Temporal and spatial variabilities of leaf-water ^{18}O enrichment in wheat and corn

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Introduction

- Leaf water ^{18}O enrichment is an important factor controlling the ^{18}O-H_2O and ^{18}O-CO_2 and ^{18}O-O_2 exchanges between the biosphere and the atmosphere.
- At present, there is limited capacity to explain the enrichment mechanisms in field conditions.
- The overall goal of this study is to investigate the processes controlling the leaf-water ^{18}O enrichment in a wheat and a corn ecosystem.
- We present new results of high-frequency leaf water ^{18}O enrichment measurement along with the ^{18}O measurements of other ecosystem water pools, interpret the canopy-scale foliage ^{18}O with a land-surface model, and identify the factors influencing the model performance.

Materials and Methods

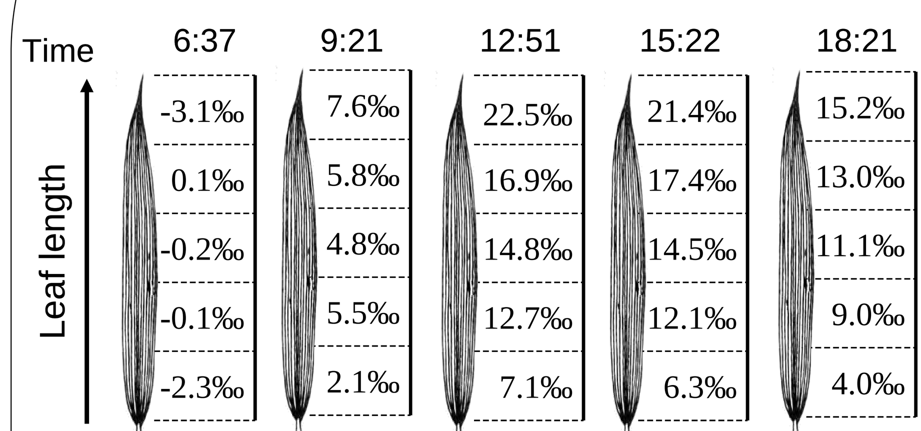
- The experiment was conducted in a winter wheat and summer corn double-cropping system at Luancheng (37º50'N, 114º40'E) in North China from April 5 to September 13, 2008.
- In-situ measurements of water vapor and water flux isotope ratios were conducted with a tunable diode laser (TDL) trace gas analyzer (Model TGA100A, Campbell Scientific Inc., Utah, USA).
- Air was sampled at two heights above the canopy from 0.6 /1.6 m at the beginning to 1.1 /2.1 m at the end of the wheat season and from 1.1 /2.1 m at the beginning to 3.2 /4.2 m by the end of the corn season, accounting for canopy growth.
- Leaf, stem and soil samples were collected at midday every 2-4 days from 4 sampling plots during the growing season. Soil samples were collected from the depth of 0-5, 15-20 and 40-45 cm. Precipitation and dew water were also collected.
- Supporting measurement consisted of an eddy covariance system and a suite of micrometeorological sensors.

Leaf-Water ^{18}O Enrichment Model

- Three models (Craig & Gordon, 1965; Dongmann et al., 1974; Farquhar & Cernusak, 2005) were employed to simulate the ^{18}O concentration of bulk leaf water.
- The models were upscaled from the leaf scale to the canopy scale by employing a canopy-scale kinetic fractionation factor and the intermediate variables at the canopy scale calculated by a big-leaf model.

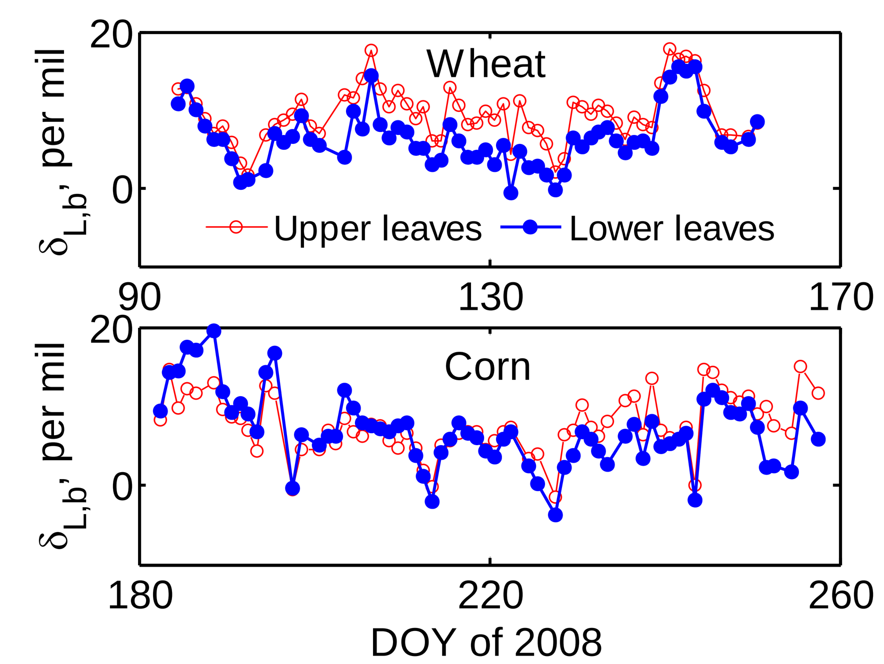
Models	Considering LWC variation	Considering Non-steady state	Considering Péclet effect
Craig-Gordon	No	No	No
Dongmann	No	Yes	No
Farquhar	Yes	Yes	Yes

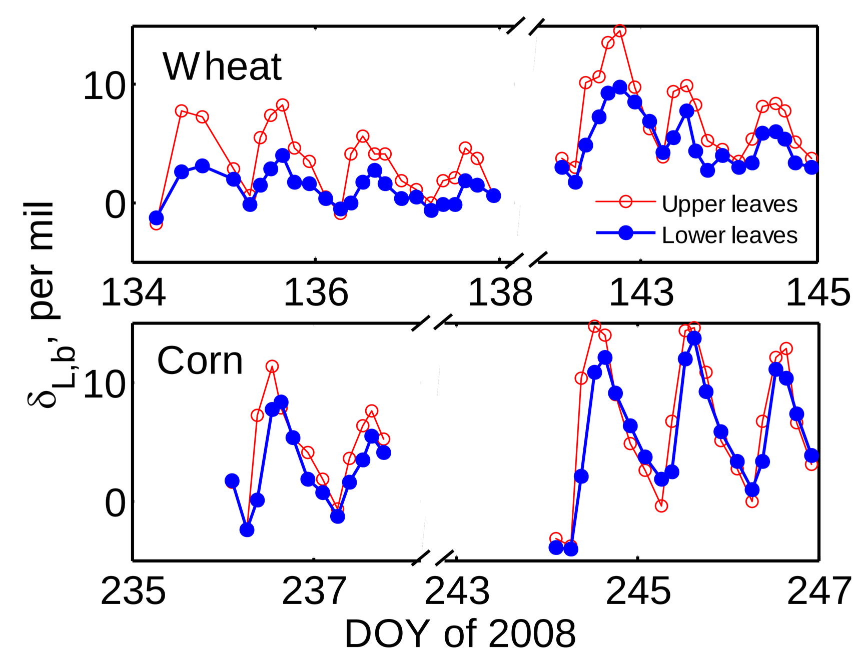
Observed Variabilities of Leaf Water ^{18}O



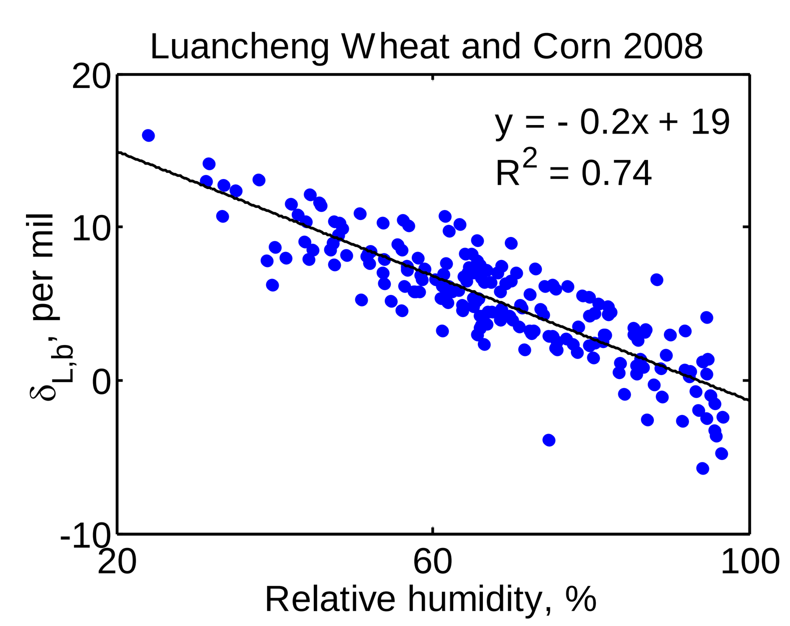
Within a single leaf, the isotopic gradient between the leaf tip and base was small in the morning and became significant with increasing evapotranspiration, reaching a value of ~15‰ (tip-to-base) in the afternoon.

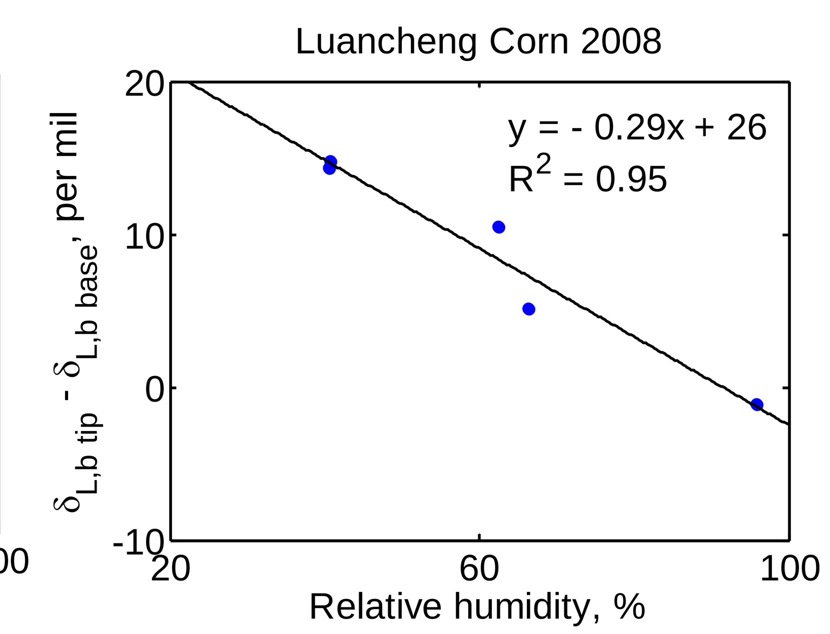
- Within the canopy stratification, leaves in the upper canopy (red open circles) were more enriched than those in the lower canopy (blue closed circles) in the whole wheat season
- In the corn season the upper leaves (red open circles) were less enriched before LAI approached the maximum and more enriched after then than the lower leaves (blue closed circles).





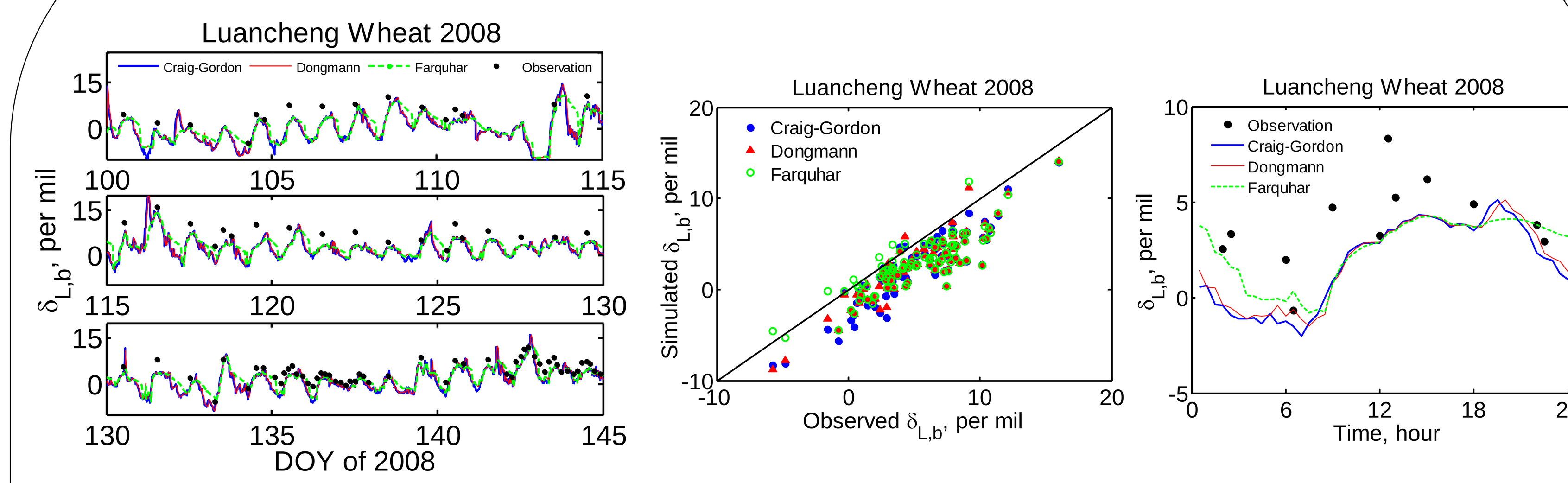
- In the wheat canopy, the upper leaves (red open circles)) were more enriched than those in the lower canopy (blueclosed circles) both in day and night.
- In the corn canopy, the vertical gradient were smaller than in the wheat canopy.



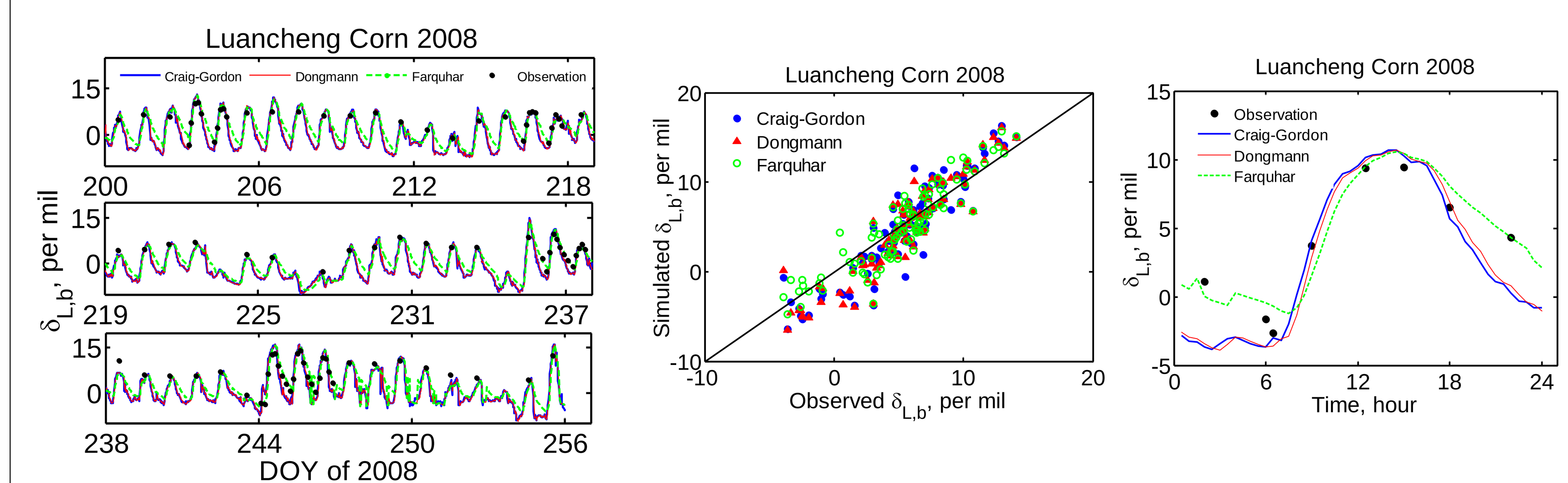


- With increasing relative humidity, both the leaf-water ^{18}O content and its tip-to-base gradient decreased.

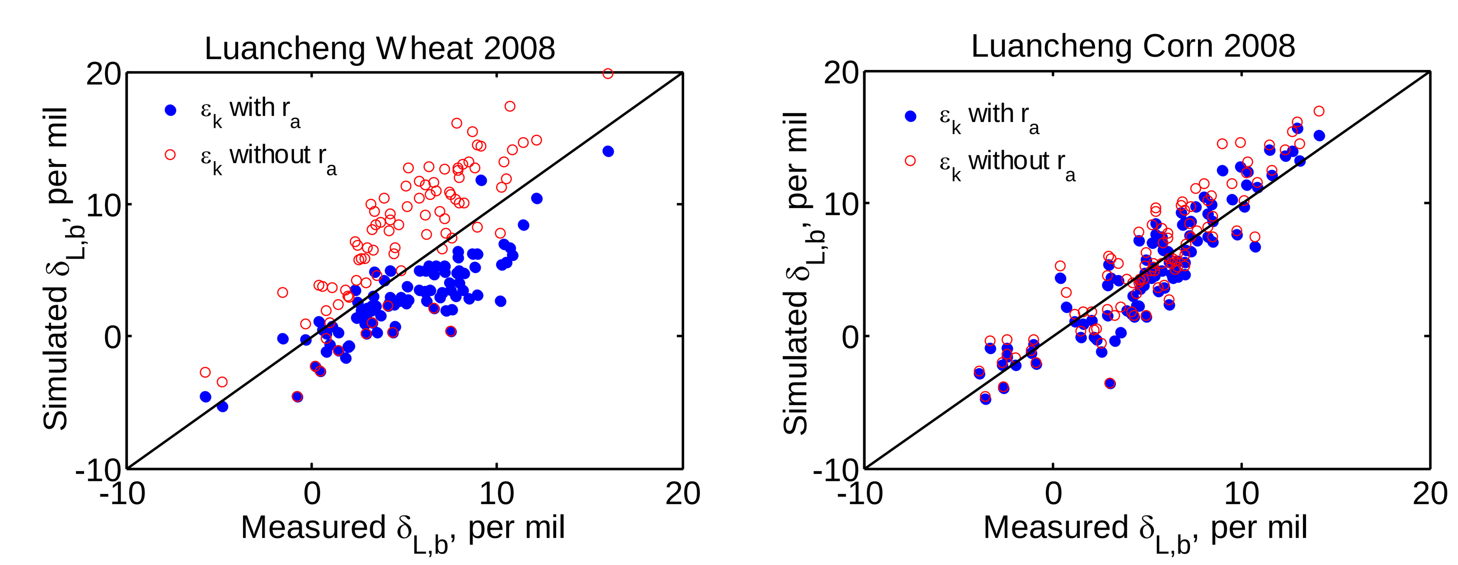
Model Results



- For the wheat ecosystem, the modeled leaf-water ^{18}O enrichment was biased low; the bias error was positively correlated to the bias in the modeled canopy temperature.



- For the corn ecosystem, the modeled enrichment was in good agreement with the observations. The Farquhar model outperformed the other two models in simulating the diurnal pattern of foliage water ^{18}O composition.



- Our model simulation confirmed the need to consider turbulent diffusion when calculating the canopy-scale foliage water ^{18}O enrichment.

Conclusions

- Humidity was a crucial factor controlling the leaf-water ^{18}O enrichment and its gradient between leaf tip and base.
- At the canopy-scale, turbulent diffusion was more important than the Péclet and the non-steady state effect for predicting the leaf-water ^{18}O enrichment.

Acknowledgement

This study was supported by the National Basic Research Program of China (grant 2010CB833501), the National Natural Science Foundation of China (grants 31070408 and 30970517), the Strategic Program of Knowledge Innovation of Chinese Academy of Sciences (grant KZCX2-EW-QN305) , the U. S. National Science Foundation (grant ATM-0914473) and a Rice Family Foundation grant.