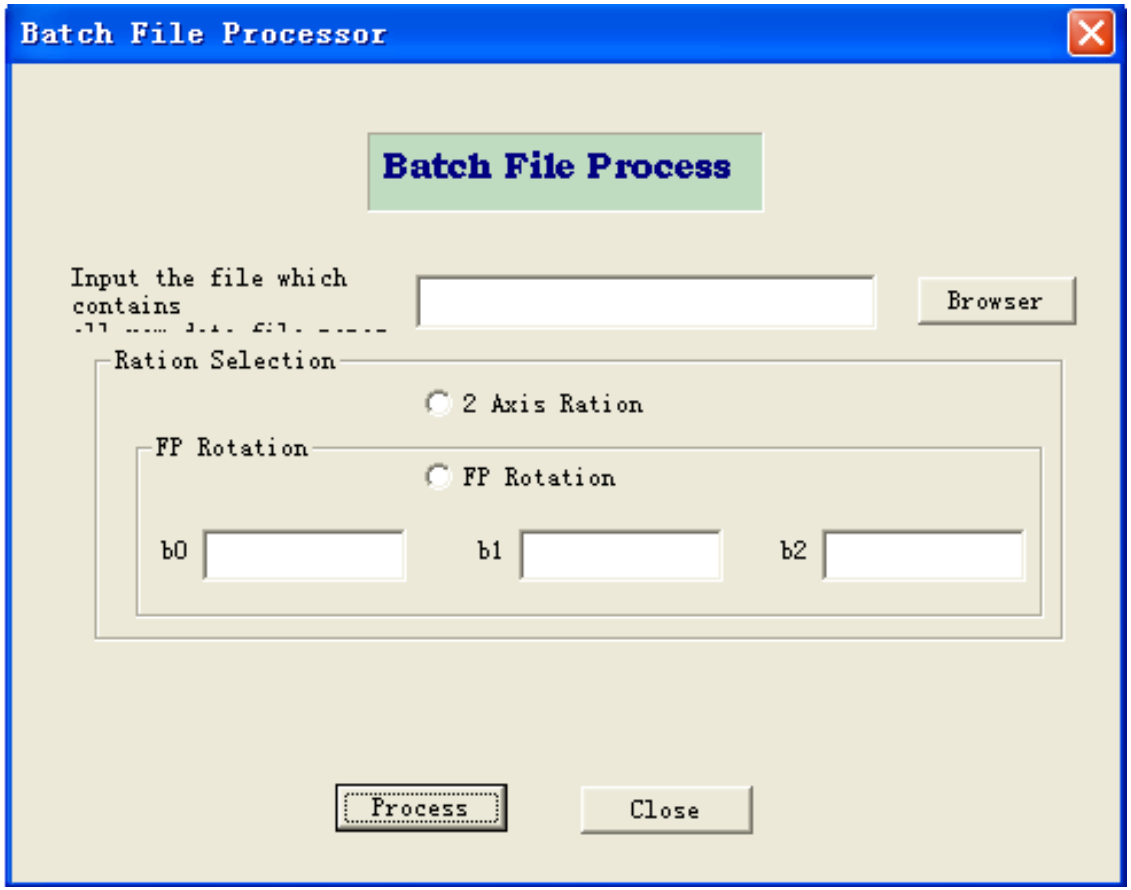




	B	C	D	E	F	G	H	I	J	K
1	TOA5			CR5000	1614	1.9	CPU:chen.	59641	ts_data	
2	TIMESTAMP		Ux(1)	Uy(1)	Uz(1)	co2(1)	h2o(1)	Ts(1)	press(1)	diag_csat(1)
3	TS		m/s	m/s	m/s	mg/m^3	g/m^3	C	kPa	unitless
4	Smp		Smp	Smp	Smp	Smp	Smp	Smp	Smp	
5	2005-5-9	06:15.8	-0.34425	-0.039	-0.18	677.749	7.1262	23.7834	98.6986	0
6	2005-5-9	06:15.9	-0.2835	-0.02925	-0.15775	677.875	7.12681	23.7955	98.7155	0
7	2005-5-9	10:06:16	-0.2395	0.00225	-0.208	677.684	7.13472	23.8058	98.7079	0
8	2005-5-9	06:16.1	-0.209	-0.015	-0.34075	677.722	7.13791	23.7903	98.6986	0
9	2005-5-9	06:16.2	-0.127	0.06225	-0.35225	677.653	7.12586	23.823	98.7339	0
10	2005-5-9	06:16.3	-0.02925	0.00775	-0.4665	677.788	7.13517	23.8711	98.7247	0
11	2005-5-9	06:16.4	-0.108	0.0925	-0.44075	677.841	7.12494	23.878	98.6986	0
12	2005-5-9	06:16.5	-0.181	0.15975	-0.445	677.591	7.12166	23.8333	98.7247	0
13	2005-5-9	06:16.6	-0.20175	0.2145	-0.3645	677.608	7.12228	23.8367	98.6894	0
14	2005-5-9	06:16.7	-0.216	0.2225	-0.33825	677.61	7.1267	23.8092	98.6986	0
15	2005-5-9	06:16.8	-0.1295	0.114	-0.427	677.776	7.12625	23.8797	98.6986	0
16	2005-5-9	06:16.9	-0.06075	0.13075	-0.40275	677.894	7.12438	23.8659	98.6894	0
17	2005-5-9	10:06:17	-0.067	0.17375	-0.2895	677.652	7.11469	23.8659	98.6894	0
18	2005-5-9	06:17.1	0.00275	0.06675	-0.27625	677.977	7.12752	23.8866	98.6986	0
19	2005-5-9	06:17.2	-0.12575	-0.0745	-0.317	677.912	7.12377	23.8453	98.7339	0
20	2005-5-9	06:17.3	-0.1155	0.056	-0.4115	678.036	7.12115	23.8797	98.6894	0
21	2005-5-9	06:17.4	-0.18375	0.10475	-0.4815	678.087	7.13834	23.8333	98.7432	0
22	2005-5-9	06:17.5	-0.24325	0.1085	-0.52225	677.773	7.12165	23.8126	98.7432	0

BATCH FILES PROCESS

• need create a text file, including all filenames that need to be processed.



Cautious: the firs and last half-hour data may not be completed.

EC DATA PROCESS

Input data

The raw data file is a ASCII (TOA5) file obtained from Campbell PC 9000 software converting.

10 hz data

Title includes four lines.
TIMESTAMP,Ux(m/s),Uy(m/s),Uz(m/s),co2(mg/(m^3)),h2o(g/(m^3)),Ts(C), press(kPa),diag_csat.

EC DATA PROCESS

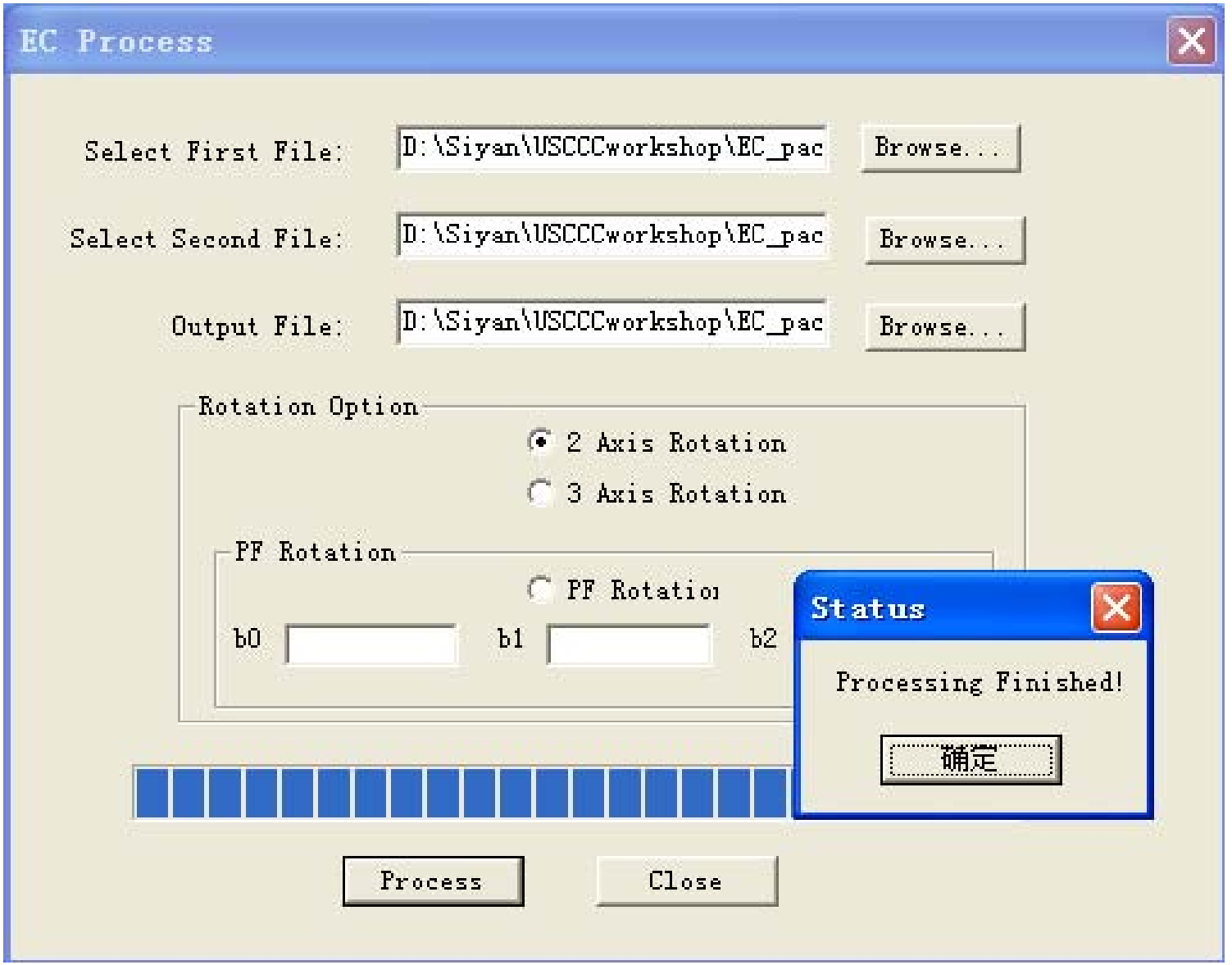
Outputs

Output files name:

The out put file extension name depends on the different processing. Adding ‘r1w’ with 2-axis rotation and adding ‘pfw’ with PF rotation as its extension name.

Example:

**.r1w: 2_axis rotation with WPL correction.
**.pfw: PF rotation with WPL correction.


EC Process
Select First File:
D:\Siyan\USCCCworkshop\EC_pac
Browse...
Select Second File:
D:\Siyan\USCCCworkshop\EC_pac
Browse...
Output File:
D:\Siyan\USCCCworkshop\EC_pac
Browse...
Rotation Option
2 Axis Rotation
3 Axis Rotation
PF Rotation
PF Rotatio
b0
b1
b2
Status
Processing Finished!
确定
Process
Close

EC DATA PROCESS

Outputs

Output list:

Time: time stamp

ustar: U-star

tau: momentum

ave_CO2: CO2 30 minutes average, mg m^{-3}

ave_H2O: H2O 30 minutes average, g m^{-3}

ave_P: air pressure 30 minutes average, kPa

ave_Ts: sonic panel temperature 30 minutes average, ^{o}C

ave_Tc: air temperature 30 minutes average ^{o}C

ave_U: X axis wind speed 30 minutes average, m s^{-1}

ave_V: Y axis wind speed 30 minutes average, m s^{-1}

ave_W: Z axis wind speed 30 minutes average, m s^{-1}

EC DATA PROCESS

Outputs

LE_CSI: LE with CSI method, W m^{-2}

Fc_CSI: CO2 Flux with CSI method, μmol m^{-2} s^{-1}

Hs: heat Flux

h2owplLE:

h2owplH:

co2wplLE:

co2wplH:

h2owpl:

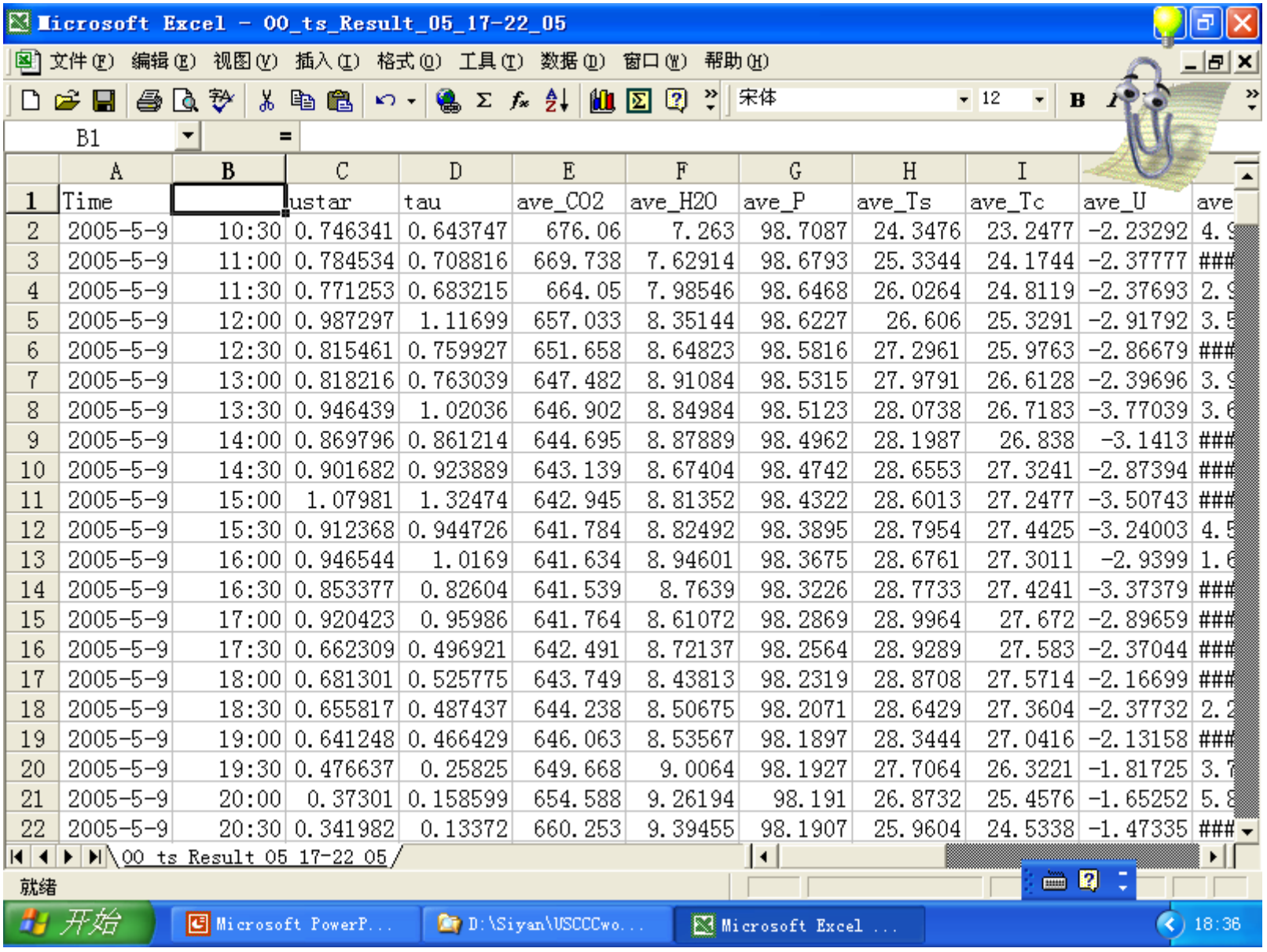
co2wpl:

Sub-parameters in WPL correction

LE_leuning: LE with Leuning method, W m^{-2}

Fc_leuning: CO2 Flux with Leuning method, μmol m^{-2} s^{-1}

Records: number of the good records in the 30 minutes period

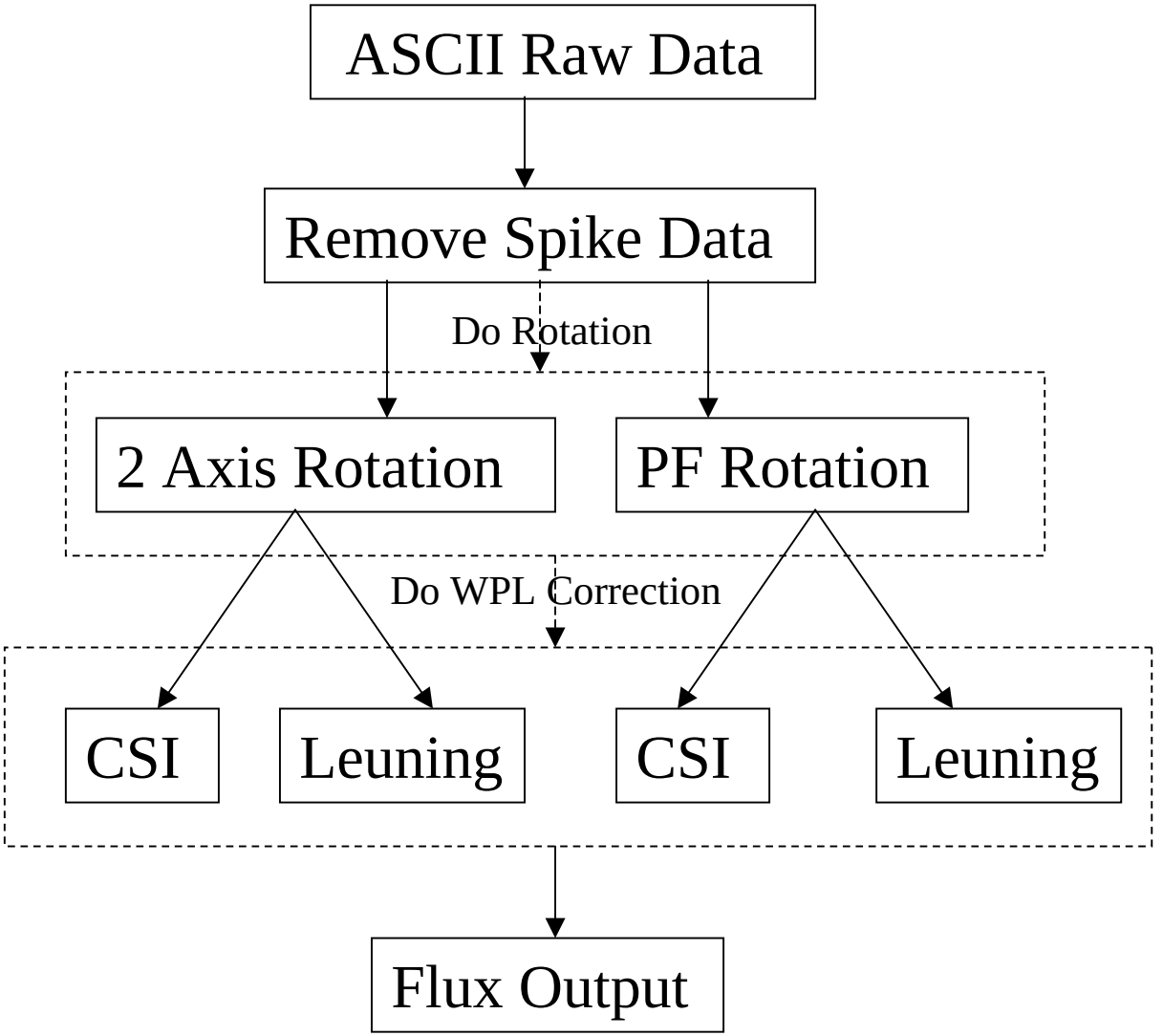


	A	B	C	D	E	F	G	H	I	
1	Time		ustar	tau	ave_CO2	ave_H2O	ave_P	ave_Ts	ave_Tc	ave_U	ave
2	2005-5-9	10:30	0.746341	0.643747	676.06	7.263	98.7087	24.3476	23.2477	-2.23292	4.9
3	2005-5-9	11:00	0.784534	0.708816	669.738	7.62914	98.6793	25.3344	24.1744	-2.37777	###
4	2005-5-9	11:30	0.771253	0.683215	664.05	7.98546	98.6468	26.0264	24.8119	-2.37693	2.9
5	2005-5-9	12:00	0.987297	1.11699	657.033	8.35144	98.6227	26.606	25.3291	-2.91792	3.5
6	2005-5-9	12:30	0.815461	0.759927	651.658	8.64823	98.5816	27.2961	25.9763	-2.86679	###
7	2005-5-9	13:00	0.818216	0.763039	647.482	8.91084	98.5315	27.9791	26.6128	-2.39696	3.9
8	2005-5-9	13:30	0.946439	1.02036	646.902	8.84984	98.5123	28.0738	26.7183	-3.77039	3.6
9	2005-5-9	14:00	0.869796	0.861214	644.695	8.87889	98.4962	28.1987	26.838	-3.1413	###
10	2005-5-9	14:30	0.901682	0.923889	643.139	8.67404	98.4742	28.6553	27.3241	-2.87394	###
11	2005-5-9	15:00	1.07981	1.32474	642.945	8.81352	98.4322	28.6013	27.2477	-3.50743	###
12	2005-5-9	15:30	0.912368	0.944726	641.784	8.82492	98.3895	28.7954	27.4425	-3.24003	4.5
13	2005-5-9	16:00	0.946544	1.0169	641.634	8.94601	98.3675	28.6761	27.3011	-2.9399	1.6
14	2005-5-9	16:30	0.853377	0.82604	641.539	8.7639	98.3226	28.7733	27.4241	-3.37379	###
15	2005-5-9	17:00	0.920423	0.95986	641.764	8.61072	98.2869	28.9964	27.672	-2.89659	###
16	2005-5-9	17:30	0.662309	0.496921	642.491	8.72137	98.2564	28.9289	27.583	-2.37044	###
17	2005-5-9	18:00	0.681301	0.525775	643.749	8.43813	98.2319	28.8708	27.5714	-2.16699	###
18	2005-5-9	18:30	0.655817	0.487437	644.238	8.50675	98.2071	28.6429	27.3604	-2.37732	2.2
19	2005-5-9	19:00	0.641248	0.466429	646.063	8.53567	98.1897	28.3444	27.0416	-2.13158	###
20	2005-5-9	19:30	0.476637	0.25825	649.668	9.0064	98.1927	27.7064	26.3221	-1.81725	3.7
21	2005-5-9	20:00	0.37301	0.158599	654.588	9.26194	98.191	26.8732	25.4576	-1.65252	5.8
22	2005-5-9	20:30	0.341982	0.13372	660.253	9.39455	98.1907	25.9604	24.5338	-1.47335	###

EC Data Processing

- **Convert Data from Binary to ASCII with PC9000 Software**
- **Remove spike**
- **Do rotation**
- **Calculate covariance**
- **WPL correction**
- **Outputs**

EC Data Processing



Remove spike

Step 1: Use range setting to calculate their averages and δ. Example:

U,V,W,Ts between –50.0 to +50.0;

H_2O between –20.0 to +20.0;

CO_2 between 0.0 to 1000.0;

P between 30.0 to 150.0.

Step 2:

If $\lvert H_2O(i)-ave\_H_2O\rvert>6.0* H_2O\_\delta$	$H_2O(i)=ave\_ H_2O;$
If $\lvert CO_2(i)-ave\_CO_2\rvert>6.0* CO_2\_\delta$	$CO_2(i)=ave\_ CO_2;$
If |Ts(i)-ave_Tc|>6.0* Ts_δ	Tc(i)=ave_ Tc;
If |U(i)-ave_U|>6.0* U_δ	U(i)=ave_ U;
If |V(i)-ave_V|>6.0* V_δ	V(i)=ave_ V;
If |W(i)-ave_W|>6.0* W_δ	W(i)=ave_ W;
If |P(i)-ave_P|>6.0* P_δ	P(i)=ave_ P;

Step 3:

```
q= H2O[i]*8.3143/(18.0*461.0);
Tc[i]=( Ts[i]+273.16)/(1.0+0.51*q);
e[i]= H2O[i]*8.3143e-3*Tc[i]/18.0;
rho_d[i]=( P[i]-e[i])/(Tc[i]*0.28704);
```

Rotation

Two Axis Rotation (ave_V=0 and ave_W=0):

1. **Calculate the sin, cos values for ratation:**

   vec1=sqrt(ave_U*ave_U+ave_V*ave_V)

   vec2=sqrt(ave_U*ave_U+ave_V*ave_V+ave_W*ave_W)

   cosA=vec1/vec2

   sinA=ave_W/vec2

   cosB=ave_U/vec1

   sinB=ave_V/vec1

2. **Do rotation along with W axis, let ave_V=0;**

$$(U',V',W')=(U[i],V[i],W[i]) * \begin{vmatrix} cosB & -sinB & 0 \\ sinB & cosB & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

Rotation(con.1)

3. Do rotate along with V axis, let ave_W=0:

$$(U'',V'',W'') = (U',V',W') * \begin{vmatrix} \cos A & 0 & -\sin A \\ 0 & 1 & 0 \\ \sin A & 0 & \cos A \end{vmatrix}$$

Planar Fit (PF) Rotation:

The purpose is to correction sensor tilt and then do rotation.

1. Calculate b0, b1, and b2 using long term data.

$w\_30min\_ave = b0 + b1 * u\_30min\_ave + b2 * v\_30min\_ave$

2. Do rotation

$\sin\alpha = -b1/\sqrt{(1+b1^2)}$

$\cos\alpha = 1/\sqrt{(1+b1^2)}$

$\sin\beta = b2/\sqrt{(1+b2^2)}$

$\cos\beta = b2/\sqrt{(1+b2^2)}$

$$(U',V',W') = \begin{vmatrix} \cos\alpha & 0 & -\sin\alpha \\ 0 & 1 & 0 \\ \sin\alpha & 0 & \cos\alpha \end{vmatrix}^T * \begin{vmatrix} 1 & 0 & 0 \\ 0 & \cos\beta & -\sin\beta \\ 0 & \sin\beta & \cos\beta \end{vmatrix}^T * (U,V,W)$$

Calculate covariance

Covariance and other:

cov_V_W, cov_U_W, cov_W_Tc, cov_CO2_W, cov_H2O_W, cov_V_V, cov_W_W, cov_U_U, cov_Tc_Tc, cov_CO2_CO2, cov_H2O_H2O;

cov_H2O_W=Lv* cov_H2O_W;

rho_a=ave_rho_d+ave_H2O/1000.0;

tau1=sqrt(cov_U_W*cov_U_W+cov_V_W*cov_V_W)

ustar=sqrt(tau1),

tau=rho_a*tau1;

WPL Correction

Constants: Cp=1004.67, Lv=2440;

CSI WPL correction formulas:

sigmawpl=ave_H2O/(1000*rho_d)
H2OwplLE=1.61* sigmawpl**cov_H2O_W
H2OwplH=(1.0+(1.61* sigmawpl))*ave_H2O*
Lv*cov_W_Tc /ave_Tc
CO2wplLE=1.61*ave_CO2*cov_H2O_W/(100.0*rho_d*Lv)
CO2wplH=(1.0+(1.61* sigmawpl))*ave_CO2*
cov_W_Tc /ave_Tc
LE_wpl=cov_H2O_W+ H2OwplLE+ H2OwplH
Fc_wpl=cov_CO2_W+ CO2wplLE+ CO2wplH
cov_W_Tc=cov_W_Tc*rho_a*Cp

WPL Correction (con.)

Leuning WPL correction formulas:

LEraw = cov_w_h2o*Lv

mixratio_H2O=Average (8.3143e-3*Tc*raw_H2O/(raw_P*18))

mixratio_CO2=Average (8.3143*Tc*raw_CO2/(raw_P*44))

airconc=Average (raw_P/(8.3143e-3*Tc))

LE_leuning=(1+mixratio_H2O)*(LEraw+ave_H2O
*cov_w_t/ave_Tc)

Fc_leuning=1000.0*(cov_w_co2+ave_CO2*(LE_leuning/
(airconc*ave_Tc*Cp)+cov_w_t/ave_Tc))/44.0