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In-stu observation of soil CO2 flux and its isotopic ratio from cropland in the North China Plain

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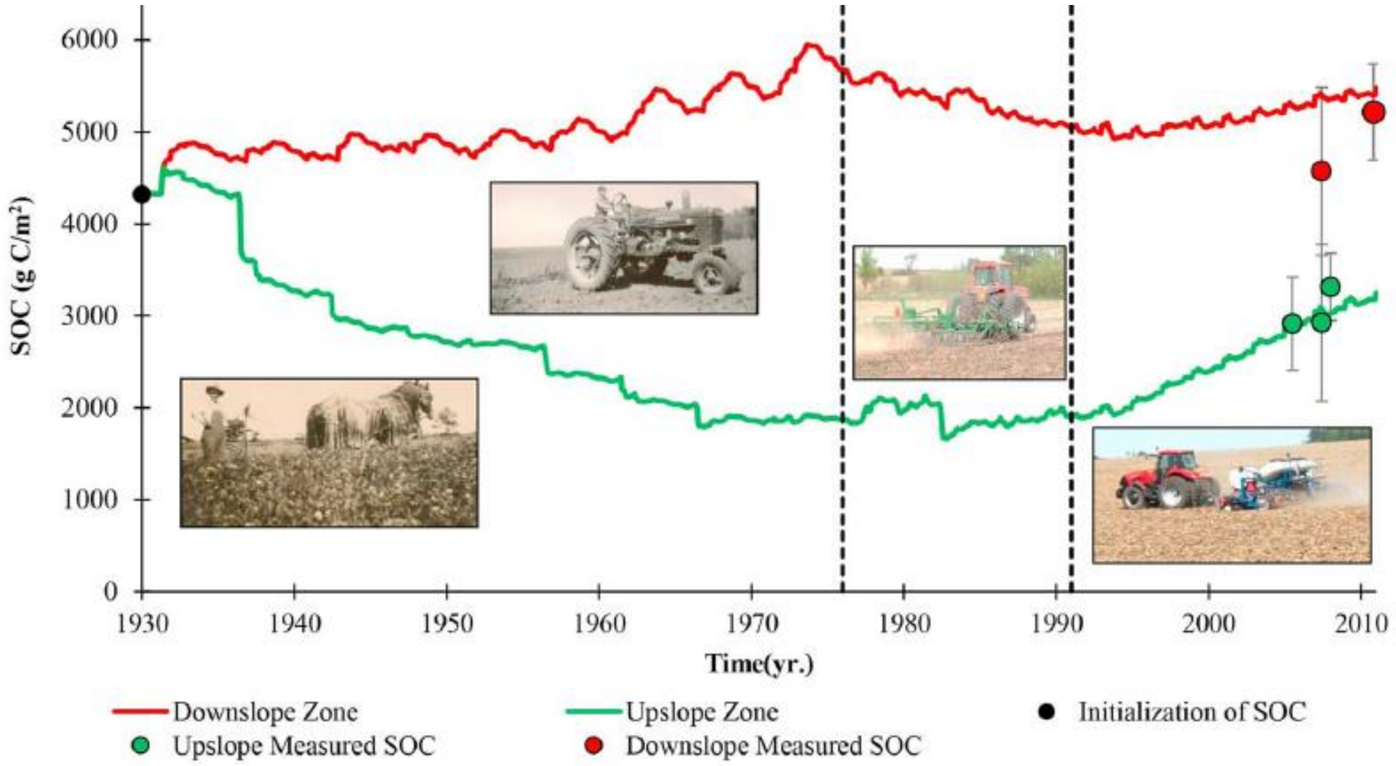
Outline

1. **Background**
2. **Methods**
3. **Results & Conclusions**
4. **Outlook**

Part 1

BACKGROUND

Background

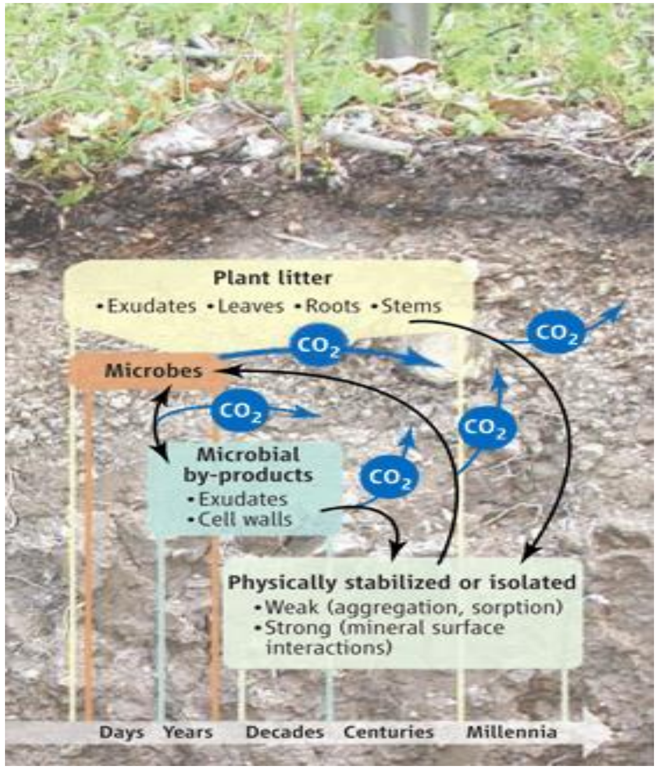


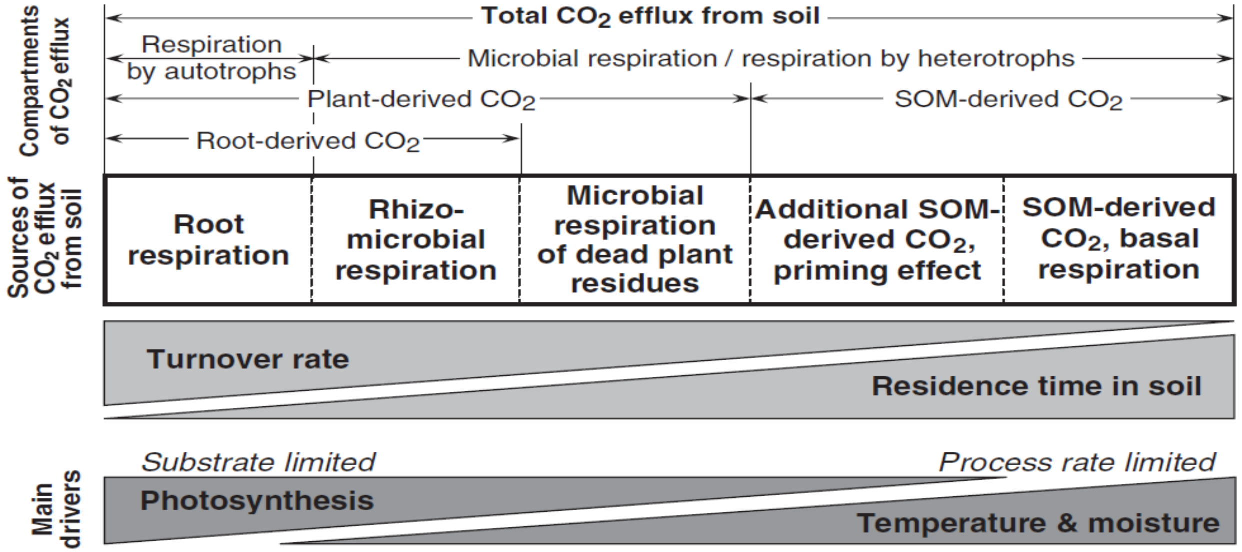
Long term farmland ecosystem management changes carbon dynamics

--fixation and emission

(Papanicolaou et al. 2015)

Complexity of C transformation





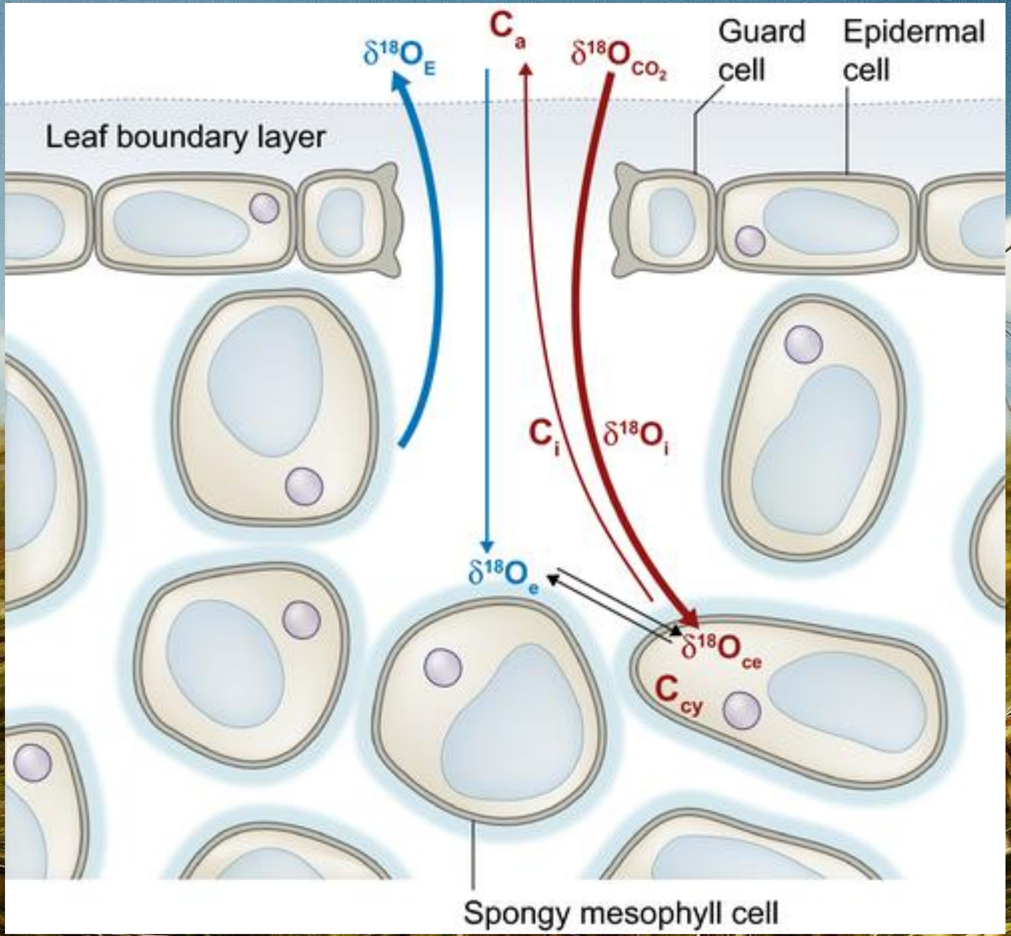
Carbon transformation pathways in soil

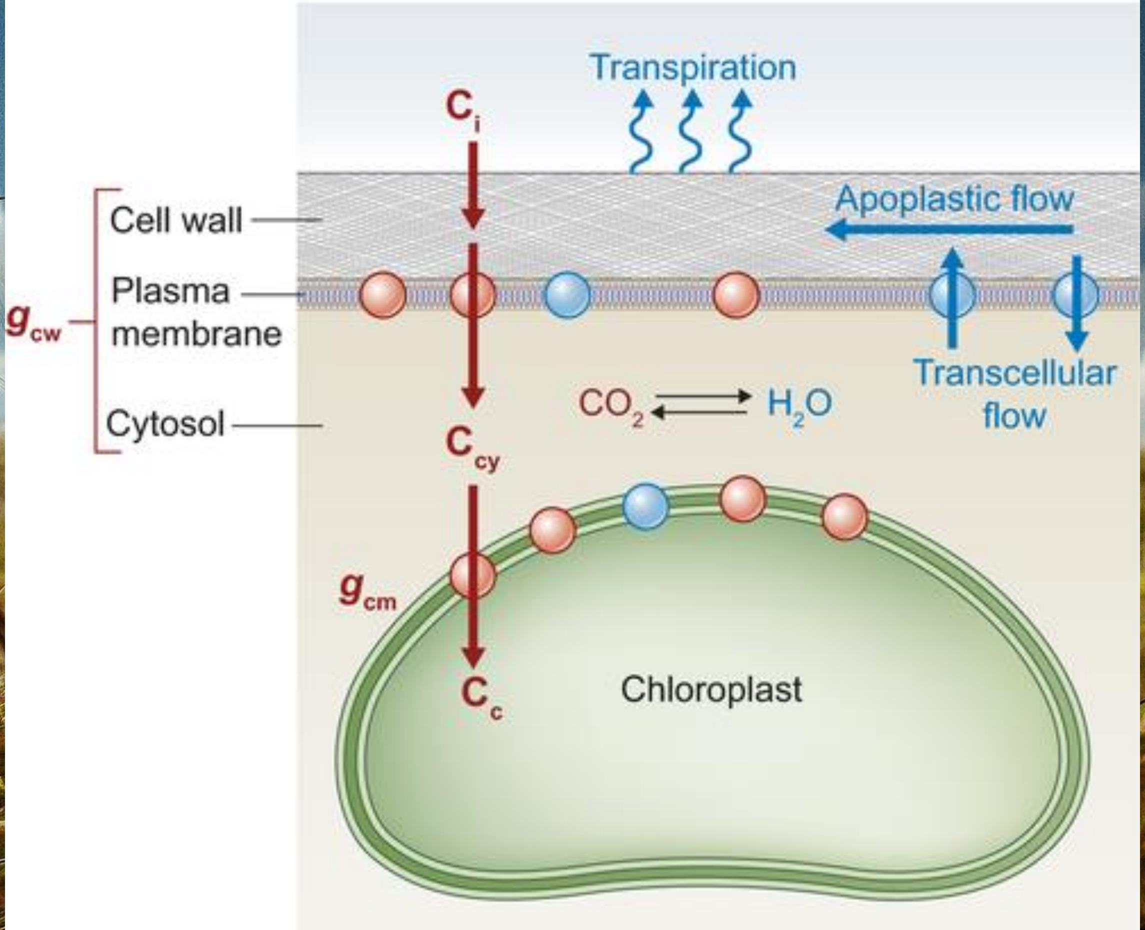
Five main biogenic sources of CO_2 efflux from soil

1. **How transformation pathways affect soil carbon cycle?**
2. **What is the proportion of root respiration and soil organic decompose in soil carbon flux**

(Trumbore et al. 2008 Science; Kuzyakov, et al. 2010 GCB; Peterson&Fry, 1987 ARES)

Online, real-time measurements of photosynthetic carbon isotope discrimination allow rapid determination of mesophyll conductance to CO2





Barbour 2017 New Phytologist

Specific objectives

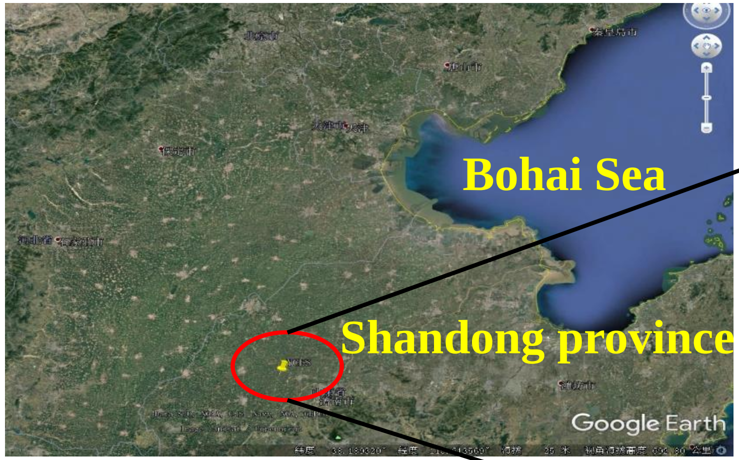
- To verify the feasibility of this experiment method.

- To in-situ monitor variations in the CO_2 flux and isotopic composition from cropland soil under alteration of managements.
- What are the factors controlling the δ13C and δ18O of respiration

Part 2

METHODS

Study area

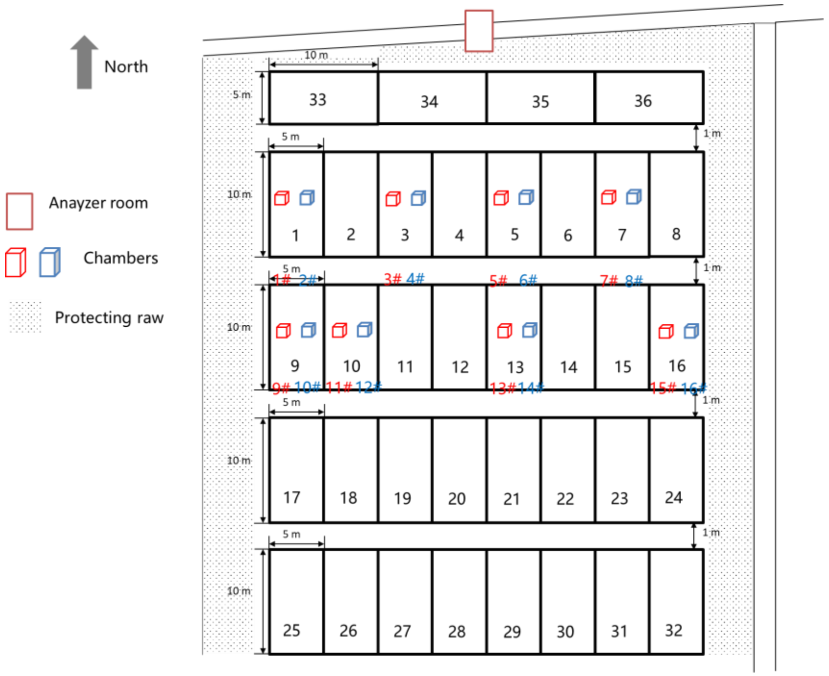


- Fluvial plain of Yellow River
- Center of North China Plain(NCP)
- Salinized brown soil
- Warm and semi-humid continental monsoon zone

Yucheng comprehensive experiment station

- **(36° 40′ ~37° 12′ N, 116° 22 ′~116° 45′E)**
- **P=580mm, E_{pan}>950mm**
- **T_{ave}=13°C**
- **Agro-ecosystem: Wheat-maize rotation system**

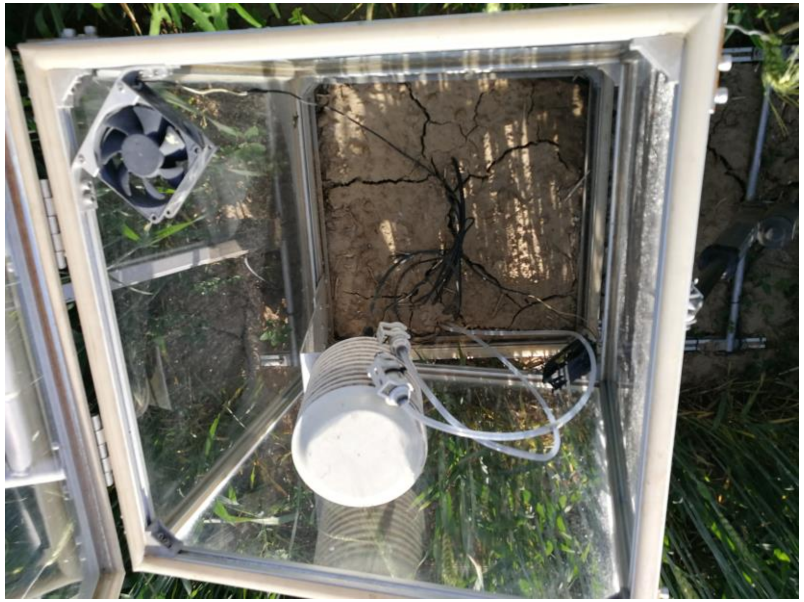
Treatments& chambers

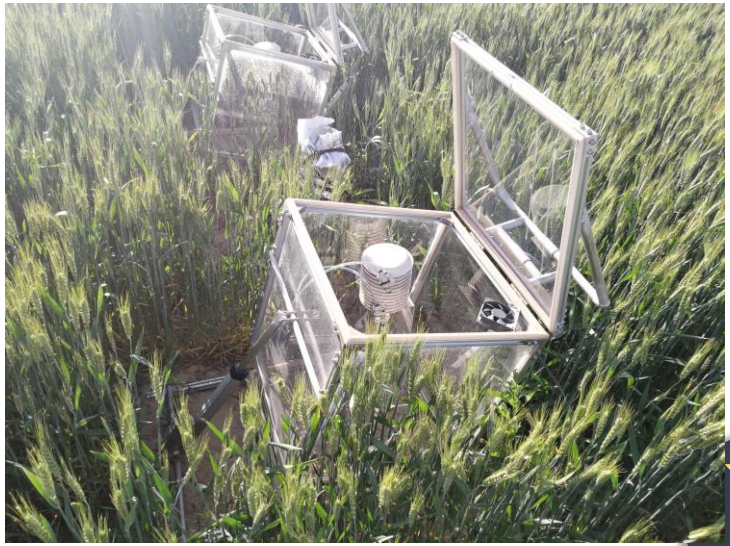


Experiment last for 5 years (from 2014, 3 replicate)
Automatic chambers and measuring devices were installed from last May

Treatments numbers	Straw return yes/no	Fertilizer levels	Tillage yes/no	Chambers No,
1	Yes	High 280 kg N ha^{-1}	No	1#， 2#
3	Yes	Middle 210 kg N ha^{-1}	Yes	3#， 4#
5	Yes	High 280kg N ha^{-1}	Yes	5#， 6#
7	No	Middle 210kg N ha^{-1}	No	7#， 8#
9	No	High 280kg/N ha^{-1}	Yes	9#， 10#
10	Yes	Middle 210kg/N ha^{-1}	No	11#， 12#
13	No	High 280 kg N ha^{-1}	No	13#， 14#
16	No	Middle 210kg N ha^{-1}	Yes	15#， 16#

16 Chambers and environment parameters





- No crops in chambers
- 5cm stainless edge were embeded into soil
- 50*50*50 cm^3
- T/RH, HMP155
- Pressure, CS100
- Soil temperature at 0cm
- Soil moisture and salinity, by CS655 at 5cm
- Datalogger for sensors, CR1000

Air sampling procedure

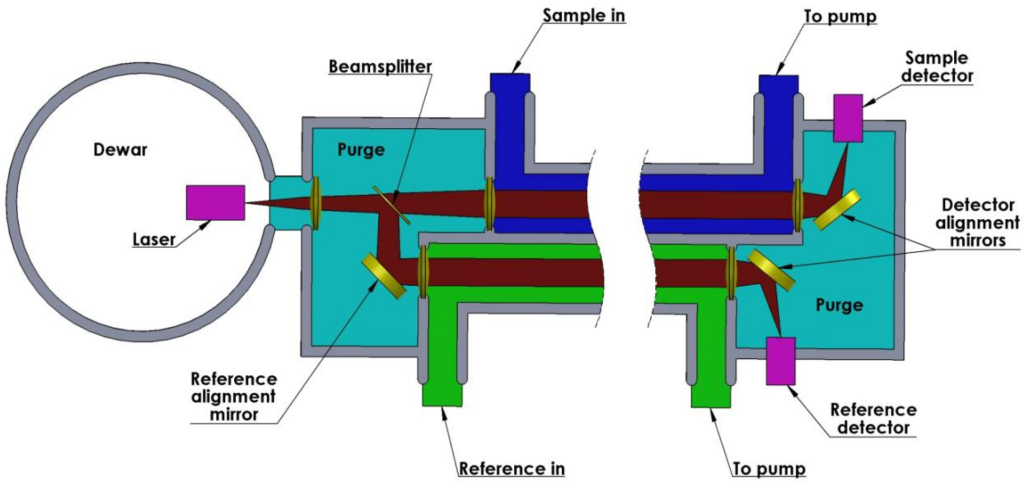
1. Monitor time of months: Winter-Wheat growth period

- From November 2018 to June 2019
- from sowing, over-wintering, turn-green, jointing, booting, heading, grouting, maturity

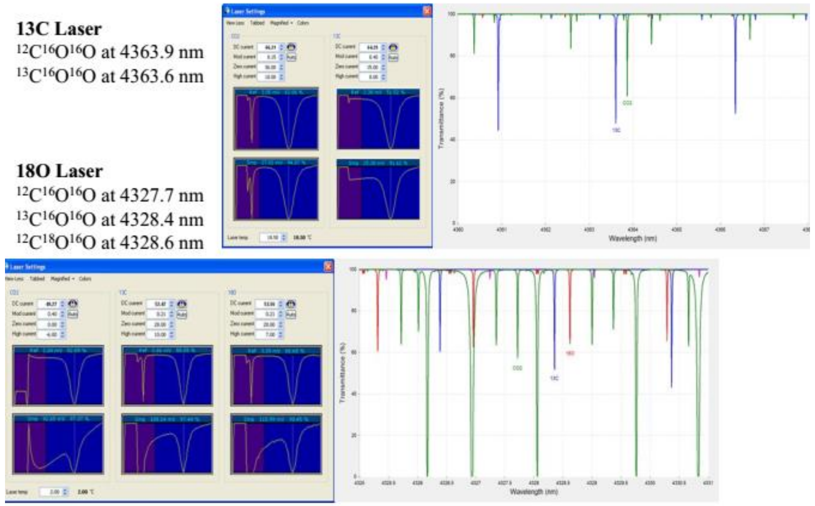
2. Monitor time in one day:

- Every hour from 0 to 24 O'clock
- Chamber is closed for 200s one by one for air intake.

TDLAS Principle (TGA200A, Campbell Scientific, USA)



TDLAS optical configuration



Laser absorption wavelength

conversion to the total CO_2

$$[C_T] = \frac{[C_{12} + C_{13} + O_{18}]}{1 - f_{other}}$$

- C_T is total CO_2 concentration (ppm)
- C_{12}, C_{13}, O_{18} is ^{12}C,^{13}C,^{18}O concentration (ppm), respectively
- f_{other} is natural abundances of other proton except ^{12}C,^{13}C,^{18}O in CO_2, ^{18}O is zero when only δ-^{13}C is calculated

Campbell Scientific Inc. 2014

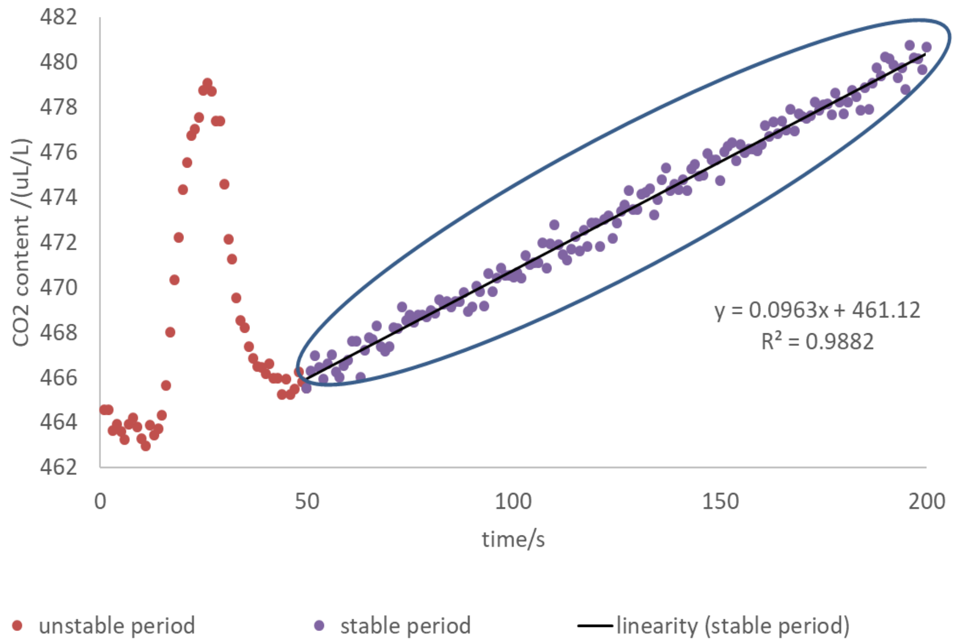
Calculating methods

1. CO_2 flux

$$F = k_1 \times \frac{273}{273+T} \times \frac{M}{V} \times H \times \frac{dc}{dt}$$

- F is the CO_2 flux rate (mg CO_2/(m^2·hr))
- K is a conversion coefficient (1 for CO_2)
- Ta (°C) is the air temperature within chamber
- M is the molecular weight (44 CO_2/mol)
- V is the mole volume (22.4 L/mol)
- H (m) is the chamber headspace height
- dc/dt (μL/(L·hr)) is the change in concentration of CO_2

Kutzbach et al. (2007)



1. Sampling time for every chamber is 200s
2. After 50s, CO_2 concentration is increased obviously and the R^2 for regression equation(from 51s to 200s) is higher than 0.95

Calculating methods

2. ^{13}C and ^{18}O ratio

calibration equation, aim to remove concentration dependence and time dependence

$$X_{s,T}^{L} = \frac{X_{2,T}^{L} - X_{1,T}^{L}}{X_{2,M}^{L} - X_{1,M}^{L}} \left(X_{s,M}^{L} - X_{1,M}^{L} \right) + X_{1,T}^{L}$$

$$X_{s,T}^{H} = \frac{X_{2,T}^{H} - X_{1,T}^{H}}{X_{2,M}^{H} - X_{1,M}^{H}} \left(X_{s,M}^{H} - X_{1,M}^{H} \right) + X_{1,M}^{H}$$

- Superscript L and H are for light and heavy protons, respectively.
- Subscript 1, 2 and a indicate standard gas 1, 2 and sampling air, respectively.
- Subscript T and M indicate the true and the measured concentration, respectively.

Wen X F, et al., 2013

Calculating methods

2. ^{13}C and ^{18}O ratio

$$^{13}R(CO_2) = \frac{^{13}C}{^{12}C} = \frac{^{13}CO_2}{^{12}CO_2}$$

$$^{18}R(CO_2) = \frac{^{18}O}{^{16}O} = \frac{C^{16}O^{18}O}{2 \times CO_2}$$

$$\delta_{sample} = \left(\frac{R_{sample}}{R_{VPDB}} - 1 \right) \times 1000$$

- ^{12}C, ^{13}C, ^{18}O are ^{12}C, ^{13}C, ^{18}O concentration (ppm), respectively
- R_{VPDB} (^{13}C) = 0.0111797， R_{VPDB} (^{18}O) = 0.002088349077

Griffis et al., 2004

Calibration methods

^{13}C and ^{18}O calibration

1. Two concentrations standard gases(about 300ppm,600ppm CO2) make calibration and one standard gas (about 400 ppm) CO2 to keep
quality control.

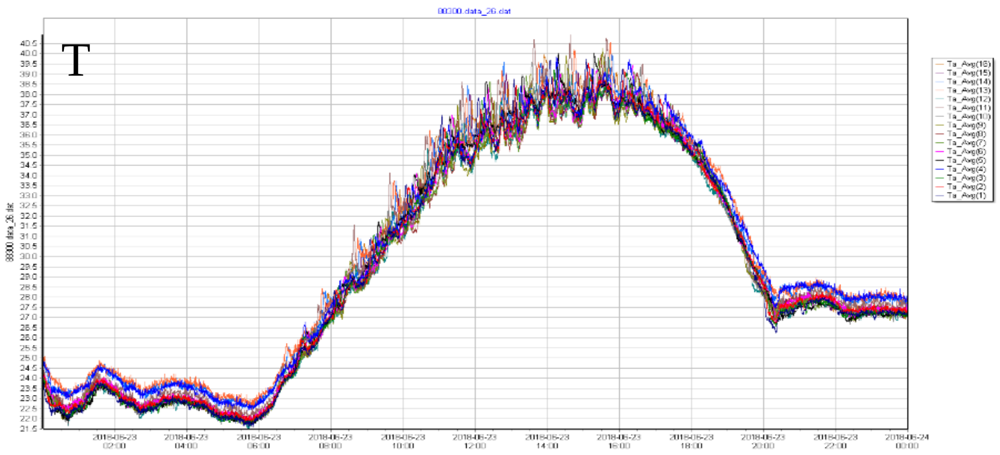
2. Every day, every standard gas will be monitored for 15min one by one from 23 to 24 O'clock.

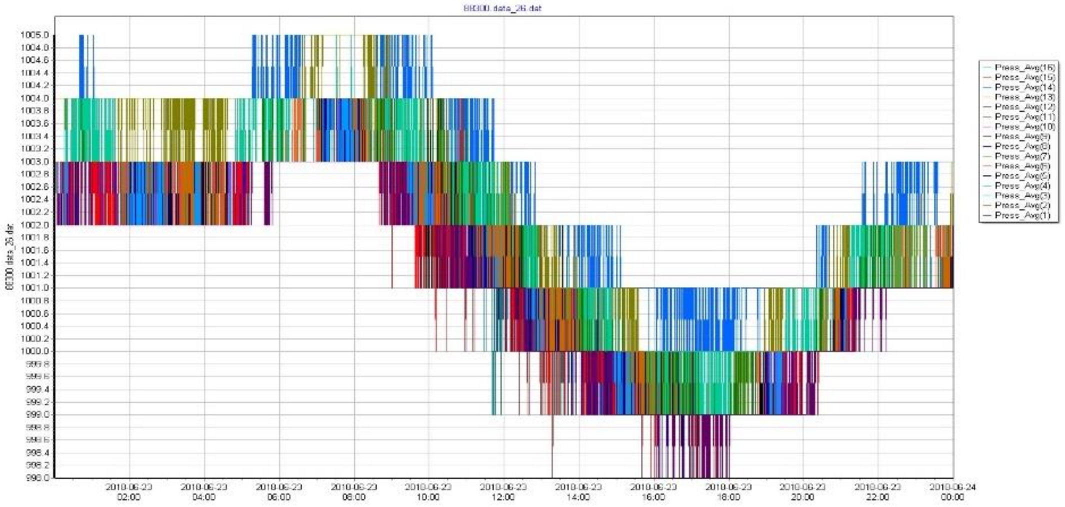
Wen XF, et al., 2013

Part 3

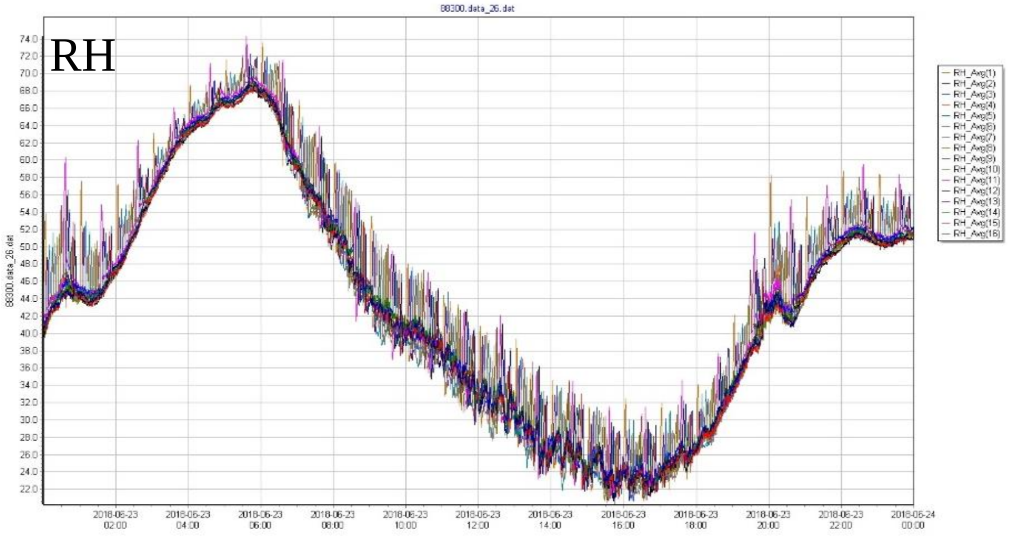
RESULT & CONCLUSIONS

Environment factors in chambers



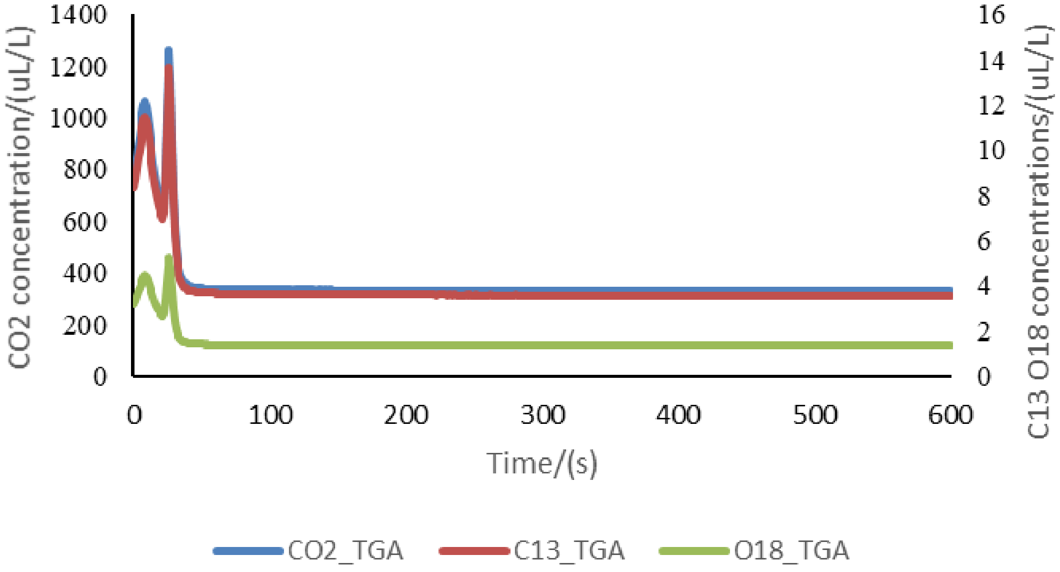


Pressure

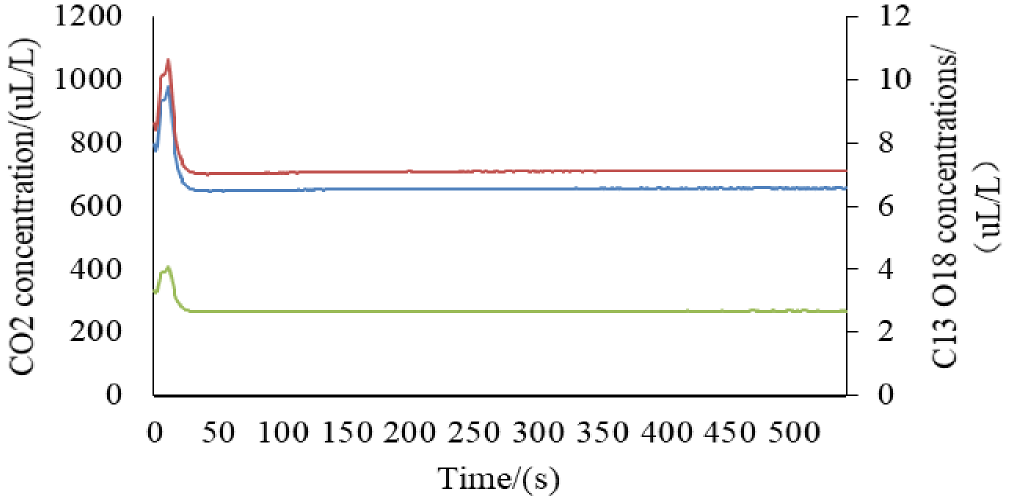


- Data for 24/6/2018
- Temperature, relative humidity and pressure were time-varying in chambers

Intake time verification in same length pipeline



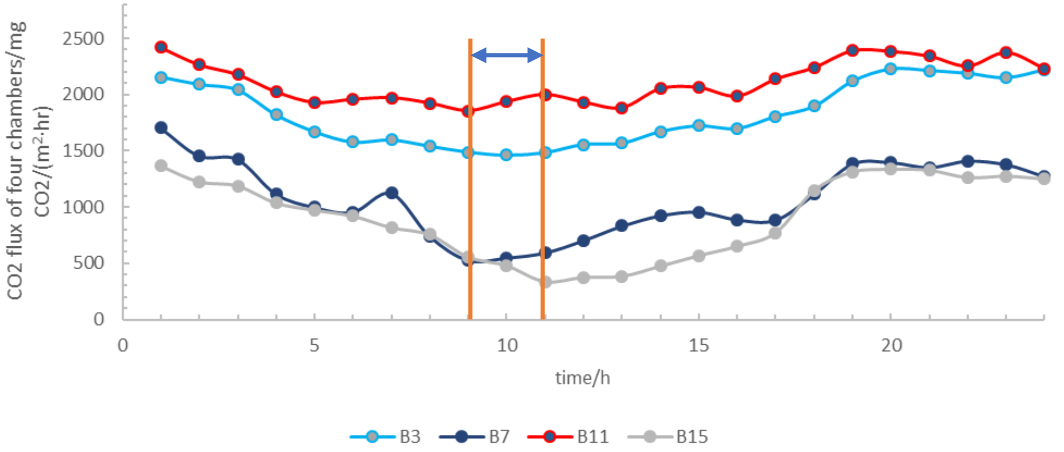
1.Middle level reference gas(300 ppm CO_2)

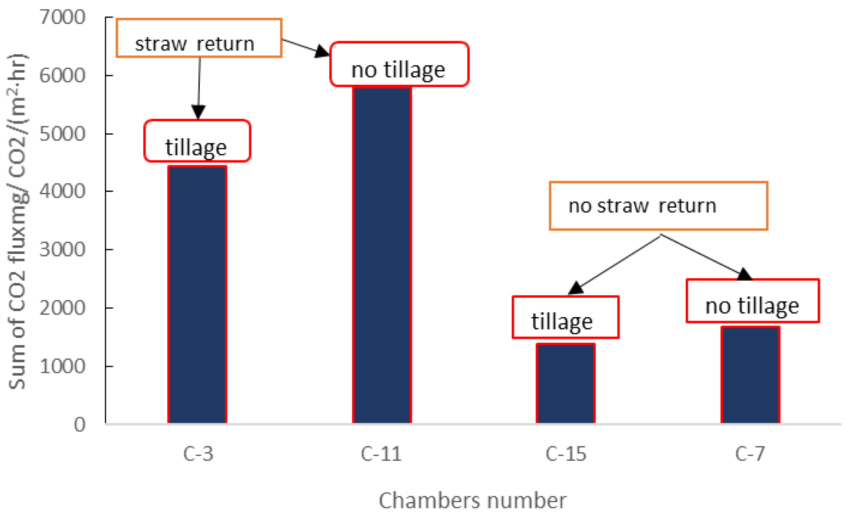


2.High level reference gas(600ppm CO_2)

- CO_2 ,^{13}C, ^{18}O concentrations were stable after 50s
- Intake time and linear time were 200s, 50-200s, respective

CO_2 flux of four chambers in 6/13/2018





Each chamber was closed one by one and then ^{13}C, ^{18}O (ppm) (measured, no calibration) were determined for 200s in an hour in 7/19/2018

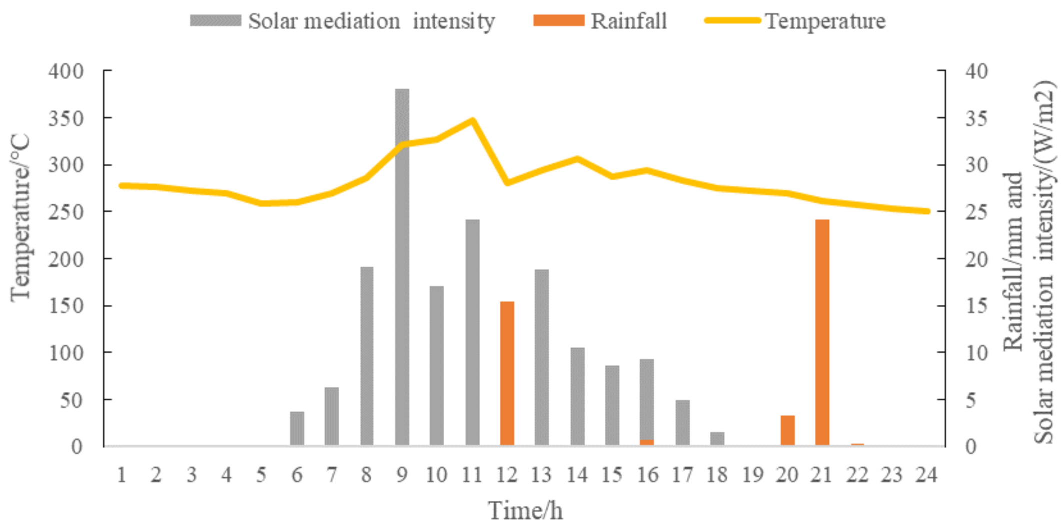
Sum of CO_2 flux of each four chambers in two hours

Chambers No.	Tillage yes/no	Fertilizer levels	Straw return yes/no
C-9	Yes	High 280 kg N ha^{-1}	No
C-15	Yes	High 280kg/N ha^{-1}	No
C-13	No	Middle 210kg N ha^{-1}	No
C-7	No	Middle 210kg N ha^{-1}	No

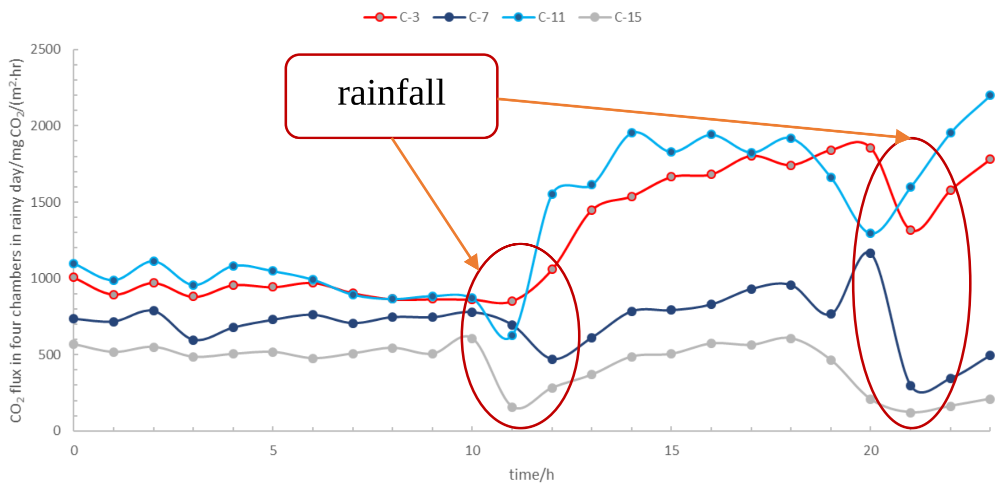
Treatments of four chambers

- Difference between treatments was significant
- CO2 flux in of straw return were higher than no-straw return
- CO2 flux were higher under tillage than no-tillage

CO_2 flux under rainfall in 7/13/2018



Rainfall, temperature and solar radiation intensity



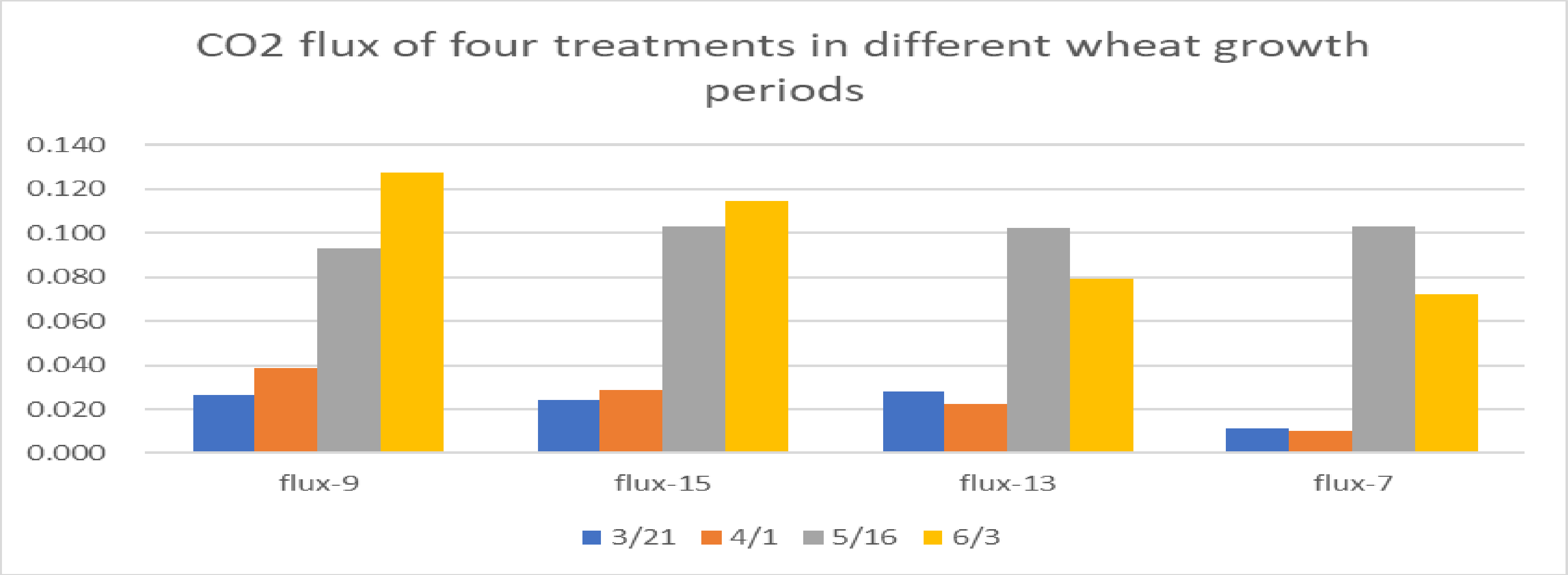
CO_2 flux under rainfall

Chambers No.	Straw return yes/no	Tillage yes/no	Fertilizer levels
C-3	Yes	Yes	Middle 210 kg N ha^{-1}
C-11	Yes	No	Middle 210kg/N ha^{-1}
C-15	No	Yes	Middle 210kg N ha^{-1}
C-7	No	No	Middle 210kg N ha^{-1}

Treatments of chambers

- Flux was restrained by too heavy rainfall
- After the rain, CO_2 flux was increased during certain time
- Difference between treatments was significant

CO2 flux of four treatments in different wheat growth periods



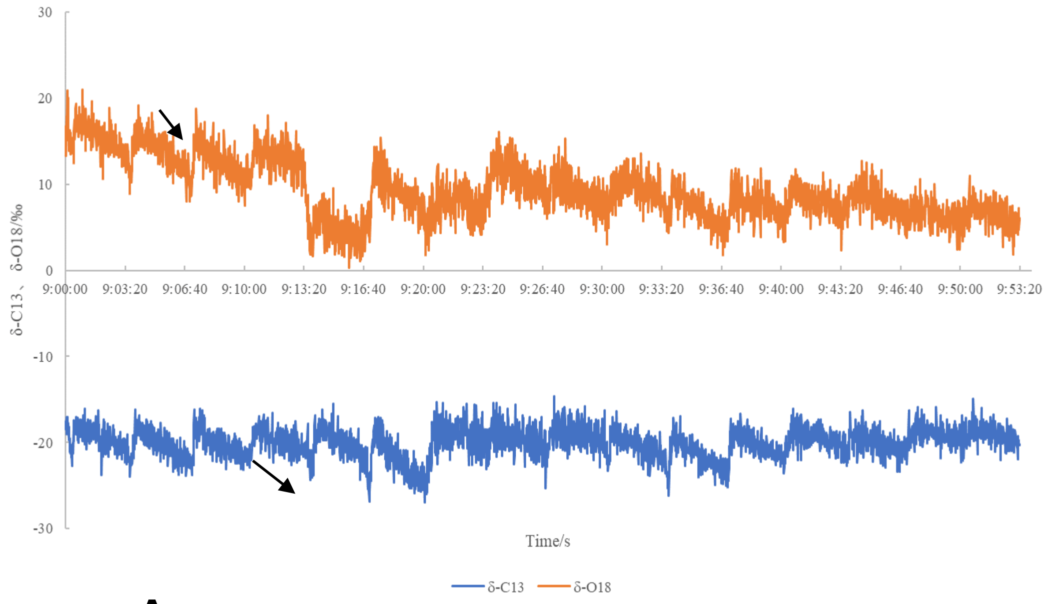
CO2 flux of four treatments in different wheat growth periods in 2019

Chambers No.	Straw return yes/no	Fertilizer levels	Tillage yes/no	Root removel
C-3	Yes	Middle 210 kg N ha^{-1}	Yes	No
C-11	Yes	Middle 210kg/N ha^{-1}	No	No
C-15	No	Middle 210kg N ha^{-1}	Yes	No
C-7	No	Middle 210kg N ha^{-1}	No	No

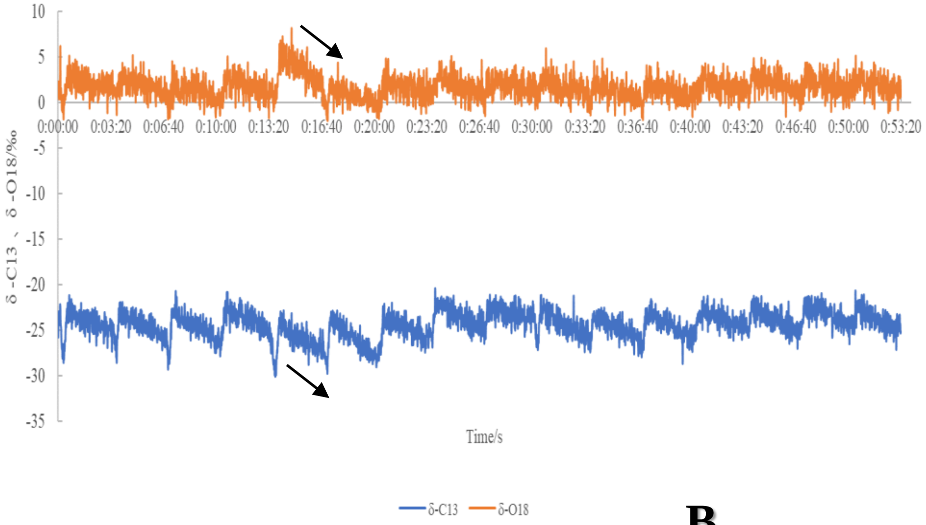
Treatments of four chambers

- Difference of flux in different wheat growth periods in single treatment was significant
- Effect of higher N fertilizer and tillage treatments on soil flux were more obvious than middle N fertilizer and no-tillage treatments.

^{13}C, ^{18}O concentrations in different chambers in an hour(7/13/2018)



A
0 O’clock



B
9 O’clock

Calibrated data of $\delta^{13}C$, $\delta^{18}O$ for all champers at 0 O’clock (A) and 9 O’clock(B)

- Data of $\delta^{13}C$, $\delta^{18}O$ for all treatments were obviously changed after champers closed.
- $\delta^{13}C$, $\delta^{18}O$ of CO2 in night(from -20‰ to -18 ‰, from -20 ‰ to -5 ‰) were different with that in daytime (from -23‰ to -27 ‰, from -5 ‰ to 0).

Conclusion

- TDLAS is stable and has high precision.
- Short intake time and linear time is appropriate.
- Effects of different treatments on soil CO2 flux are different, and soil flux is obviously changed under various weathers.
- Depletion of carbon isotopes in atmospheric CO_2 was significant, and this methods could be used for C source separation.

Part 4

OUTLOOK

Outlook

- Long-term monitoring for CO_2 flux and isotopic ratio.
- Understanding the mechanisms of carbon cycles in cropland soil.
- Higher precision and lower maintenance

acknowledgement

- Prof. Guanghui Lin at Tsinghua University

- NSFC
- CAS

Thanks for your attention!