The Role of Surface Water Flow in Gas Fluxes from a Subtropical Rice Field

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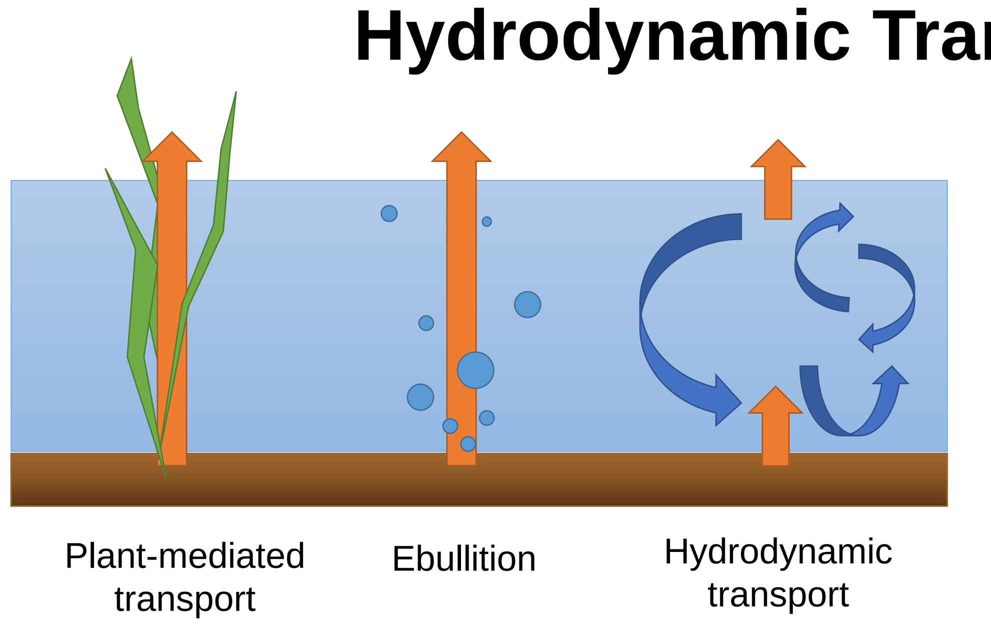
Motivation

This work aims to reveal: (1) the fraction of total methane flux that is governed by hydrodynamics, (2) daily cycles in hydrodynamic fluxes, and (3) variation in flux with canopy structure.

Hydrodynamic Transport



Methane is released from wetlands via plant-mediated transport, bubbling, and hydrodynamic transport (Figure 1).

Figure 1: Methane transport mechanisms

Hydrodynamic transport is driven by stirring in the water column, which can be caused by convection, wind, rain, bioturbation, currents, seiches, etc.

Fluxes from hydrodynamic transport can be modeled with a diffusion equation, but it requires modification.

$$J = -D_m \frac{\partial C}{\partial Z}$$

Flux   Molecular diffusivity   Concentration gradient

Site Description

Humnoke, Arkansas
34.5415° N, 91.7571° W
(Figure 2)

Subtropical climate

Rice paddies equipped with eddy covariance towers for long-term total methane flux measurements

Measurements were taken between July 26th and August 3rd, 2016 (Figure 3)

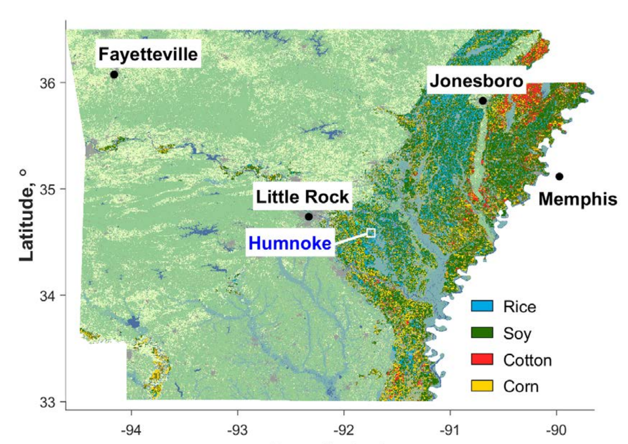


Figure 2:Field location (marked by white square near the town of Humnoke) within the state of Arkansas on the 2015 CropScape crop cover dataset from the National Agricultural Statistics Services (Han et al., 2014) with selected crops in legend

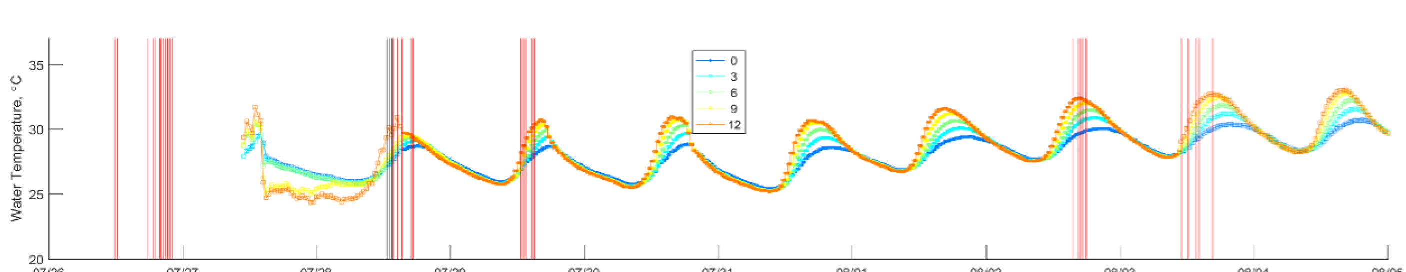


Figure 3: Water temperature at varying heights above the ground (0, 3, 6, 9, and 12 cm). The vertical red lines indicate when methane concentration measurements were taken in the field.

Water-side Measurement
Thin-film Method

Relates methane flux to the difference in concentration, between atmosphere and water, (Figure 4) and the gas transfer velocity (degree of stirring) (Figure 5)

$$J = -k\left(\frac{C_{atm}}{H} - C_w\right)$$

Atmospheric concentration   Dissolved concentration   Gas transfer velocity   Henry's Law constant

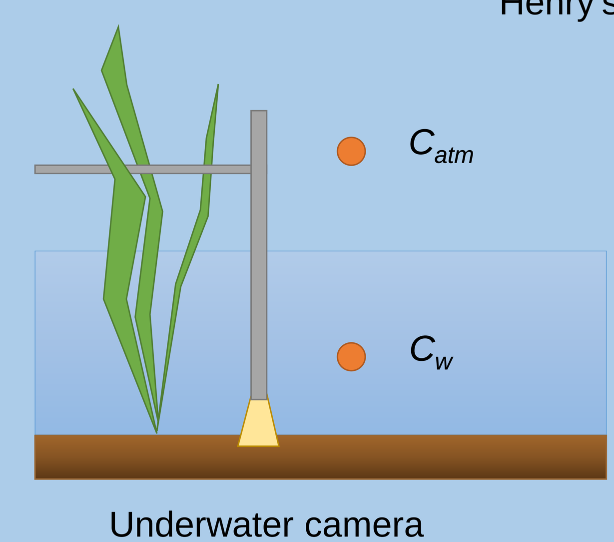


Figure 4: Sampling set-up for thin-film method. Methane concentration is measured in both the atmosphere and in the water.

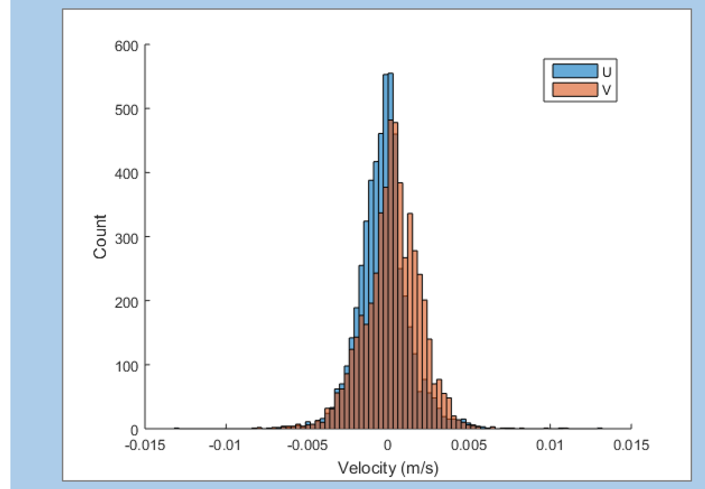


Figure 5: Histogram of water velocity measured with the underwater camera in the field on July 29th, 12:31 PM (CST). The average U velocity was -2.8 $10^{-4} \pm 1.57\ 10^{-3}$ m/s. The average V velocity was 2.7 $10^{-4} \pm 1.72\ 10^{-3}$ m/s.

Discussion

The percent contribution is the methane flux from hydrodynamic transport divided by the total flux (Figure 6). The percent contribution at night was between 0.96% to 8.31% on August 2nd and August 3rd.

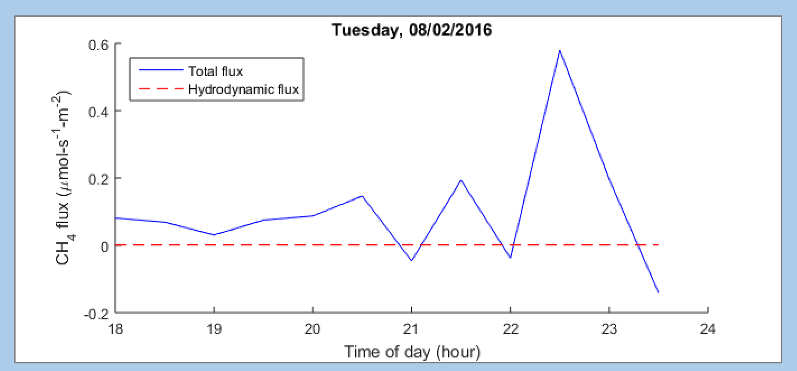


Figure 6: Hourly total flux of methane concentrations and calculated flux from hydrodynamic transport on August 2nd. The gas transfer velocity was equal to 2.78 10^{-6} m/s. The total flux was measured with eddy covariance towers on site.

Air-side Measurement
Flux Gradient Method

Determines flux by measuring the concentration gradient close to the air-water interface (Figure 7) and inferring turbulent diffusivity using wind data (Figure 8)

Must partition flux into different transport processes

$$J = -K_T \frac{\partial C}{\partial Z}$$

Turbulent diffusivity

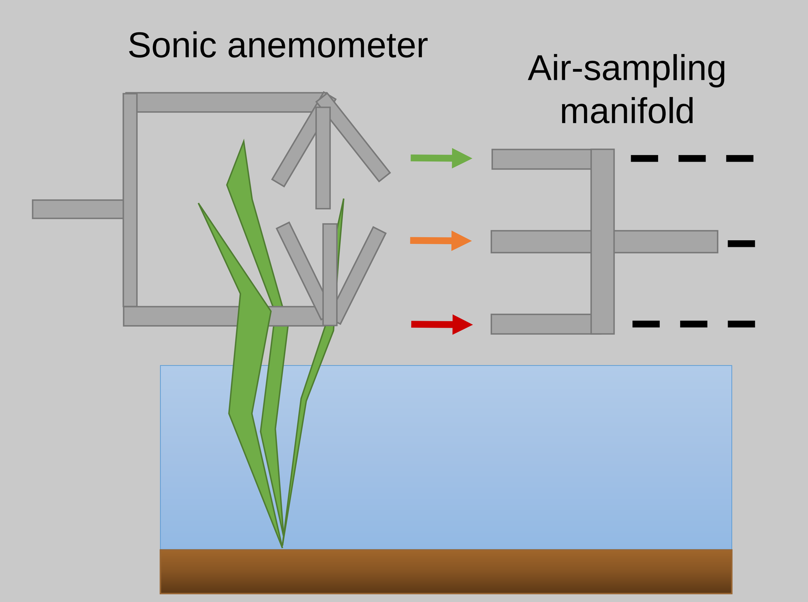


Figure 7: Sampling set-up for flux gradient method

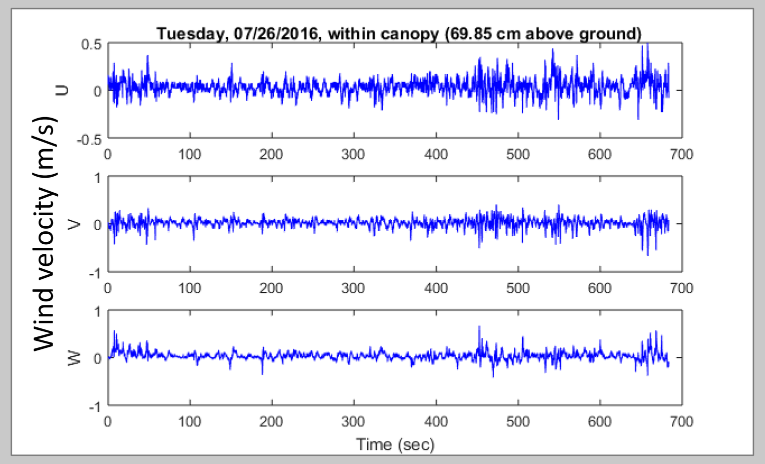


Figure 8: Time series of wind velocity in x, y, and z directions. Measurements were taken within the canopy at a height of 69.85 cm above the ground.

Discussion

At the 95% confidence level, there was not a statistically significant difference in mean methane concentration between the three heights measured (Figure 9, 10).

The concentration gradient was too small to measure, which meant the flux from hydrodynamic transport could not be measured.

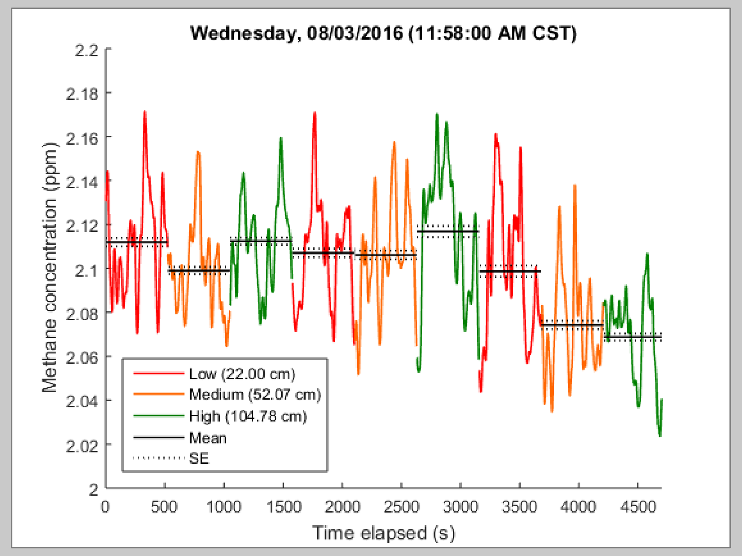


Figure 9: Time series of methane concentrations at three different heights

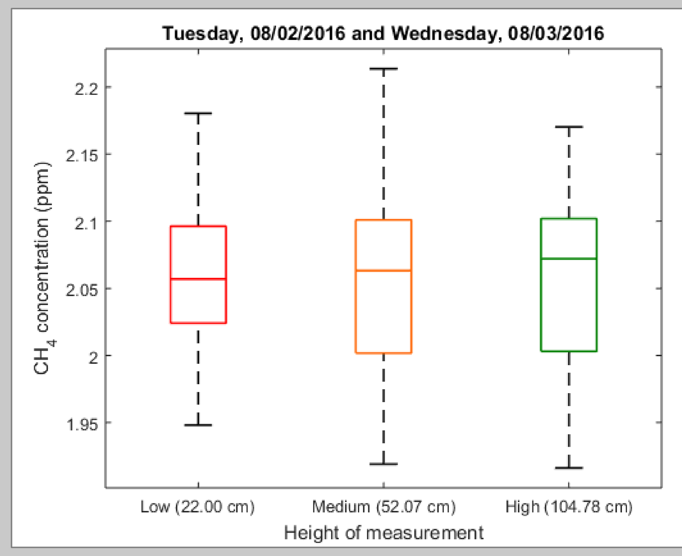


Figure 10: Box plot of methane concentrations at three different heights

Conclusion

The contribution of hydrodynamic transport to methane flux was low at this site during the nighttime. However, in terms of precipitation and water depth, the measurement period was not representative of a typical growing period of rice in this area. Further measurements in the field, over a period of weeks, should be accomplished using the thin-film technique.

References

Han, W., Yang, Z., Di, L., Yue, P., 2014. A geospatial Web service approach for creating on-demand Cropland Data Layer thematic maps. Trans. ASABE 57, 239–247. doi:10.13031/trans.57.10020