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Factors controlling evaporation and CO2 flux over an open water lake in southwest of China on multiple temporal scales

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Outline

- Introduction
- Observation site
- Results
- Conclusion

Introduction

- There are 304 million lakes globally and they are of significant importance in determining local weather and climate through complex physical, biochemical and biological interactions;

- Because of the substantial differences in underlying surface characteristics between lake surface and its surrounding land surface, the carbon and energy exchange processes over lakes are expected to respond different way to climate change;

- Understanding the turbulent exchange processes between the lake surface and atmosphere and the response to atmospheric properties is essential for improving numerical weather prediction and climate models

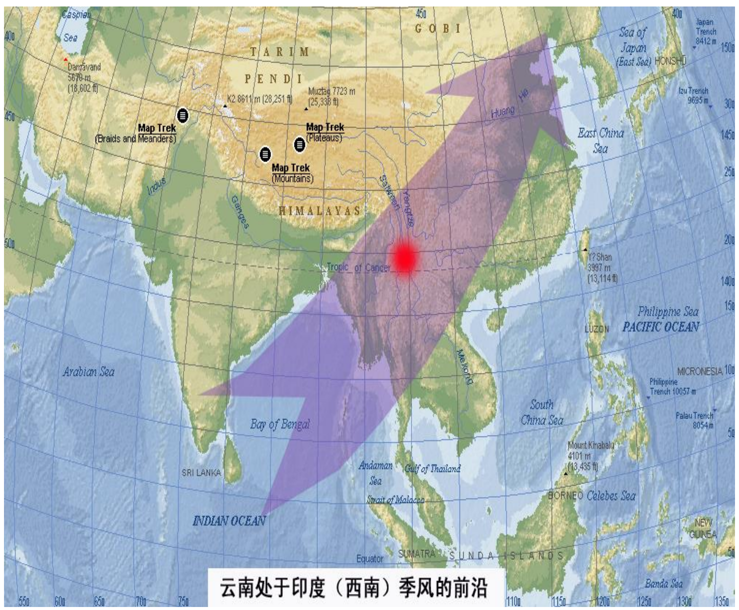
Introduction

- the characteristics of water–atmosphere exchange processes differ for lake size, water depth, regional climate and geographical location;
- Highaltitude lakes are exposed to more extreme meteorological conditions and are more sensitive to variations in meteorological forcing;
- Shallow lakes respond more quickly to changes in the atmospheric forcing due to a smaller heat capacity;
- Based on 4-year continuous measurement of energy and CO2 fluxes with EC technique from 2012 to 2015 over Lake Erhai, the patterns of CO2 flux and energy flux are analysed.

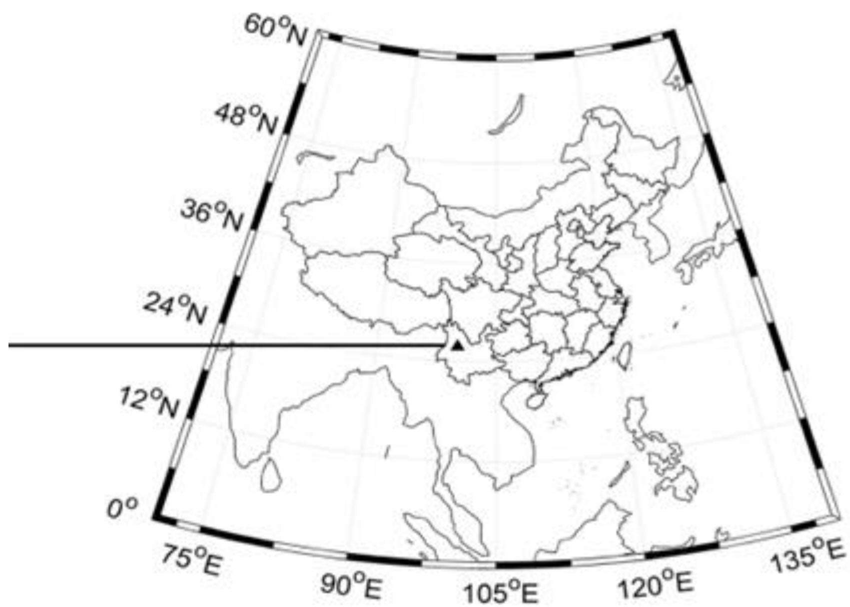
Introduction

- The observation site is located in the southeast margin of the Tibet Plateau.

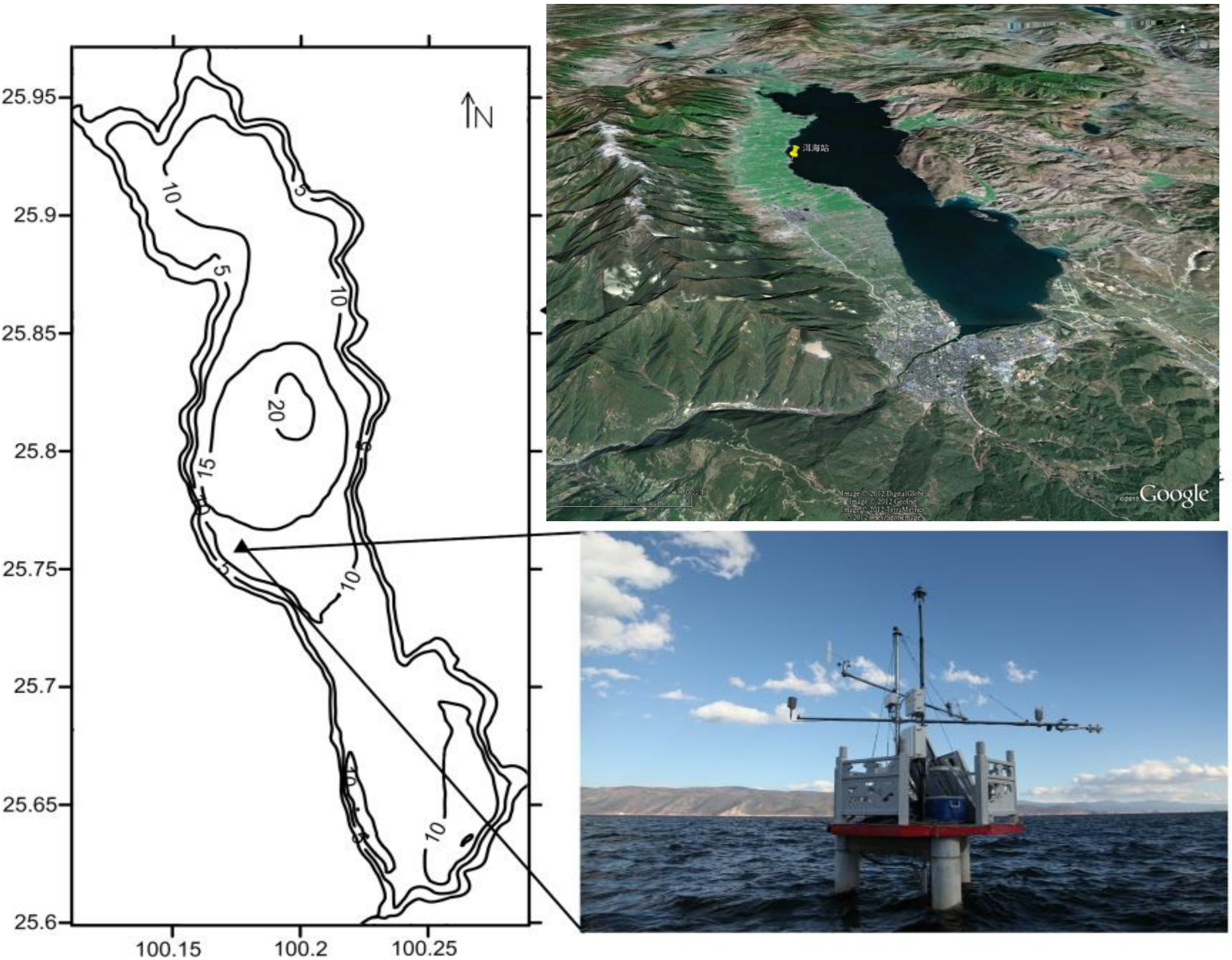
Geographic position:25°46′N, 100°10′E;



- Highland (1972 a.s.l)
- Low latitudes (sub-tropical, ice free)
- Affected by monsoon （South Asian and East Asian summer monsoons ）
- Sensitive to climate change

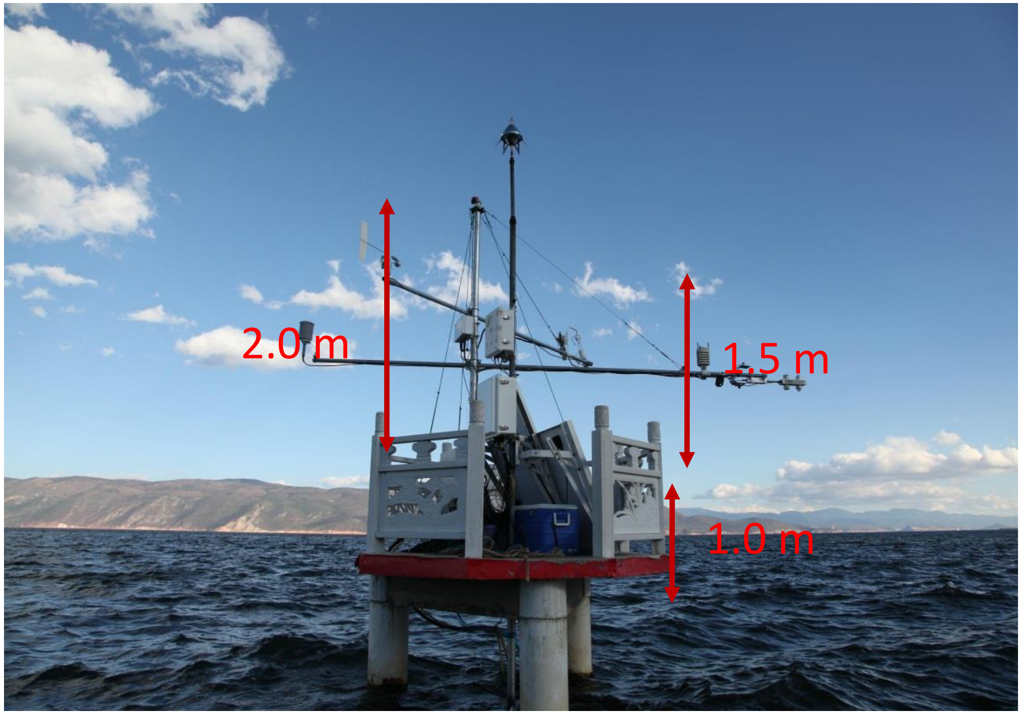


Introduction-The Erhai Lake



Area 256.5km2;
A south-north length of 42.6 km,
A mean east-west width of 6.3 km (ranges from 3.05 to 8.8 km);
An average depth of 10 m.

Observation site



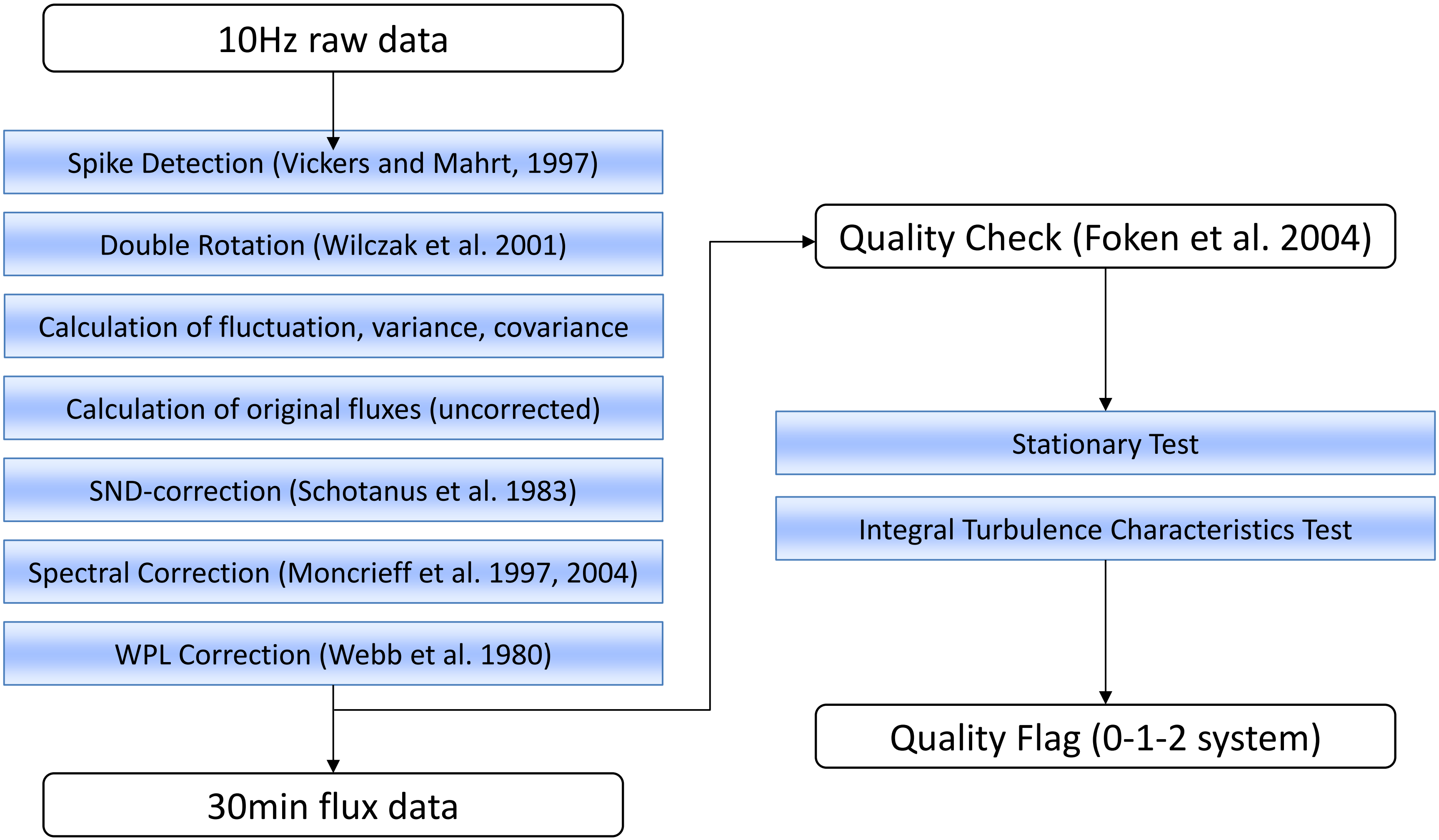
- Radiation components
- Photosynthetic active radiation
- meteorological variables: Ta, U
  Rh,
- Ts at eight depths
(0.05, 0.2, 0.5, 1, 2, 4, 6, and 8 m)

Instrument setup

Variable	Instrument	Setup Height
u, v, w	CAST3, Campbell	2m
CO2/H2O density	LICOR, LI-7500A	2m
Wind Speed/Direction	034B, Campbell	2m
Radiation	CNR1, Kipp&Zones	1.5m
PPFD	LICOR, LI190SB	1.5m
Air temperature/Humidity	HMP45C, Vaisala	2m
Surface temperature	SI-111, Apogee	1.5m
Water temperature profile	109-L, Campbell	5cm, 20cm, 50cm, 1m, 2m, 4m, 6m, 8m

Data Process-raw data

- Raw data was processed using EddyPro (v4.2, Licor Inc.)



Data Process- despike

Data filtering

- Outside of the range

  a window size of 3days: mean±3.5SD

  (Vickers & Mahrt,1997)

- QC flag

  Quality Flag should be 0 (Foken et al., 2004)

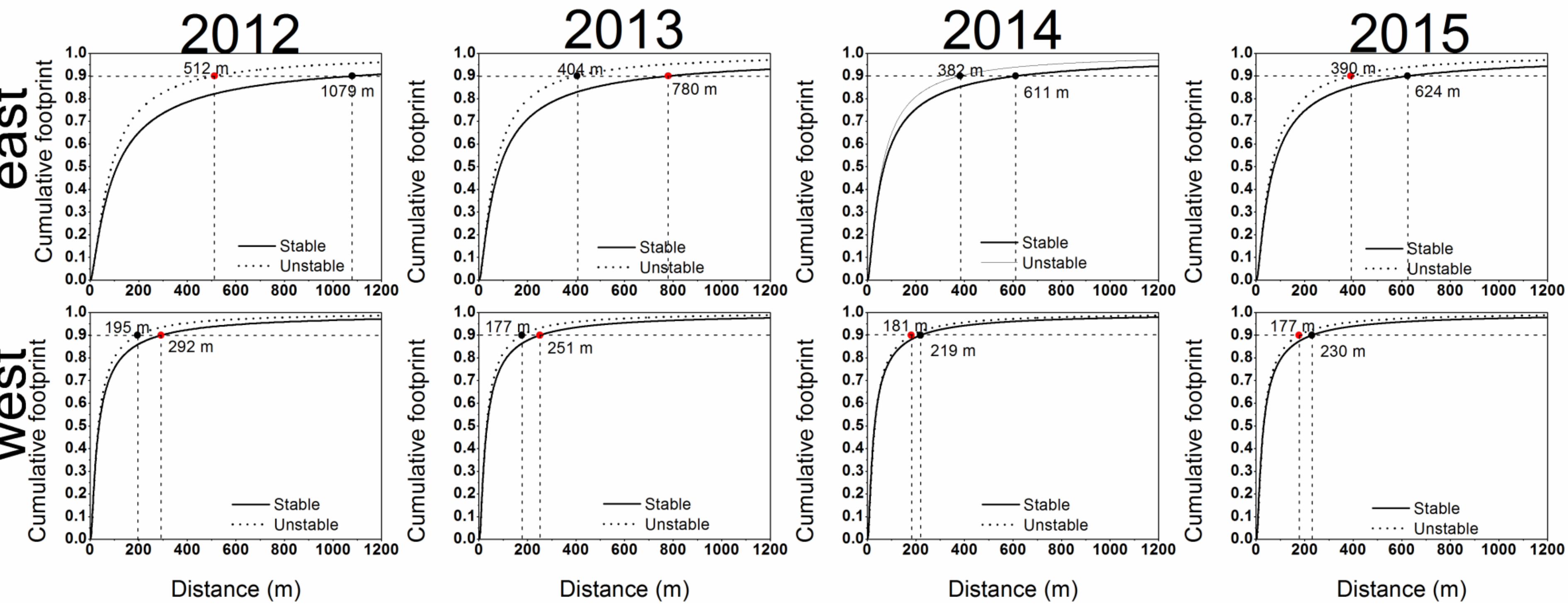
- AGC

  $\overline{w'u'} < 0$

  Automatic gain control from the Li-7500

- Cov(w,u)

Data Process- despike



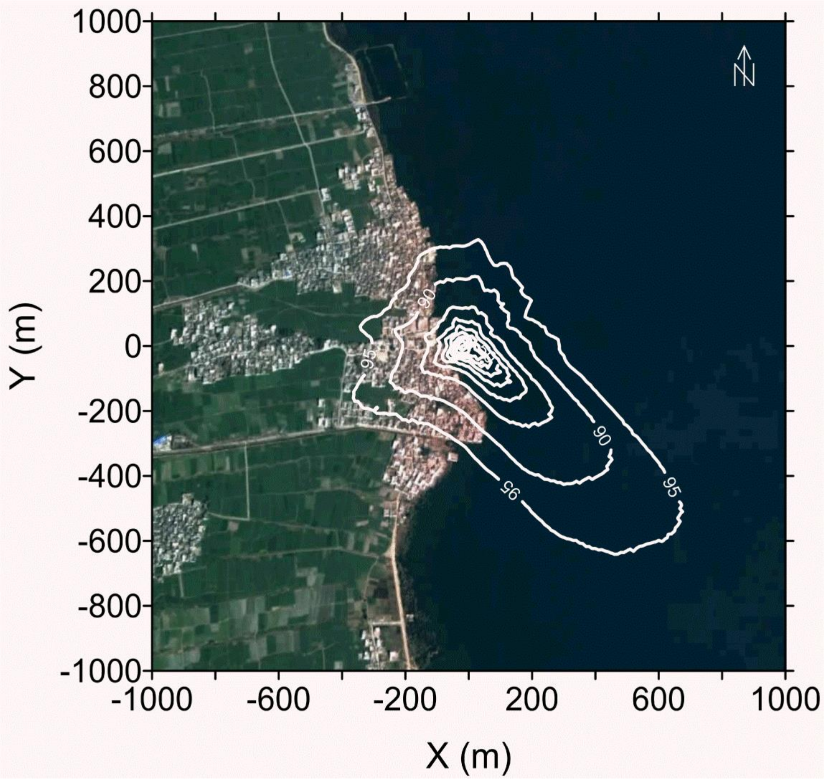
•The cumulative footprint distance in east direction varied between 611 m and 1079 m during stable condition and between 382 m to 512 m during unstable condition;

•The variability of west footprint distance is relatively small, with a 90% cumulative footprint distance about 200 m during different atmospheric conditions .

•The flux from the west direction is excluded.

Data Process- despike

➢Wind direction: 0° < wd < 180 °



•Turbulent fluxes from the west sector were excluded in the analysis.

Data Process- energy balance ratio

- Heat storage change

$$\Delta Q_s = \rho_w C_{pw} \frac{\overline{\Delta T_w}}{\Delta t} z$$

$$\Delta T_w = T_s - T_a$$

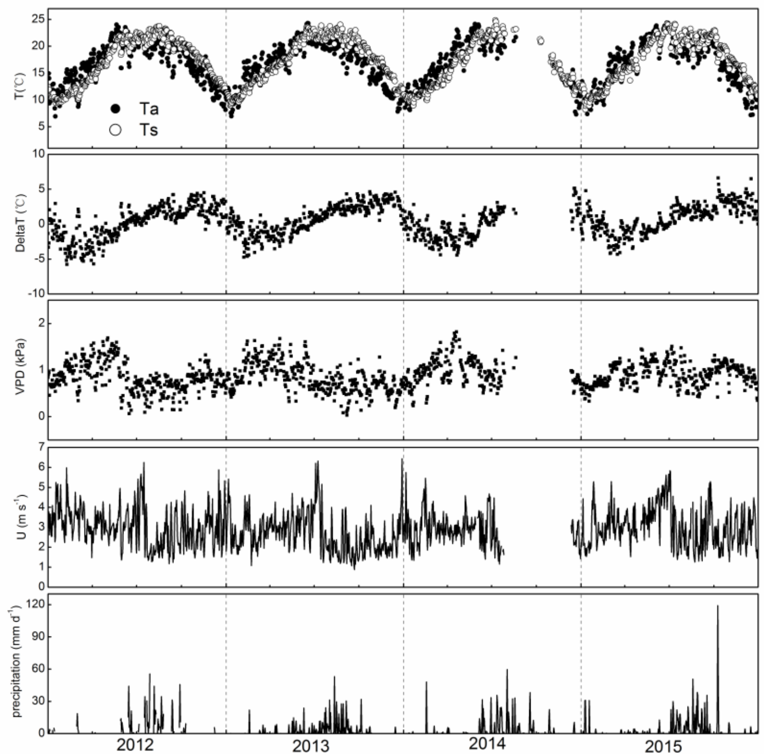
$$\overline{\frac{\Delta T_w}{\Delta t}} = \frac{1}{z} \sum_{i=1}^{n} \frac{\Delta T_{wi}}{\Delta t} \Delta z_i$$

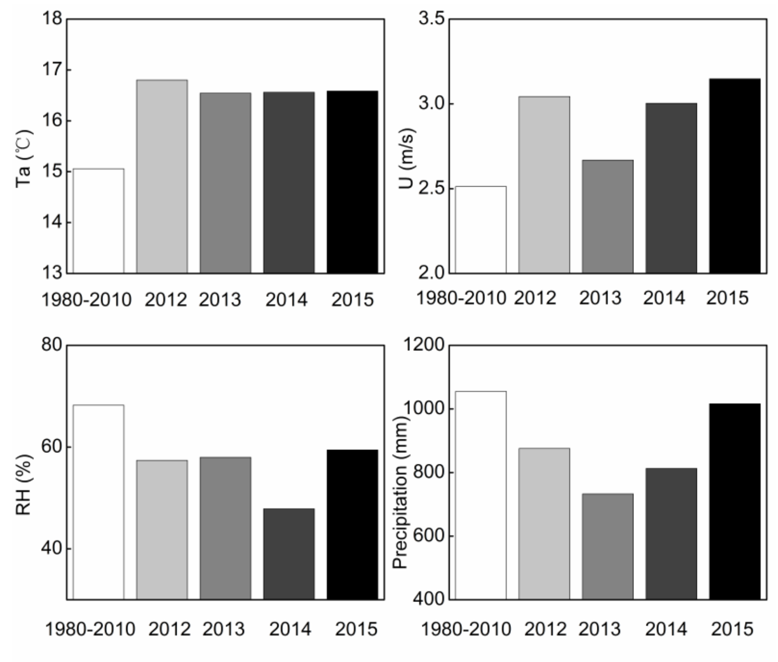
- Energy balance ratio

$$EBR = \frac{H_s + LE}{R_n - \Delta Q_s} \times 100\%$$

Following Nordbo et al. (2011), EBR was calculated using cumulative fluxes over an ensemble of averaged daily courses on a monthly basis

Meteorological condition from 2012 to 2015

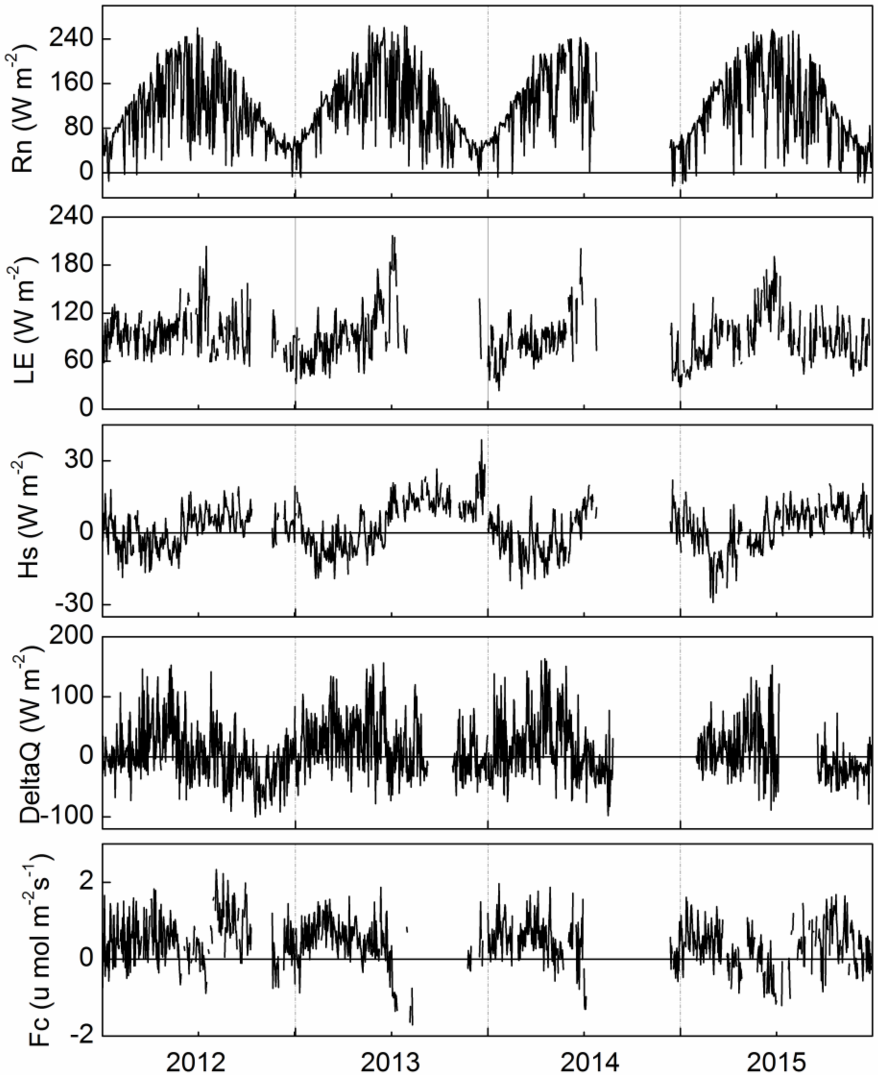




Year	Ta (℃)	Ts (℃)	ΔT (℃)	VPD (kPa)	U (m/s)	precipitation (mm)
2012	16.78	17.17	0.17	0.84	3.04	876
2013	16.65	17.37	0.77	0.83	2.67	733
2014	17.65	17.33	-0.35	0.96	2.85	813
2015	16.90	17.41	0.82	0.91	3.03	1016
Average	17.00	17.32	0.35	0.88	2.90	859.5

The study period has a higher Ta, U, lower RH (relative humidity) and precipitation compared to climate average condition.

The seasonal variation of daily average energy flux

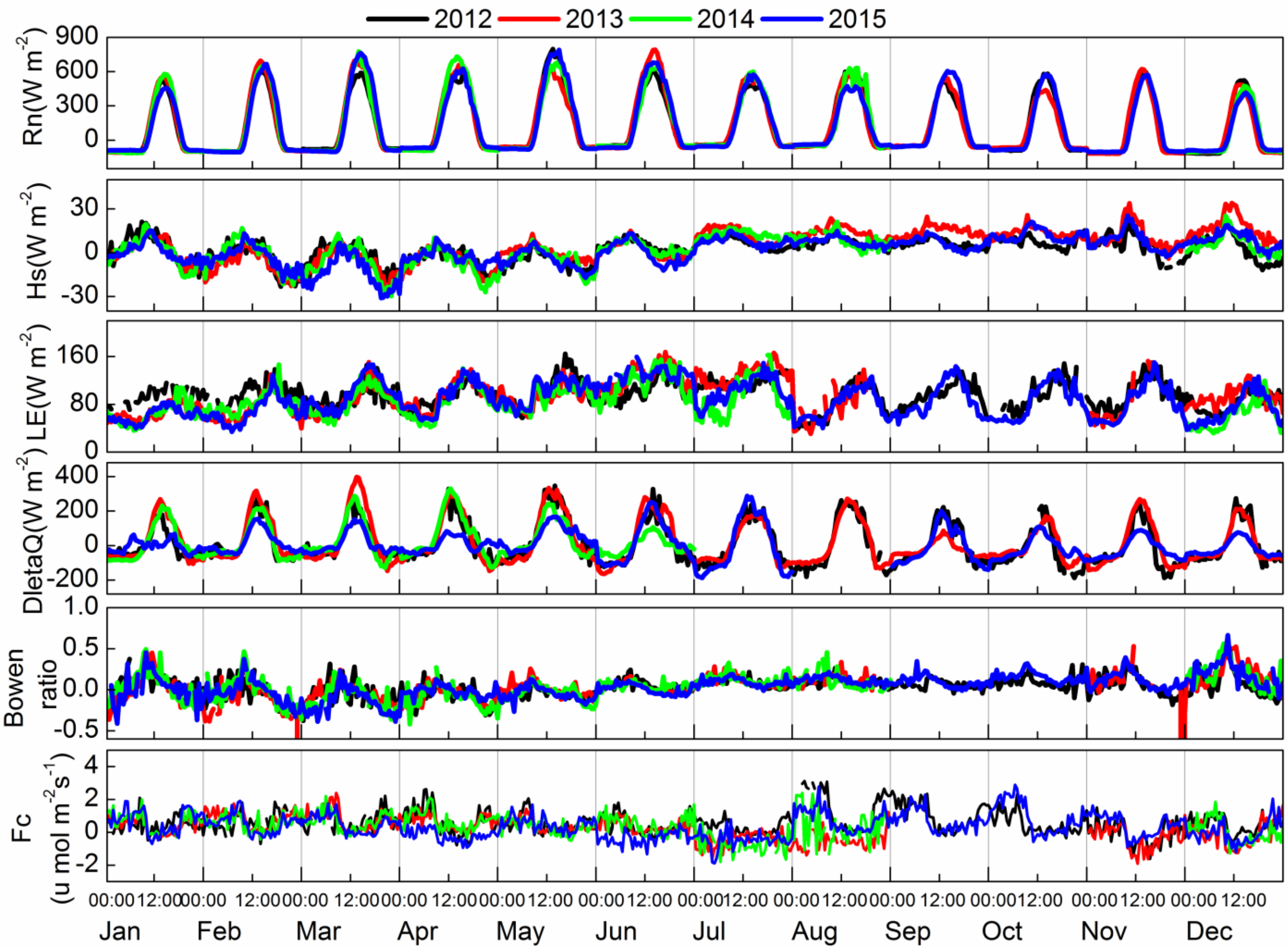


Daily average LE ranges from 23 to 216 Wm-2;
LE reached the peak in June;

Hs has a different seasonal pattern with LE.
The daily average Hs ranges from -29 to 38 Wm-2.
Hs reaches the minimum mostly in March, and maiximim in December.

The daily average storage heat in the lake (Q) varies from -97 to 163 Wm-2;
Q reaches the peak mostly in May, and the minimum in October;
Q remains almost negative during July and December, indicating the heat release period.
Carbon uptake is observed during June and July.

The monthly diurnal variation of turbulent fluxes and Bowen ratio



Hs reaches the maximum around 8:00 and minimum around 19:00. Negative Hs exists during Jan and Jun;

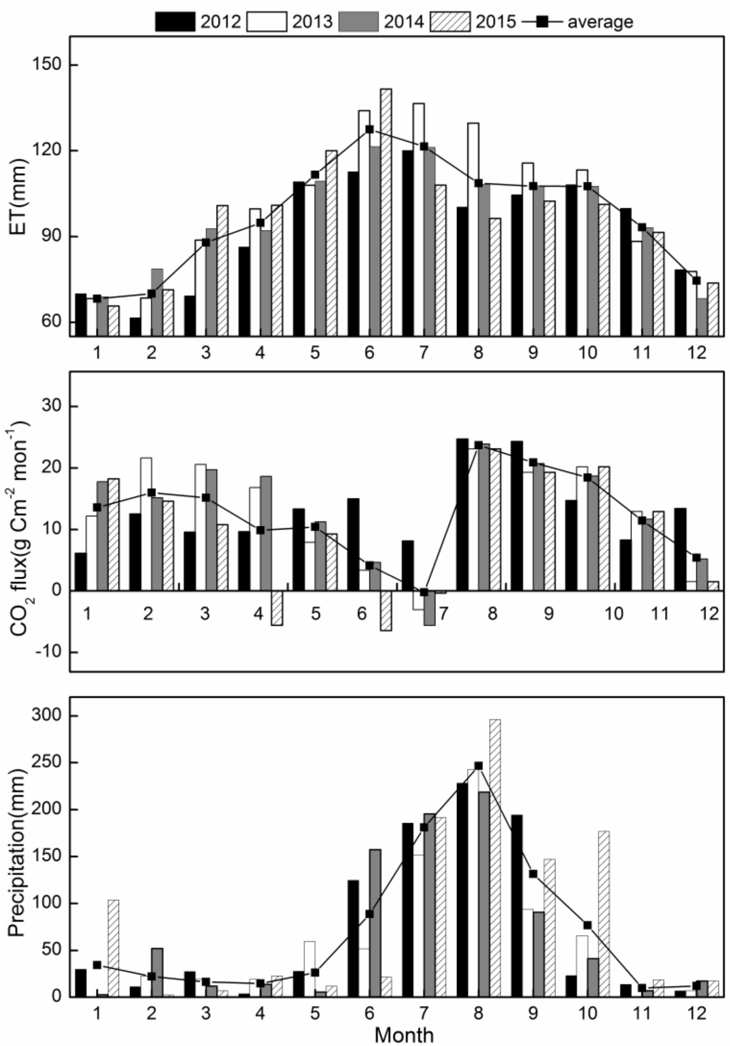
LE reaches the maximum in the afternoon (around 16:00). The positive LE indicates the evaporation is continued during nighttime;

The Q has a diurnal course similar to Rn.

The CO2 fluxes is almost negative in the midday time.

Carbon uptake is noticeable during early summer and November. Two peaks of phytoplankton is reported during summer and November.

Seasonal variation of monthly total ET, CO2 fluxes

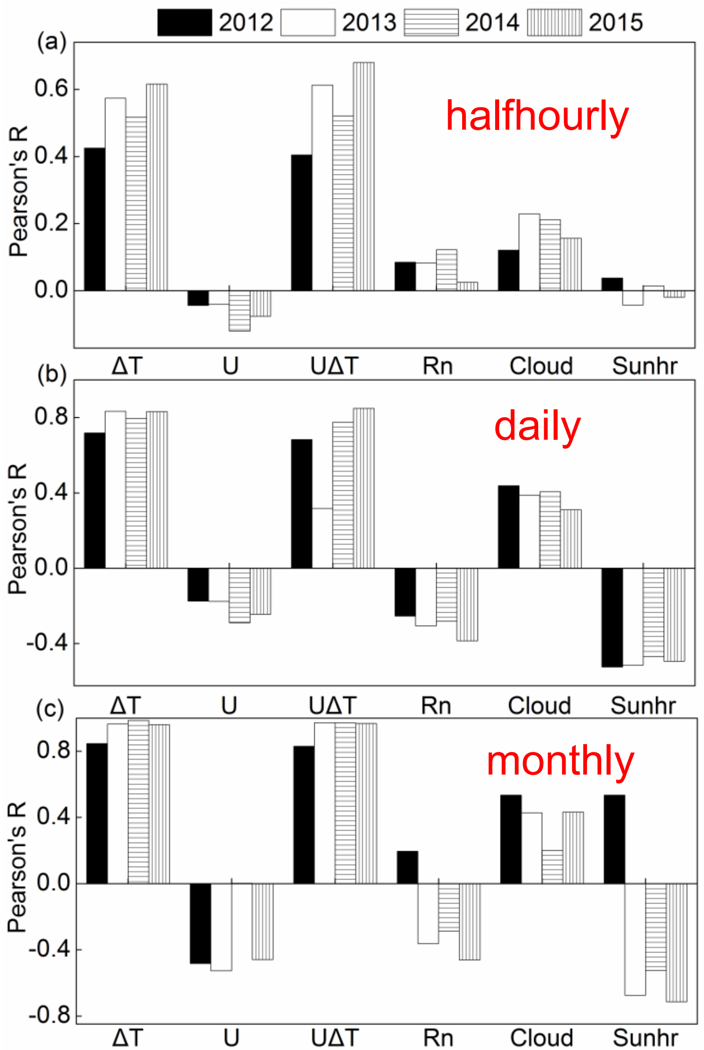


The annual ET varies from 1120.8 to 1228.5 mm during the four-years period.
The annual ET is always higher than annual precipitation. The average difference between annual ET and precipitation is 313 mm.

The monthly CO2 flux ranges from -6.4 to 24.7 g C m-2 mon-1.
The negative CO2 fluxes are observed during June and July. The maximum carbon emission is usually observed during August and September.

Year	precipitation (mm)	Fc (gCm-2)	ET (mm)
2012	876	159.6	1120.8
2013	733	156.3	1228.5
2014	813	151.7	1169.8
2015	1016	117.5	1173.5
Average	859.5	146.3	1173.1

Controlling factors of Hs from half-hourly to annual scales

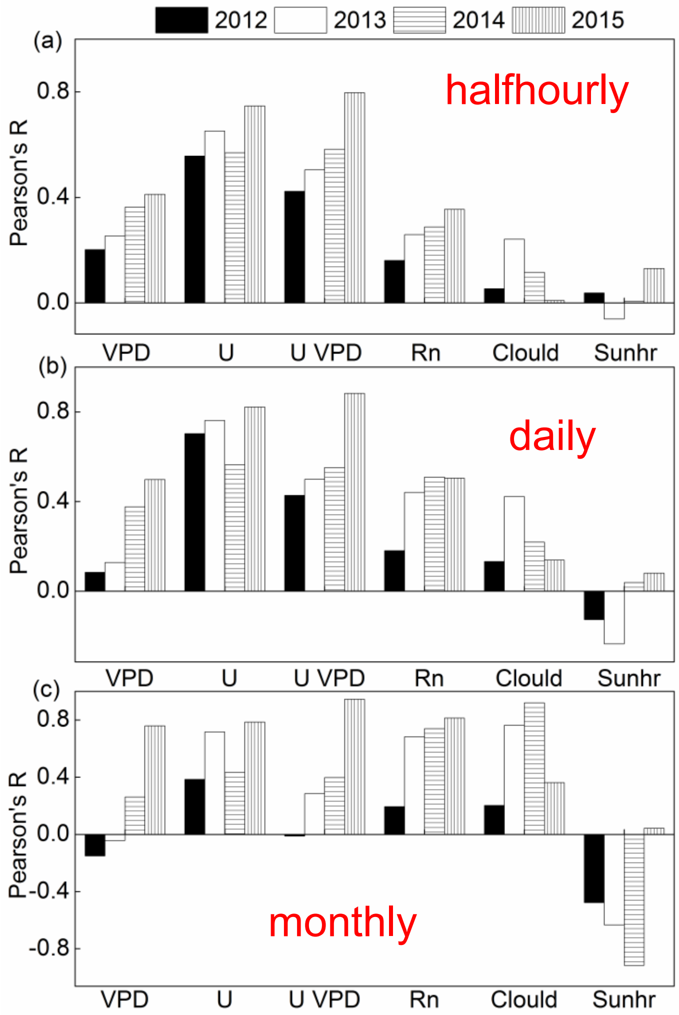


T andUT is the main controlling factors from halfhourly to mothly scales.

U has a weak effect on Hs.

The total cloud amount and sun hours are also well correlated with daily and monthly Hs, which indicates the effect of weather condition on Hs.

Controlling factors of LE from half-hourly to annual scales

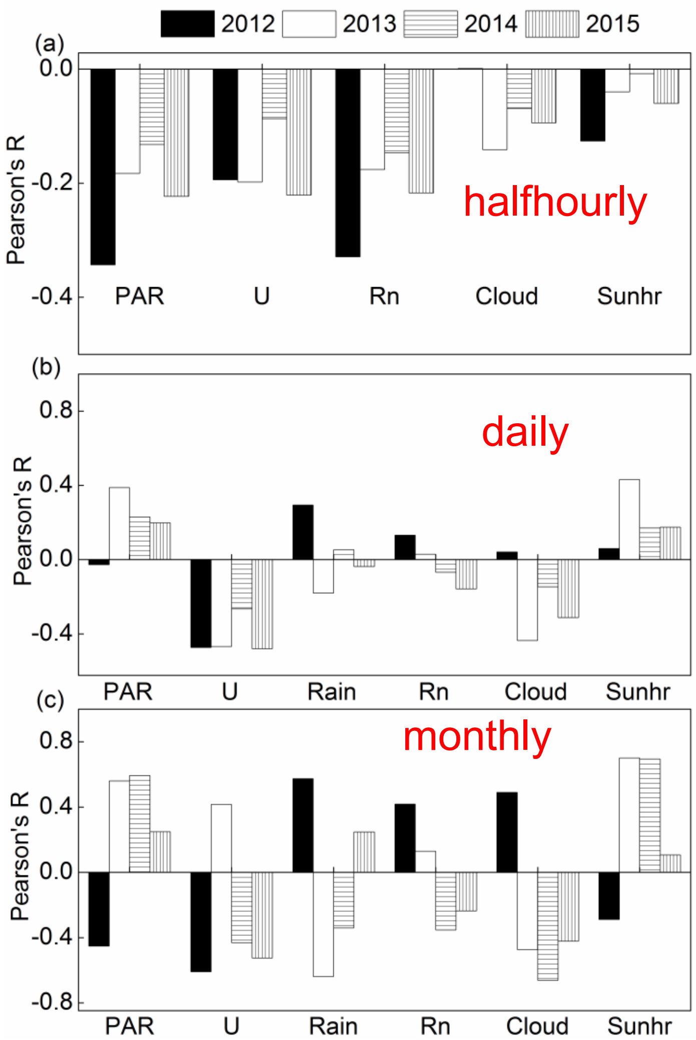


The U and U·VPD has the highest correlation coefficients with LE at halfhourly and daily scales.

There is a lower correlation coefficient between LE and VPD at halfhourly, which is similar to a small high-altitude lake of Tibet Plateau.

The correlation coefficient between Rn and LE increases when the time scaled from halfhourly to monthly.

Controlling factors of CO2 flux from half-hourly to annual scales



The correlation coefficients between halfhourly CO2 fluxes and PAR are relatively higher at halfhourly scale.

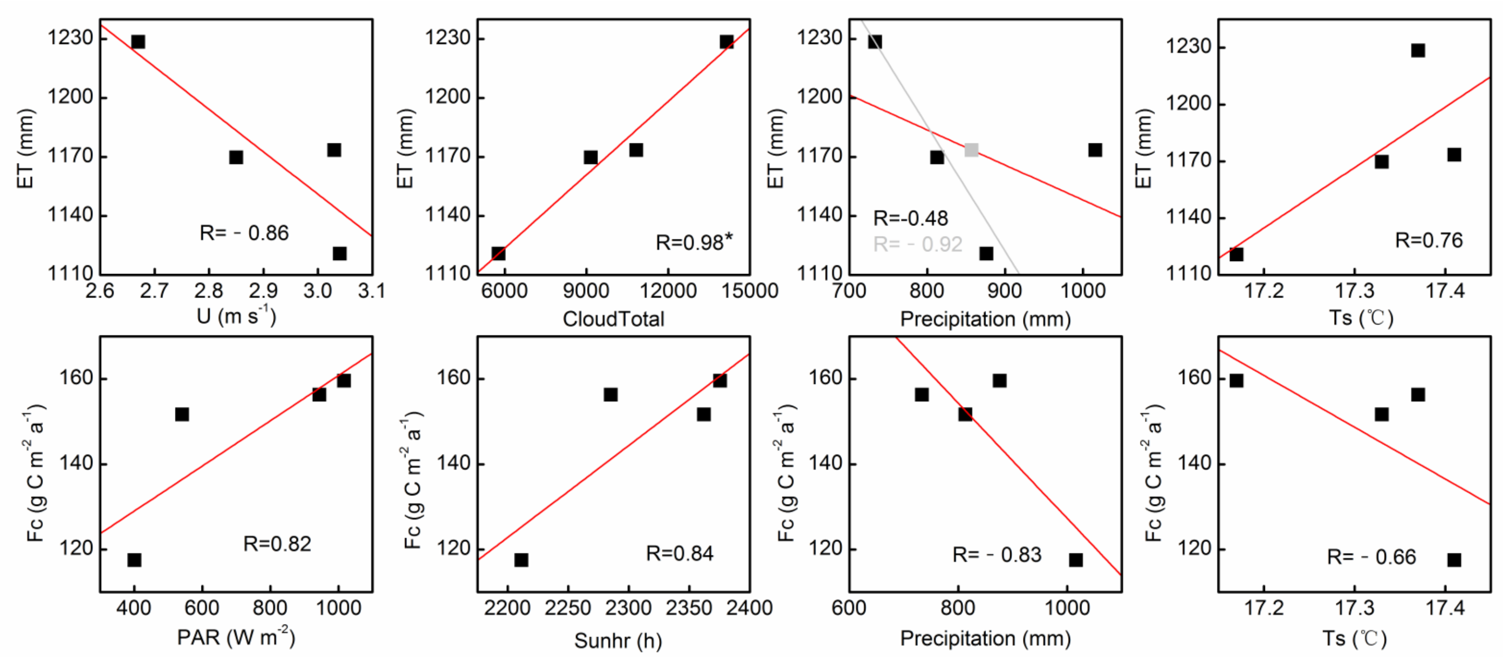
At daily scale, the wind speed is found to have an obvious relationship with CO2 fluxes.

Sun hours is found to have the highest correlation coefficients with monthly CO2 fluxes in the year of 2013 and 2014

Drivers for annual ET and CO2 fluxes

The total cloud amount is most significantly related with annual total ET.
The higher Ts will also increase the annual total ET.
The negative relationship between annual precipitation and ET implies that the more rainfall will result in lower annual ET. The correlation enhances from 0.48 to 0.92 when getting rid of an extreme precipitation event (160 mm) in 2015.

The larger rainfall and higher water surface temperature results in more carbon uptake.



The higher Ts benefits for the growth of phytoplankton.

Conclusions

- LE and Hs has a distinct diurnal and seasonal variation, which causes the diurnal variation of bowen ratio.
- The magnitude of Hs is much lower than LE.
- The Erhai Lake acts as a net carbon source at annual scale but acts as a small carbon sink during the summer time.
- The effect of meteorological factors varies at different temporal scales. T and U·T show remarkable relationship with Hs from halfhourly to monthly scales.
- While the U and U·VPD have a large impact on LE at halfhourly and daily scales.
- The effect of meteorological factors varies at different temporal scales. ΔT and U·ΔT show remarkable relationship with Hs from halfhourly to monthly scales.

- While the U and U·VPD have a large impact on LE at halfhourly and daily scales.

- PAR shows a relatively closer relationship with CO2 flux at halfhourly scale. The U has a large effect on LE and CO2 fluxes at monthly scale.


Thank you!