Supplement Figure. 1

non-freezing period to early freezing period (top) and freeze-thaw period (bottom) flux contribution zones.

Supplement Figure. 2

Integrated CO_2/H_2O Open-Path Gas Analyzer & 3D Sonic Anemometer (left 1、right 1) Digital mining CR3000 (left 2).

Supplement Figure. 3

High frequency water quality monitoring system sensors.

Supplement Figure. 4

Zscore (FH_2O) fitting.

Supplement Table. 1

Name and abbreviation of high frequency meteorological-water quality monitoring index.

Supplement Table. 2

Regression analysis of H_2O fluxes and meteorological factors

Supplement Table. 3

H_2O fluxes Cumulative variance rate contribution

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Covariance analysis of H_2O fluxes with environmental factors

Supplement Table. 5

Zscore(FH_2O) principal component

Supplement Table. 6

Zscore(FH_2O) principal component regression equation

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Zscore(FH_2O) principal component regression equation covariance

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Zscore(FH_2O) principal component score coefficient matrix

Supplement Table. 9

Zscore(FH_2O) regression equation fit

Supplement Table. 10

Zscore(FH_2O) regression equation ANOVA

Supplement Table. 11

Average evapotranspiration at daily scale eddy and Dashetai station

Supplement Table. 12

Independent sample T test for evaporated water at daily scale eddy and Dashetai station

2.2.2 High frequency meteorological-water quality monitoring

Table.1 Name and abbreviation of high frequency meteorological-water quality monitoring index

Indicator name	Abridge
Mean dissolved oxygen	DOavg
Mean turbidity from 0 to 30 cm below the water surface	Turb1avg
Mean turbidity at 30 to 60 cm below the water surface	Turb2avg
Mean turbidity at 60 to 90 cm below the water surface	Turb3avg
pH at 0 to 30 cm below water surface	pH1
pH at 60 to 90 cm below water surface	pH3
Mean water temperature	WTavg
Mean value of temperature at 0 to 30 cm below the water surface	WT1avg
Mean value of temperature at 30 to 60 cm below the water surface	WT2avg
Mean value of temperature at 60 to 90 cm below the water surface	WT3avg
Mean value of conductivity at 0 to 30 cm below the water surface	EC1avg
Mean value of conductivity at 30 to 60 cm below the water surface	EC2avg
Mean value of conductivity at 60 to 90 cm below the water surface	EC3avg
Carbon dioxide flux	FCO_2
Solar shortwave incident radiation at meteorological stations	SWIN1
Eddy station air pressure	PA
Eddy station humidity	RH
Eddy station air temperature	TA
Eddy station saturated water-air pressure difference	VPD
Eddy station wind speed	WS
Maximum wind speed at eddy station	MWS
Eddy station evaporation	ET
Eddy station sensible heat flux	H
Latent heat flux at eddy station	LE
Maximum wind speed at weather station	MWS1
Weather station barometric pressure	PA1
Humidity at weather station	RH1
Weather station air temperature	TA1

Fig.1 non-freezing period to early freezing period (top) and freeze-thaw period (bottom) flux contribution zones

Fig.2 Integrated CO_2/H_2O Open-Path Gas Analyzer & 3D Sonic Anemometer (left 1、right 1) Digital mining CR3000 (left 2)

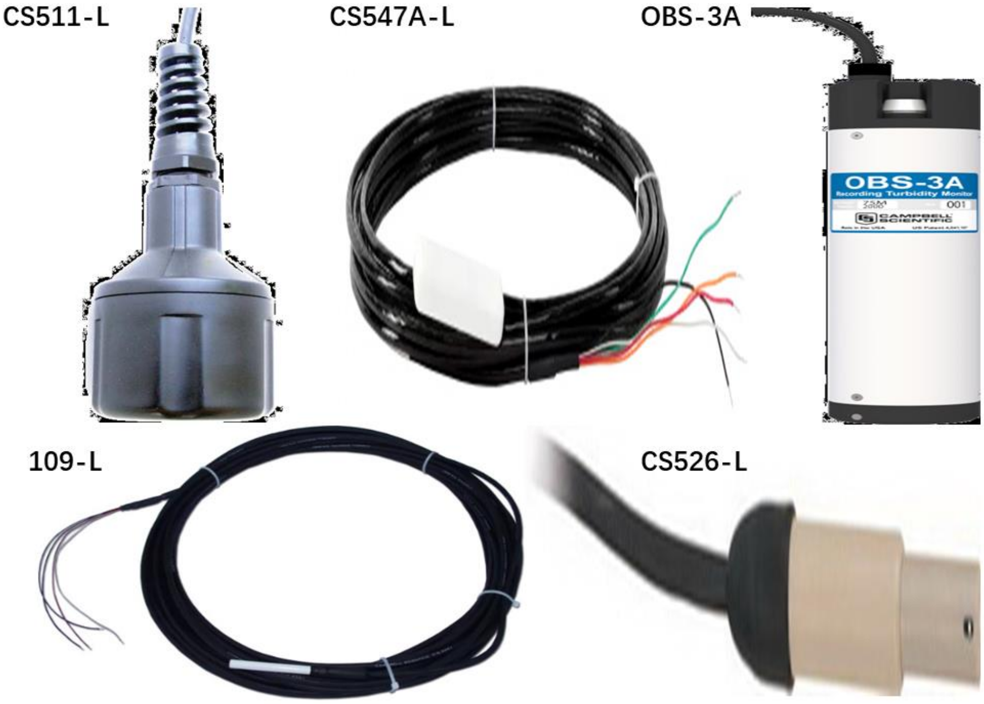

Fig.3 High frequency water quality monitoring system sensors

3.2.1 Correlation between overall scale FH_2O and meteorological factors

Table.2 Regression analysis of H_2O fluxes and meteorological factors

R	R^2	F change quantity	Significant F change quantity
0.734	0.538	594.994	0

a Predictive variables : (constant),RH,FCO_2,WS,TA1,RH1,H,MWS1,SWN1,MWS

b Dependent variables :FH_2O

3.2.2 Correlation between FH_2O and environmental factors in the non-freezing period to early freezing period

~~The environmental factors affecting H2O flux are closely related to each other, and each factor has different effects on it. Due to the collinearity between the indicators, it may not be possible to draw correct conclusions in the analysis. The purpose of principal component analysis is to simplify the data and improve the reliability of the analysis results. Through linear transformation, some original indicators are combined into a few independent comprehensive indicators. In this paper, the influence of half-hour eddy-meteorology-water quality data on H2O flux during the non-freezing-early glacial period (May 17 to December 28,2018) was analyzed. In order to determine whether principal component analysis is needed, the data can be standardized first. The Zscore (FH2O), that is, the standardized H2O flux, is set as the dependent variable, and other standardized factors are used as independent variables. Linear regression is performed to perform collinearity diagnosis. The diagnostic results are shown in table 4. The variance inflation factor VIF has multiple variable values greater than 10, indicating that there is a high degree of collinearity, which requires principal component analysis.~~

~~Extracting the principal component needs to calculate the eigenvalues and eigenvectors of the matrix after obtaining the correlation coefficient matrix, and finally calculate the cumulative contribution rate.~~

Table.3 H_2O fluxes Cumulative variance rate contribution

principal component	eigenvalue	variance proportion	Cumulative %
1	12.374	47.593	47.593
2	2.836	10.908	58.501
3	1.972	7.583	66.084
4	1.747	6.718	72.803
5	1.38	5.307	78.11
6	1.054	4.053	82.163

Table.4 Covariance analysis of H_2O fluxes with environmental factors

	B	Beta	t	significance	allowance	VIF
(constant)	0.008		0.885	0.376		
Zscore(FCO_2)	-0.055	-0.046	-8.432	0	0.703	1.422
Zscore(SWIN1)	0.016	0.017	1.602	0.109	0.182	5.482
Zscore(PA)	-0.112	-0.095	-1.234	0.217	0.004	284.355
Zscore(RH)	0.012	0.008	1.195	0.232	0.442	2.264
Zscore(TA)	0.016	0.011	0.277	0.782	0.014	71.318
Zscore(VPD)	0.035	0.038	1.43	0.153	0.029	34.488
Zscore(WS)	0.076	0.074	6.446	0	0.159	6.27
Zscore(MWS)	-0.007	-0.007	-0.55	0.582	0.135	7.398
Zscore(ET)	-0.024	-0.024	-0.881	0.378	0.028	36.276
Zscore(H)	-0.016	-0.018	-2.221	0.026	0.318	3.149
Zscore(LE)	0.903	0.92	33.213	0	0.027	36.574
Zscore(MWS1)	-0.006	-0.007	-0.822	0.411	0.285	3.511
Zscore(PA1)	0.151	0.126	1.375	0.169	0.002	400.408
Zscore(RH1)	-0.021	-0.024	-1.936	0.053	0.137	7.287
Zscore(TA1)	-0.112	-0.08	-1.643	0.1	0.009	112.729
Zscore(DOavg)	0.011	0.009	1.056	0.291	0.298	3.359
Zscore(Turb1avg)	-0.021	-0.02	-2.316	0.021	0.294	3.404
Zscore(Turb2avg)	-0.003	-0.003	-0.391	0.696	0.449	2.227
Zscore(Turb3avg)	-0.007	-0.011	-1.661	0.097	0.462	2.167
Zscore(pH1)	-0.01	-0.01	-1.143	0.253	0.283	3.54
Zscore(pH3)	0.023	0.009	1.046	0.296	0.317	3.159
Zscore(WT1avg)	0.163	0.123	0.786	0.432	0.001	1173.26
Zscore(WT2avg)	-0.341	-0.265	-1.098	0.272	0	2786.976
Zscore(WT3avg)	0.341	0.267	1.715	0.086	0.001	1152.636
Zscore(EC1avg)	0.056	0.038	0.509	0.611	0.004	260.276
Zscore(EC2avg)	-0.045	-0.033	-0.436	0.663	0.004	280.145
Zscore(EC3avg)	0.018	0.018	1.161	0.246	0.091	11.016

a Dependent variables :Zscore(FH_2O)

Table.5 Zscore(FH_2O) principal component

environmental factor	principal component					
	1	2	3	4	5	6
Zscore(WT1avg)	0.967	-0.169	-0.04	-0.023	-0.037	0.111
Zscore(WTavg)	0.967	-0.169	-0.041	-0.022	-0.037	0.112
Zscore(WT2avg)	0.966	-0.172	-0.028	-0.023	-0.041	0.113
Zscore(WT3avg)	0.963	-0.173	-0.024	-0.017	-0.048	0.116
Zscore(TA1)	0.959	-0.174	-0.006	-0.037	-0.039	0.137
Zscore(TA)	0.943	-0.002	-0.154	-0.065	0.033	-0.046
Zscore(EC2avg)	-0.911	0.139	-0.008	0.07	0.035	-0.147
Zscore(VPD)	0.909	0.015	-0.197	-0.029	0.091	-0.087
Zscore(EC1avg)	-0.901	0.151	0.008	0.07	0.054	-0.149
Zscore(EC3avg)	-0.865	0.044	-0.063	0.181	0.27	-0.139
Zscore(PA1)	-0.79	0.205	0.085	0.034	-0.068	0.492
Zscore(PA)	-0.689	0.298	0.002	0.028	-0.087	0.557
Zscore(Turb1avg)	0.654	0.038	0.009	0.014	0.272	0.409
Zscore(pH3)	-0.487	0.214	0.021	0.022	-0.373	0.204
Zscore(H)	0.201	0.666	-0.465	-0.07	-0.077	-0.008
Zscore(SWIN1)	0.357	0.659	-0.521	0.043	-0.095	-0.042
Zscore(MWS1)	0.372	0.647	0.204	-0.365	0.082	-0.21
Zscore(RH1)	-0.541	-0.578	0.258	0.236	-0.145	0.1
Zscore(WS)	0.389	0.336	0.76	0.066	0.151	-0.016
Zscore(MWS)	0.414	0.487	0.658	-0.09	0.197	-0.068
Zscore(ET)	0.546	0.269	0.227	0.674	-0.139	-0.018
Zscore(LE)	0.556	0.264	0.223	0.669	-0.138	-0.02
Zscore(FCO_2)	-0.242	-0.316	0.261	-0.491	0.317	0.068
Zscore(Turb3avg)	0.364	0.208	0.238	-0.45	-0.321	0.097
Zscore(Turb2avg)	0.259	-0.109	-0.208	0.365	0.712	0.086
Zscore(RH)	0.257	-0.433	0.132	0.084	-0.455	-0.257

3.3 Evaporation model from the non-glacial period to early glacial period

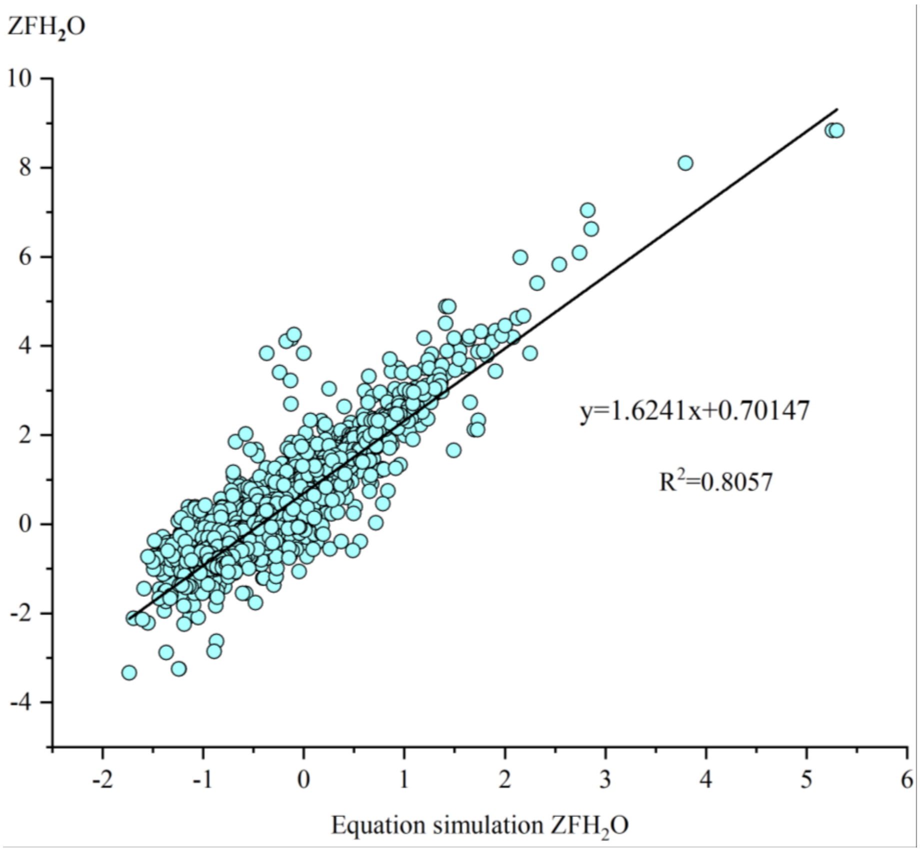

Fig. 4. Zscore (FH_2O) fitting.

Table.6 Zscore(FH_2O) principal component regression equation

R	R^2	After adjustment R^2	F variable quantity	Significant F variation
0.93	0.866	0.865	3451.6	0

a Dependent variables :Zscore(FH_2O)

b Predictive variables : (constant), Y6, Y5, Y4, Y3, Y2, Y1

Table.7 Zscore(FH_2O) principal component regression equation covariance

	B	Beta	t	significance	allowance	VIF
(constant)	-0.039		-6.151	0		
Y1	0.159	0.568	87.788	0	1	1
Y2	0.159	0.272	42.012	0	1	1
Y3	0.161	0.229	35.37	0	1	1
Y4	0.472	0.633	97.865	0	1	1
Y5	-0.107	-0.13	-19.728	0	1	1
Y6	-0.028	-0.03	-4.495	0	1	1

a Dependent variables :Zscore(FH_2O)

Table.8 Zscore(FH_2O) principal component score coefficient matrix

	1	2	3	4	5	6
Zscore(FCO_2)	-0.02	-0.111	0.132	-0.281	0.23	0.064
Zscore(SWIN1)	0.029	0.233	-0.264	0.024	-0.069	-0.04
Zscore(PA)	-0.056	0.105	0.001	0.016	-0.063	0.529
Zscore(RH)	0.021	-0.153	0.067	0.048	-0.329	-0.244
Zscore(TA)	0.076	-0.001	-0.078	-0.037	0.024	-0.043
Zscore(VPD)	0.073	0.005	-0.1	-0.016	0.066	-0.082
Zscore(WS)	0.031	0.119	0.386	0.038	0.109	-0.015
Zscore(MWS)	0.033	0.172	0.334	-0.052	0.143	-0.065
Zscore(ET)	0.044	0.095	0.115	0.386	-0.101	-0.017
Zscore(H)	0.016	0.235	-0.236	-0.04	-0.056	-0.007
Zscore(LE)	0.045	0.093	0.113	0.383	-0.1	-0.019
Zscore(MWS1)	0.03	0.228	0.104	-0.209	0.059	-0.2
Zscore(PA1)	-0.064	0.072	0.043	0.02	-0.049	0.467
Zscore(RH1)	-0.044	-0.204	0.131	0.135	-0.105	0.095
Zscore(TA1)	0.078	-0.061	-0.003	-0.021	-0.028	0.13
Zscore(Turb1avg)	0.053	0.013	0.004	0.008	0.197	0.388
Zscore(Turb2avg)	0.021	-0.038	-0.105	0.209	0.516	0.081
Zscore(Turb3avg)	0.029	0.073	0.121	-0.257	-0.232	0.092
Zscore(pH3)	-0.039	0.075	0.011	0.013	-0.27	0.194
Zscore(WTavg)	0.078	-0.06	-0.021	-0.012	-0.027	0.106
Zscore(WT1avg)	0.078	-0.06	-0.02	-0.013	-0.026	0.105
Zscore(WT2avg)	0.078	-0.061	-0.014	-0.013	-0.03	0.107
Zscore(WT3avg)	0.078	-0.061	-0.012	-0.01	-0.035	0.11
Zscore(EC1avg)	-0.073	0.053	0.004	0.04	0.039	-0.141
Zscore(EC2avg)	-0.074	0.049	-0.004	0.04	0.026	-0.14
Zscore(EC3avg)	-0.07	0.016	-0.032	0.104	0.196	-0.132

Table.9 Zscore(FH_2O) regression equation fit

	intercept	slope	statistics
	value	value	Adjusted R squared
ZFH_2O	0.70147	1.6241	0.8057

Table.10 Zscore(FH_2O) regression equation ANOVA

analysis of variance		DF	quadratic sum	mean square	F ratio	probability > F
ZFH_2O	model	1	3858.594	3858.594	20510.76	0
	error	4945	930.2796	0.18813		
	grand total	4946	4788.873			

4.3 Comparison of the model with evaporation dish conversion and regional empirical C formula method

Table.11 Average evapotranspiration at daily scale eddy and Dashetai station

	peer group	Number of cases	mean value	standard deviation	Average standard error
evaporated water	EC station	121	0.0935	0.0882	0.0080
	Dashetai station	197	0.2127	0.1256	0.0089

Table.12 Independent sample T test for evaporated water at daily scale eddy and Dashetai station

		F	significance	t	p	Mean value difference	Standard error difference
evaporated water	Assume equal variance	26.074	0	-9.14	0	-0.119	0.0130
	No assumption of equal variance			-9.916	0	-0.119	0.0120