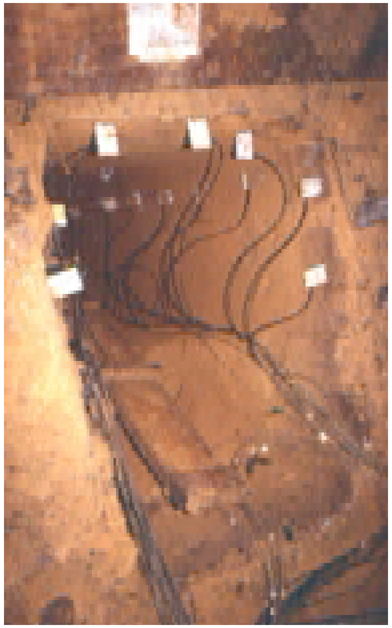
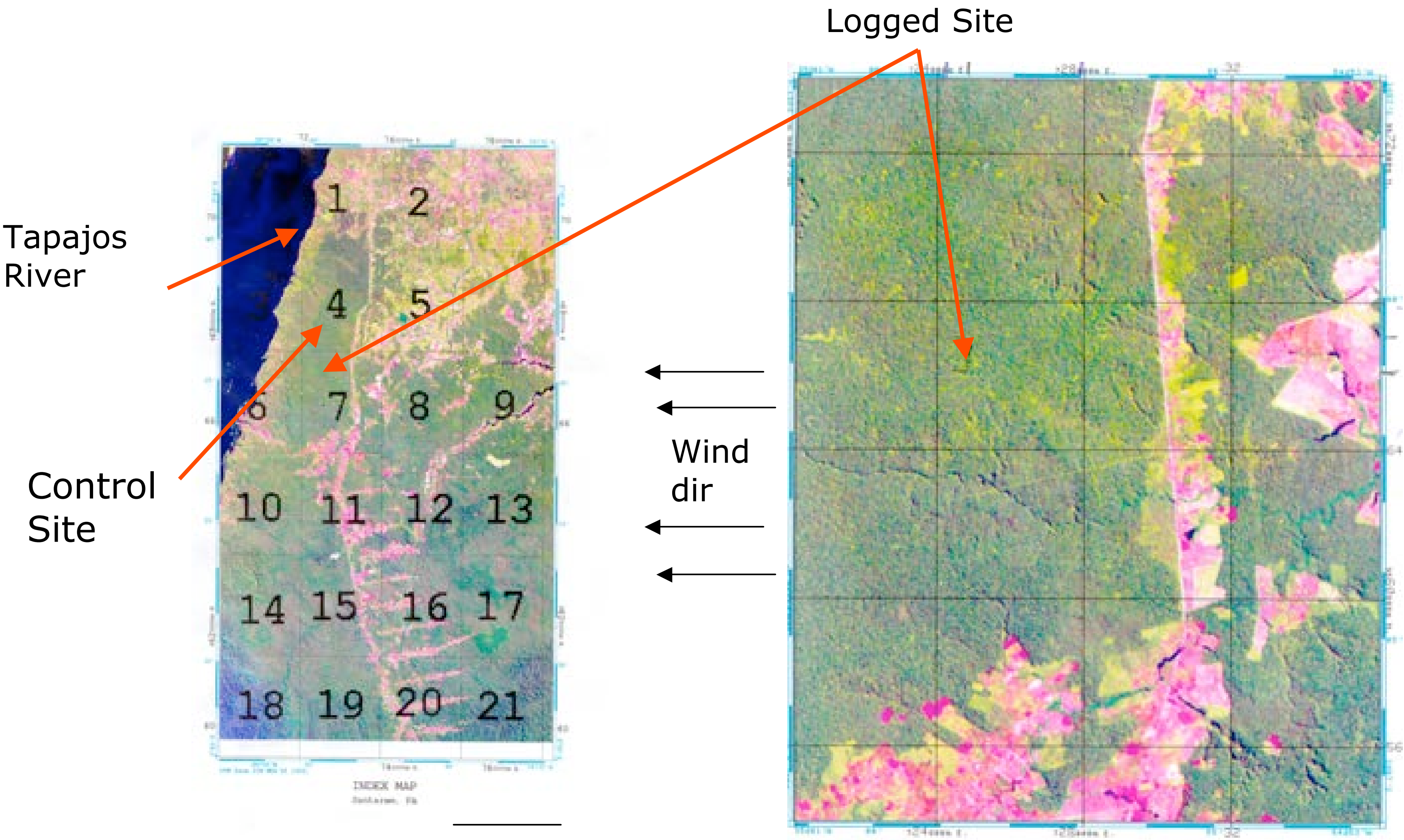
The Effects of Selective Logging on Tropical Forest-Atmosphere Exchange



Scott Miller, SUNY Albany


Logged Site
Tapajos River
Control Site
Wind dir
1 2
4 5
6 7 8 9
10 11 12 13
14 15 16 17
18 19 20 21
INDEX MAP

How is the physics of forest-atmosphere exchange affected by canopy gaps?

•increased subcanopy ventilation? flamability

•Does transport occur preferentially out of the gaps? flux bias

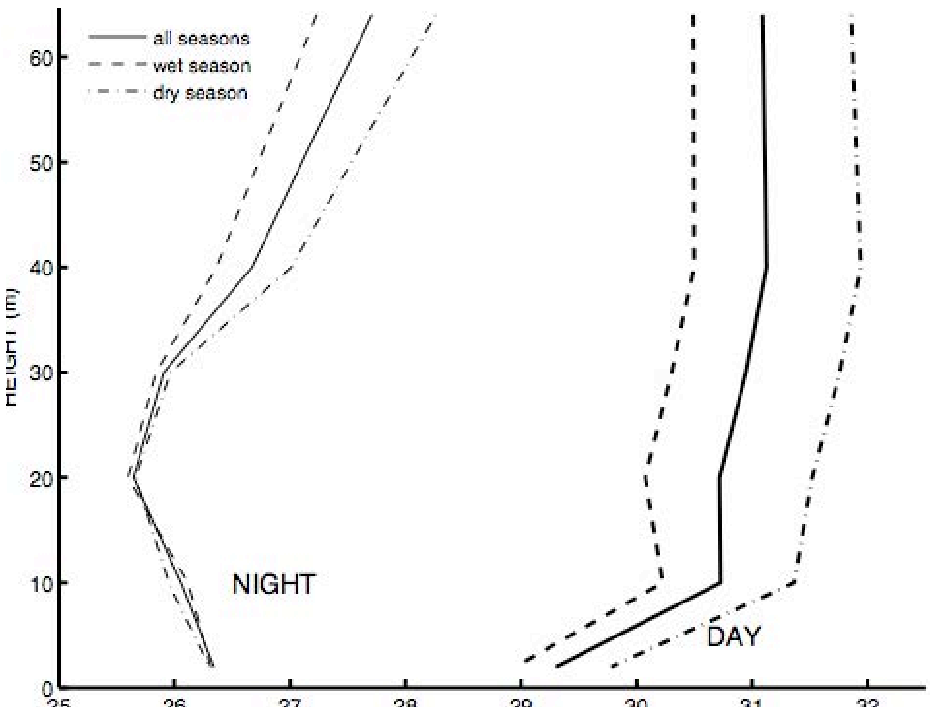
note: few relevant field data sets

Subcanopy-atmosphere coupling

- temperature gradients can increase (daytime) or decrease (nighttime) vertical mixing
- forest canopy can also affect mechanical mixing across canopy layer by damping penetration of turbulence into subcanopy
- canopy removal effects both of these processes

intact forest

height



virtual potential temperature

unstable

canopy layer

stable

paired-tower measurements

400 m

tower measurements

CO_2,H_2O profile (0.1-64 m)

CO_2,H_2O,H_S,H_L flux

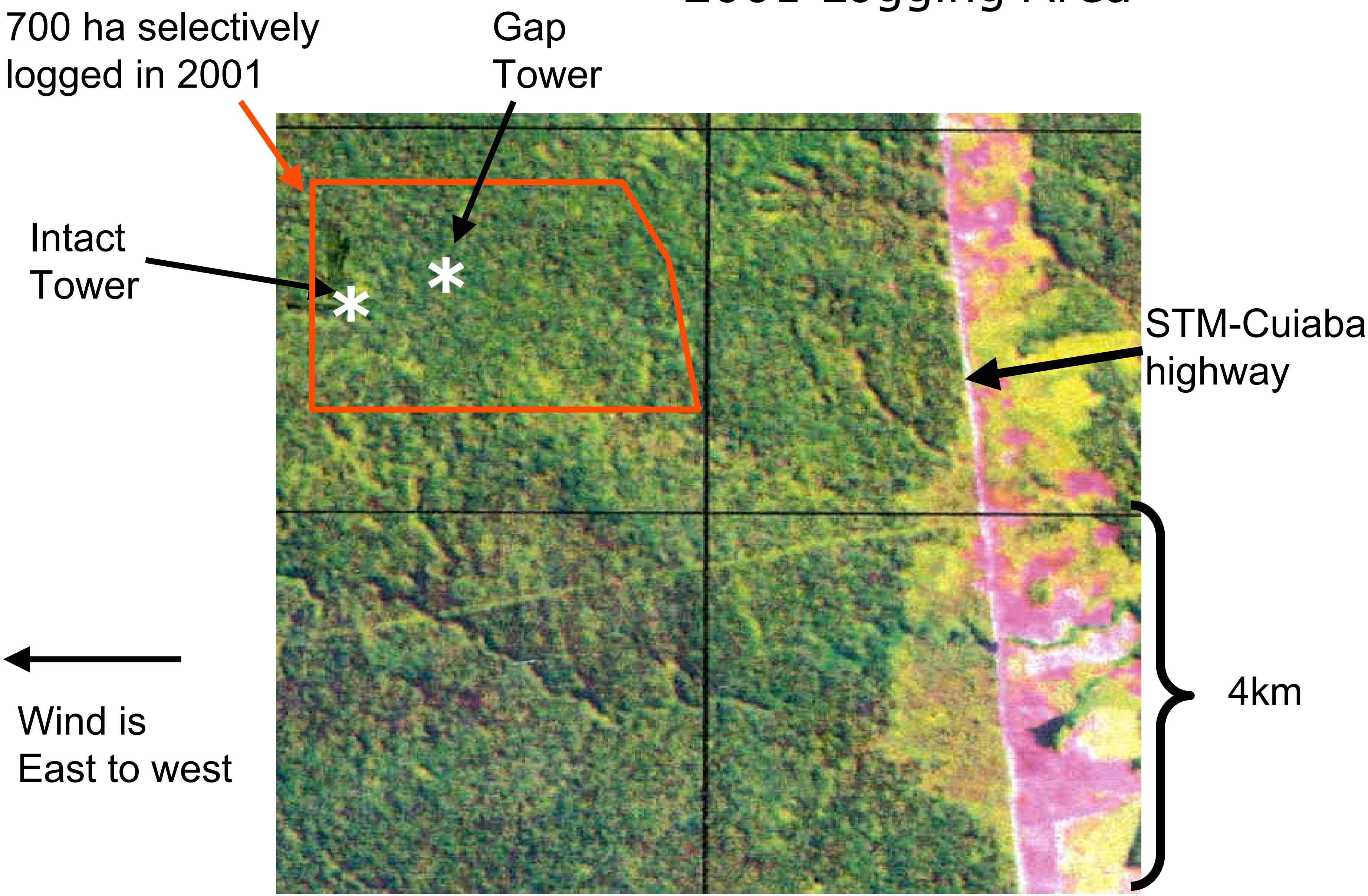
installed in intact area within logged site

operated from 1 year before logging
until 2.5 years after logging

persistent gap due to 0.5 m
thick laterite cap

operated from 6 months after
logging for ~ 2 years

2001 Logging Area

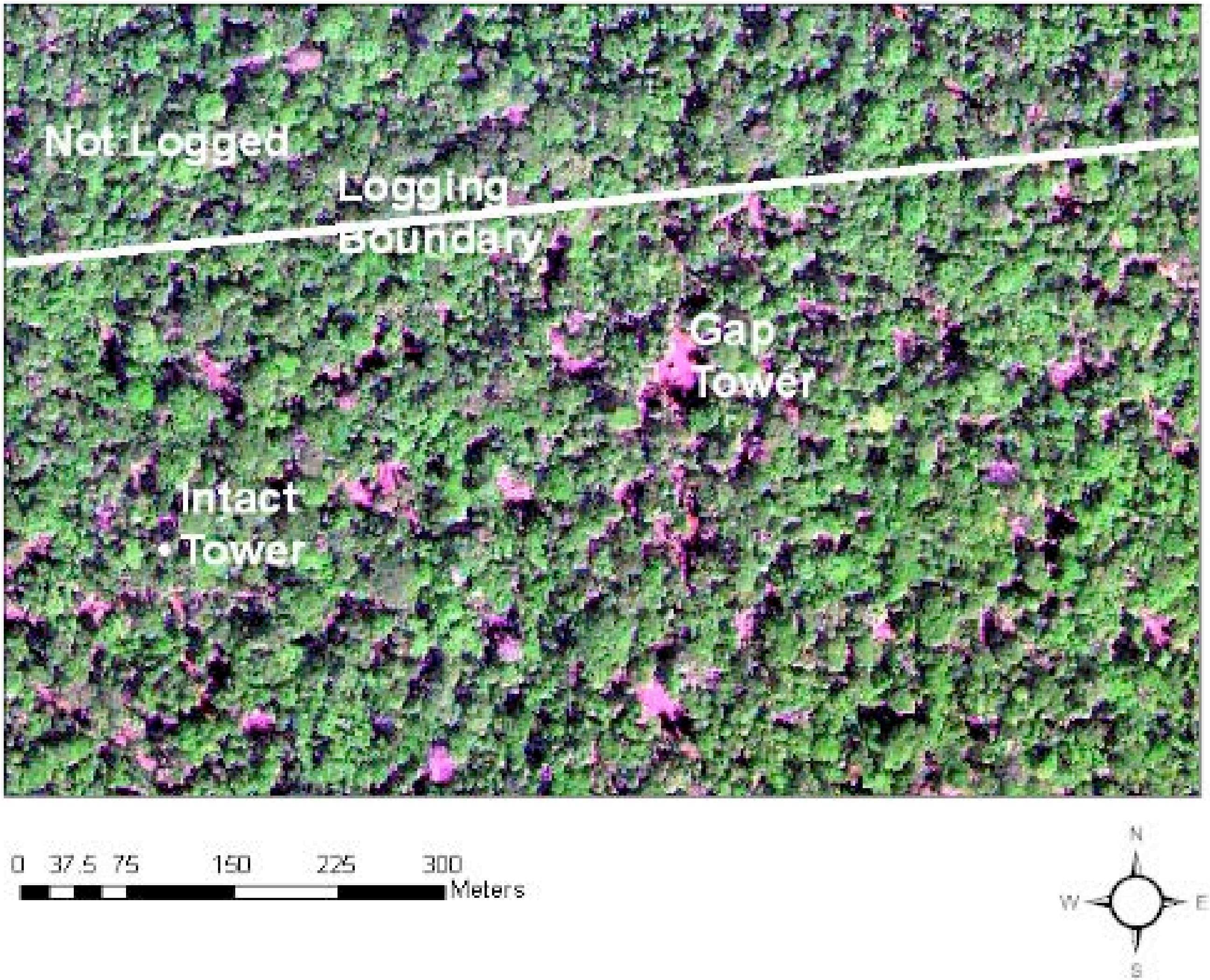


low percentage of canopy removal

•4% gaps unlogged area

•12% gaps in logged area

FIGURE 1a

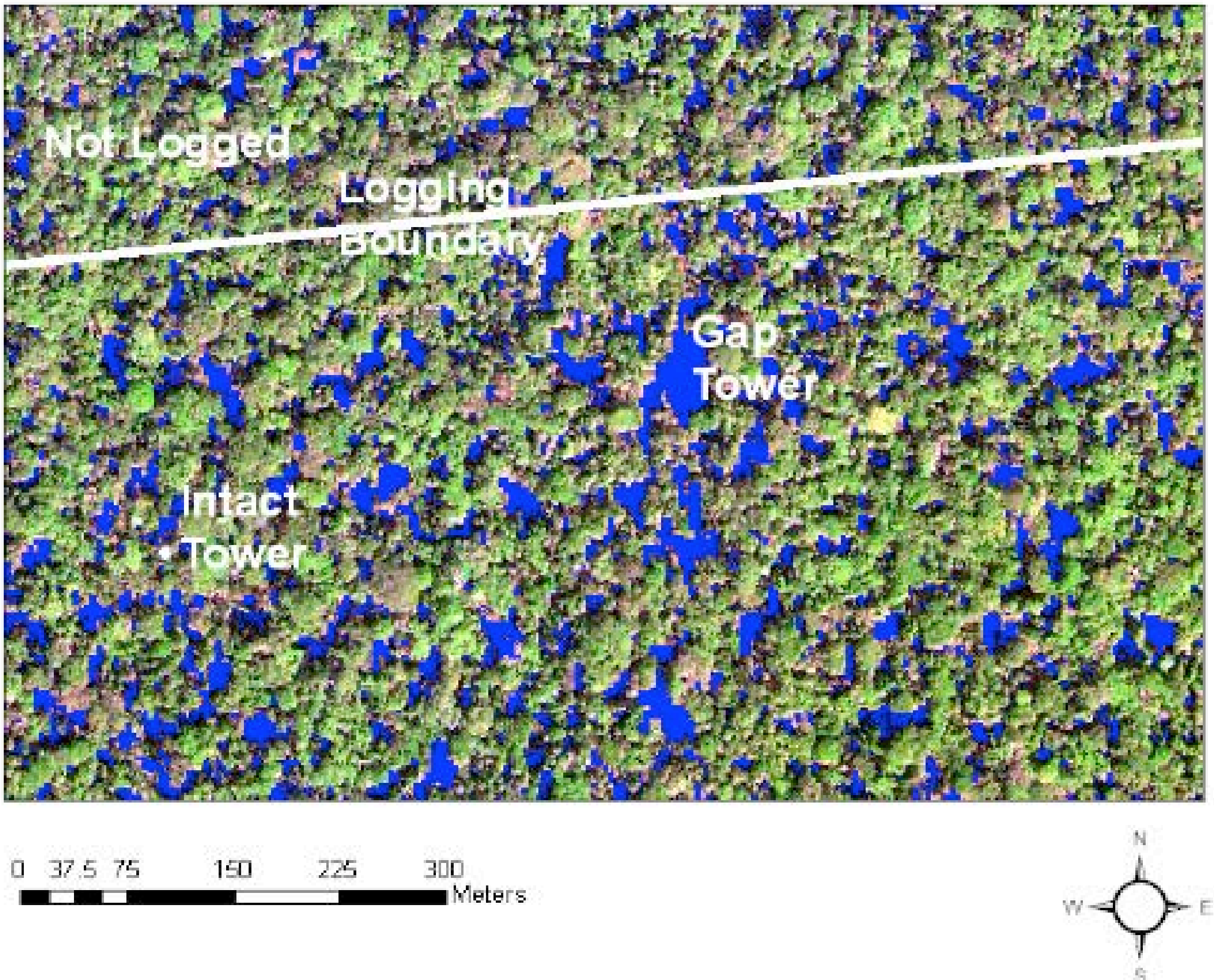


low percentage of canopy removal

- 4% gaps unlogged area
- 12% gaps in logged area

FIGURE 1b

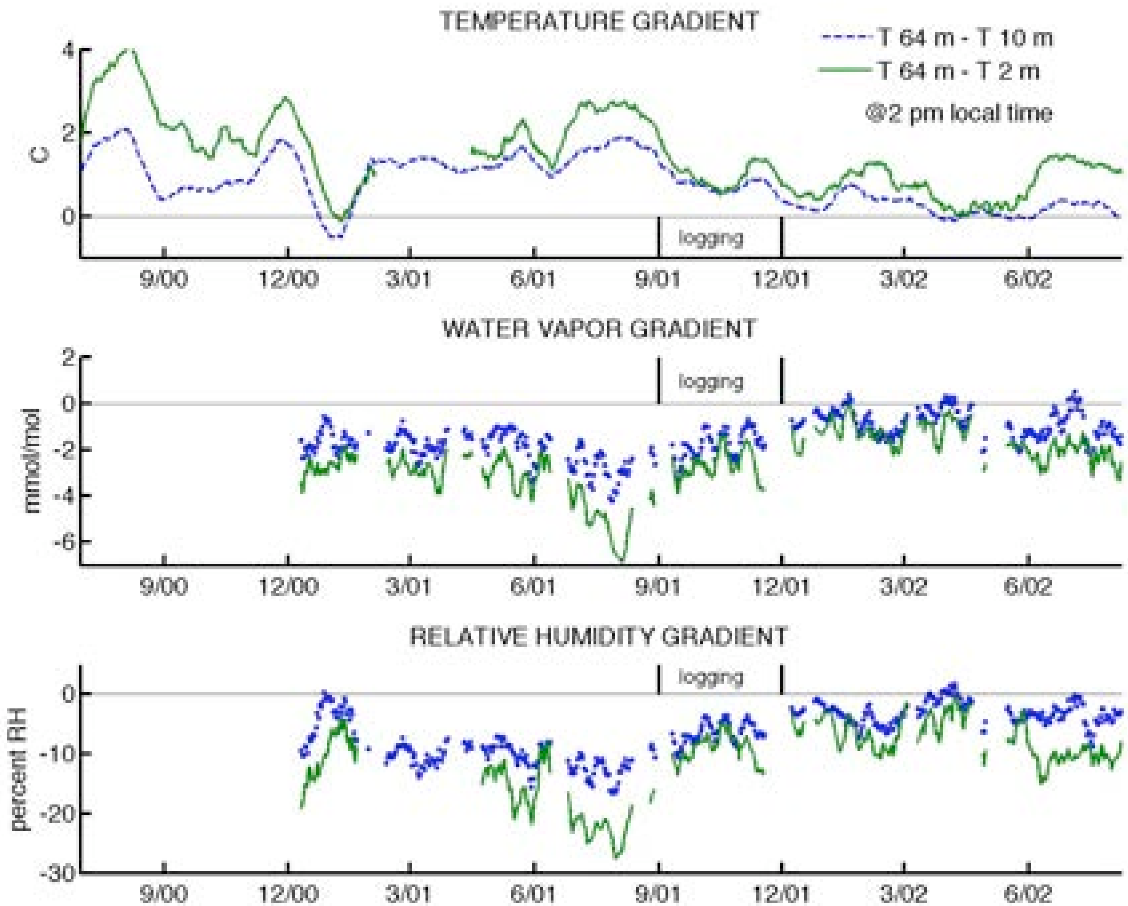
blue areas NDVI<0.4



Subcanopy-microclimate at intact area (single tower)

•after logging, daytime subcanopy airspace warmer and drier - increased ventilation

•relative humidity in subcanopy decreased ~10% - increased flamability (e.g., Uhl and Kauffman 1990, Nepstad 1999, Laurance 2004)



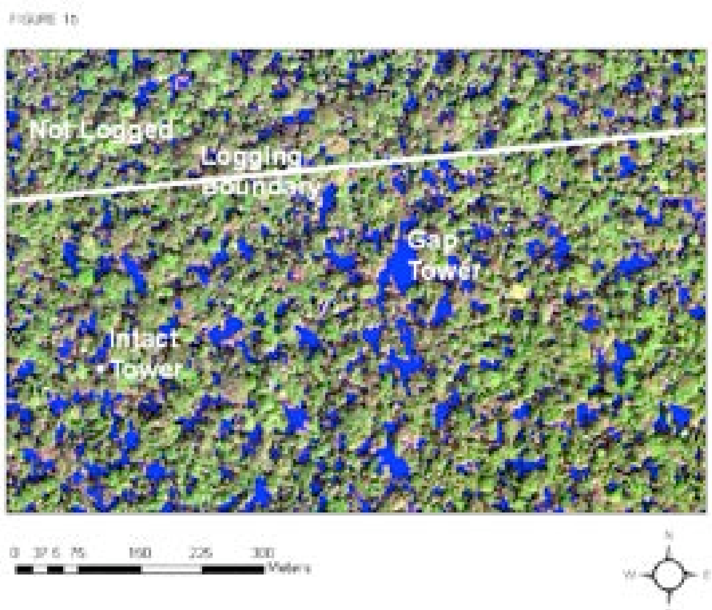
Contributions to Tower Footprint

footprint defines the source area contributing to a measured flux, generally dependent on stability, canopy "roughness", measurement height

separate canopy gap effect on footprint into two parts:

1. upwind gap effect - caused by the many gaps distributed upwind of a tower

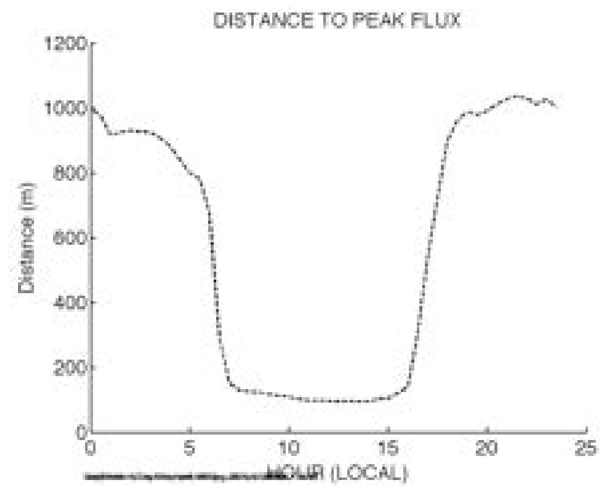
2. near-gap effect - caused by the presense of the the single large gap in which the gap tower was located



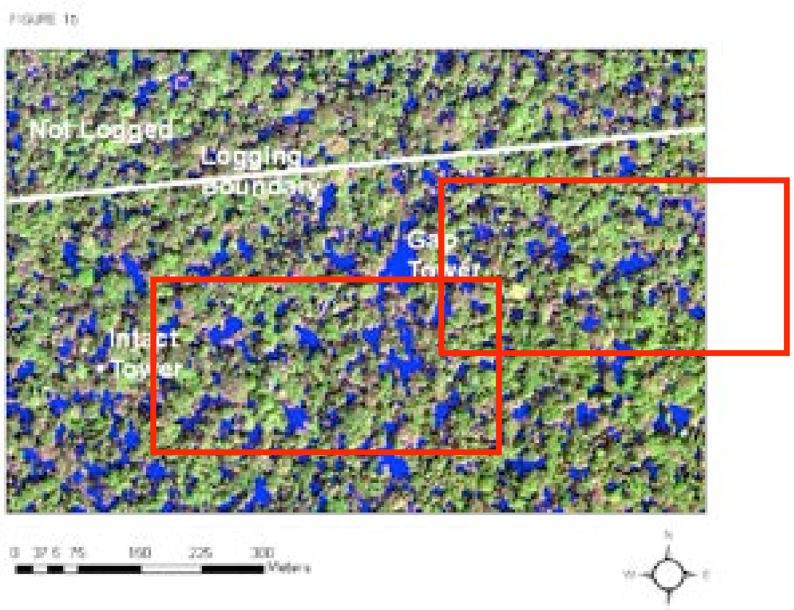
Analysis of upwind-gap areas

daytime peak contribution to flux **of order** 100 m upwind of tower

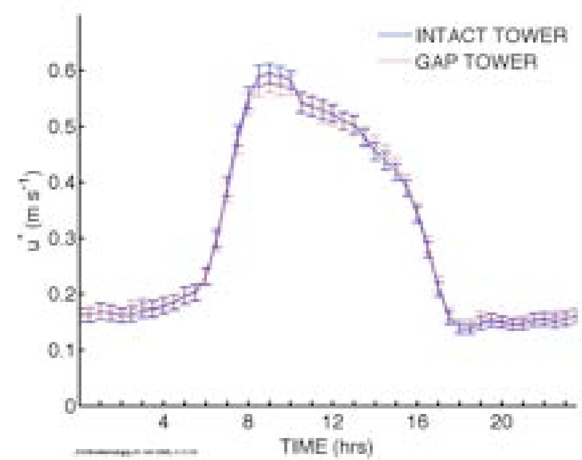
homogeneous footprint model (Hsieh et al, 2001)



canopy gap fraction in 400 m X 200 m area upwind of two towers was similar (~12%, red rectangles)



comparison of momentum flux (related to canopy roughness) also suggests that upwind-gap areas were aerodynamically similar



Near-Gap Contribution to flux

contributions close to a tower are poorly understood - current footprint models cannot handle complex surfaces

Some results suggest that the area very near to a tower can contribute significantly to turbulent flux

homogeneous canopy (Rannik, 2000)

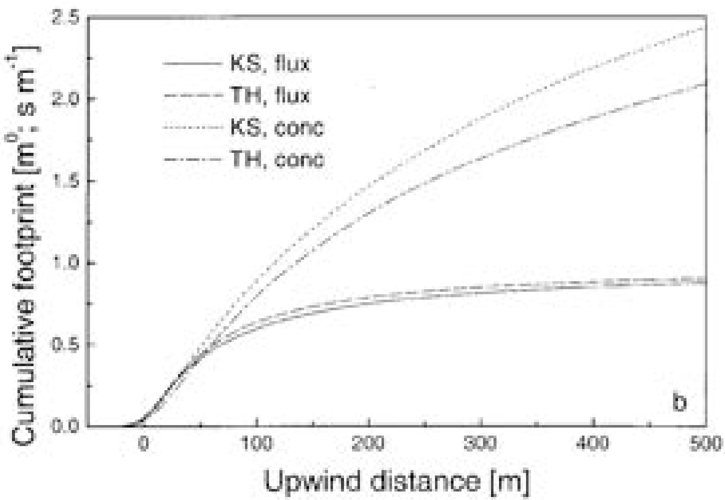
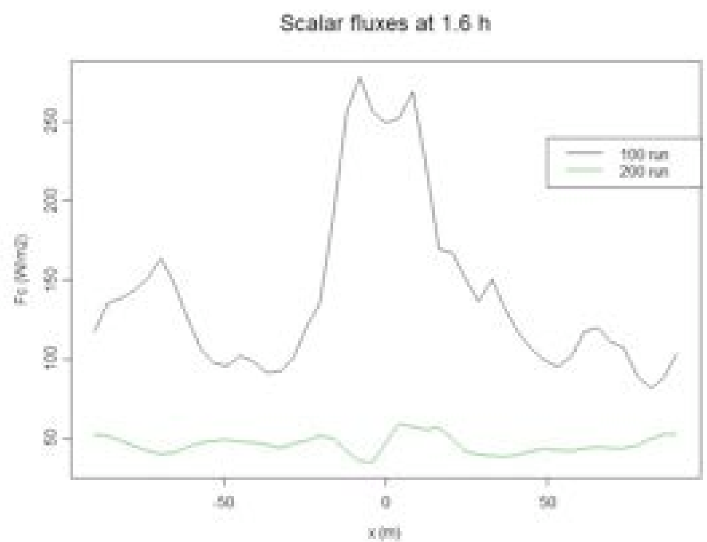


Figure 1b.

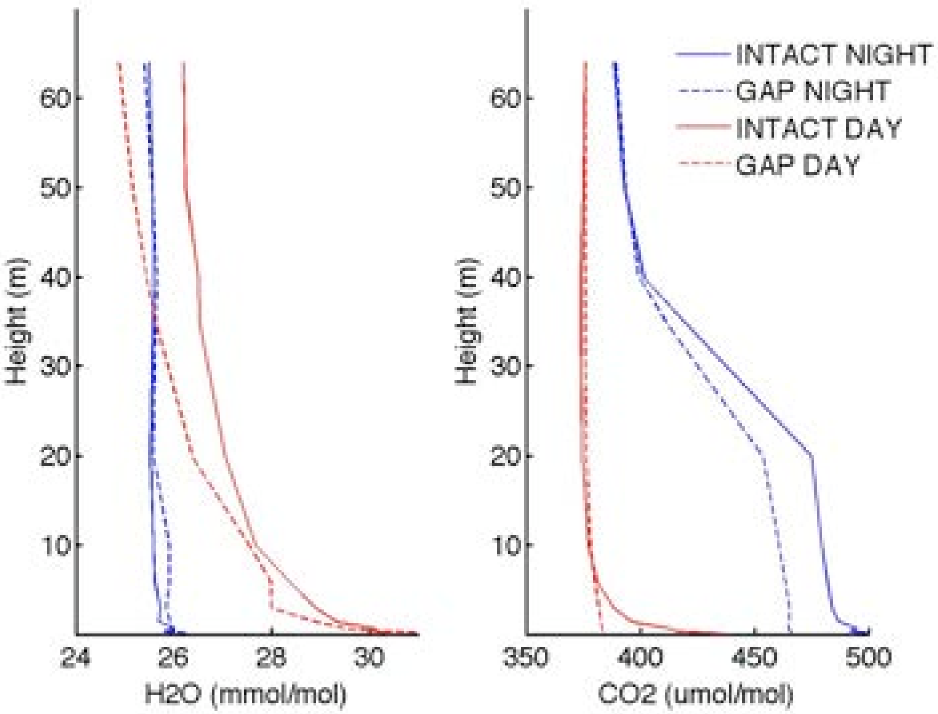
canopy gap (Acevedo, 2000)

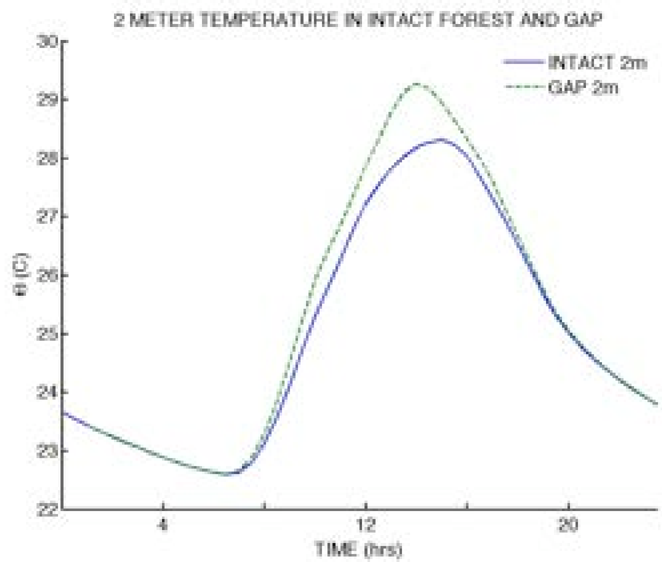


based on similarity in upwind areas, and evidence that near-tower areas can contribute to flux footprint we conclude that the gap tower likely can “see” the gap in which it is located

CO_2/H_2O profiles at intact and gap towers

- lack of canopy results in less CO_2 drawdown, less water vapor than intact area.
- near surface concentrations of CO_2/H_2O in intact area high relative to gap
- Nearby gap surface temperature (2m) was warmer than same level in intact area



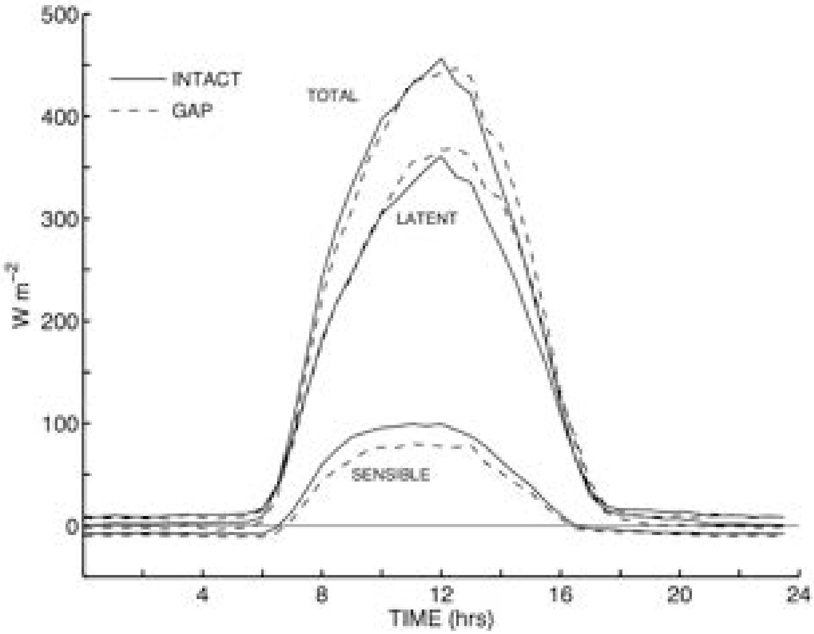


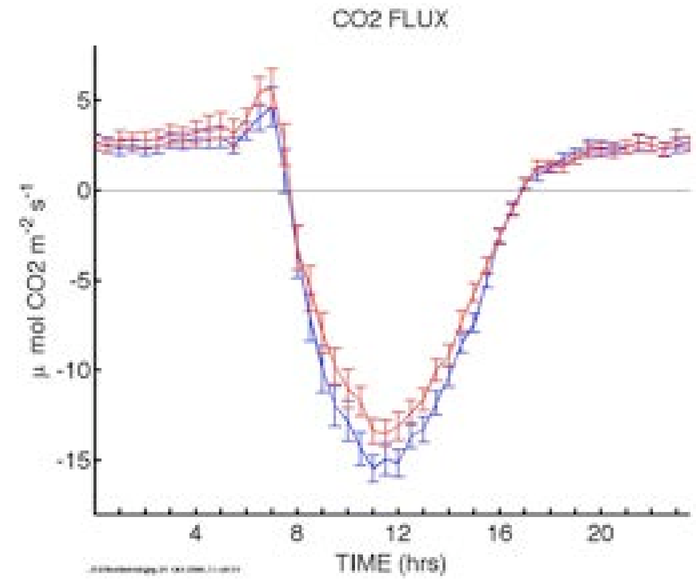
loss of canopy effect, would “expect” daytime:

- less CO_2 uptake above the gap
- less H_2O flux above gap
- more heat flux above gap

Energy flux differences opposite to canopy loss...

•more latent heat flux above gap
•less sensible heat flux above gap





CO2 flux difference consistent with canopy loss, **but** also consistent with increased respiration flux out the gap is also consistent

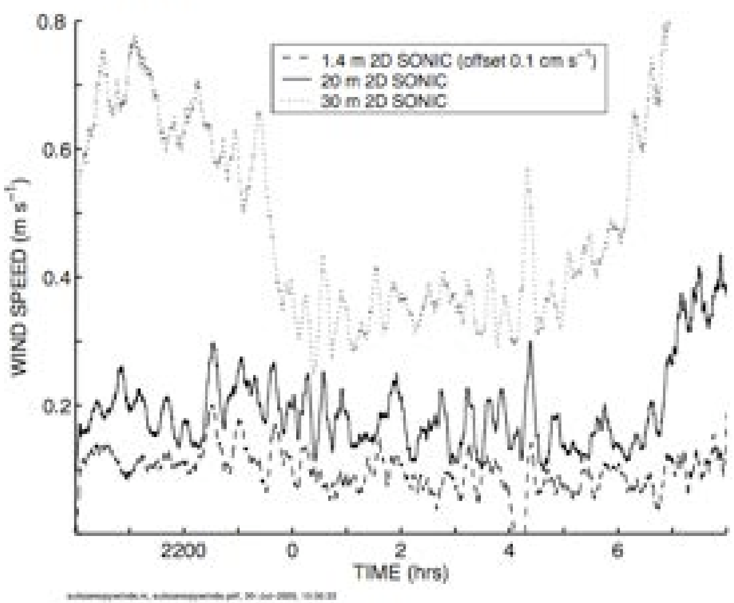
taken together, the between tower co2/h2o and heat flux differrences are consistent with transport of subcanopy air out the gap

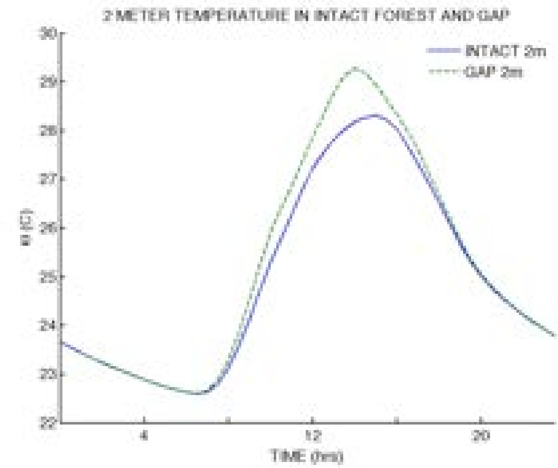
Mechanisms that could facilitate venting

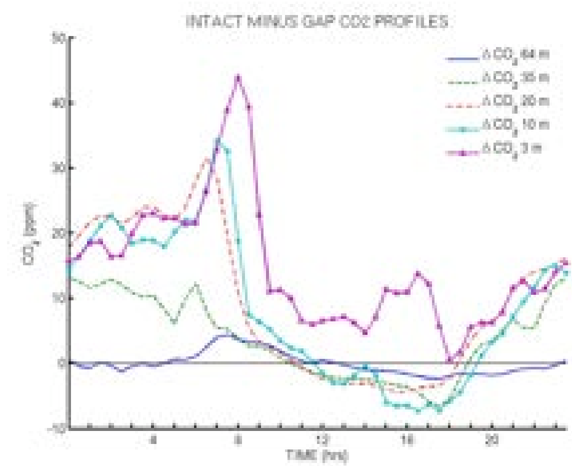
subcanopy winds transport CO2 into gaps

warmer gap near-surface temperature

FIGURE 8







The lack of canopy above gap also facilitates wind penetration into subcanopy (eg morning flush)

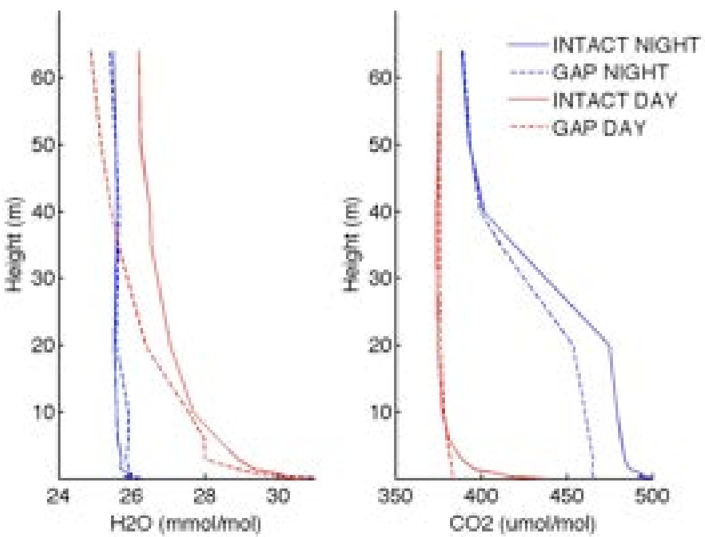
Daytime Flux/Gradient ratios

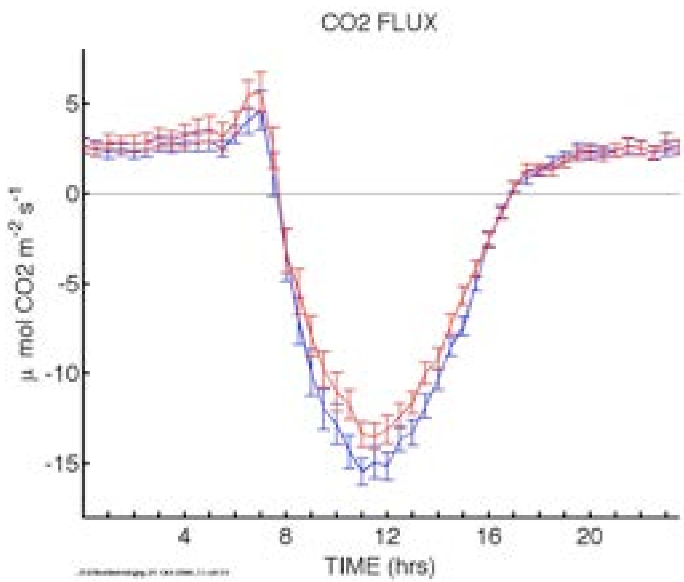
•"exchange coefficients" calculated as (FLUX DIFFERENCE)/GRADIENT

co2 flux difference: 1.8 umol/m2/s
co2 gradient subcanopy layer of intact to gap tower top: 8.1 ppm
co2 flux/gradient ratio: 0.006 m/s

h2o flux difference: 0.47 mmol/m2/s
h2o gradient subcanopy layer of intact to gap tower top: 2.4 mmol/mol
h2o flux/gradient ratio: 0.005 m/s

•similarity of this ratio for CO2/H2O when using gradient between *subcanopy of intact area and gap tower top* is consistent with a subcanopy contribution to flux difference

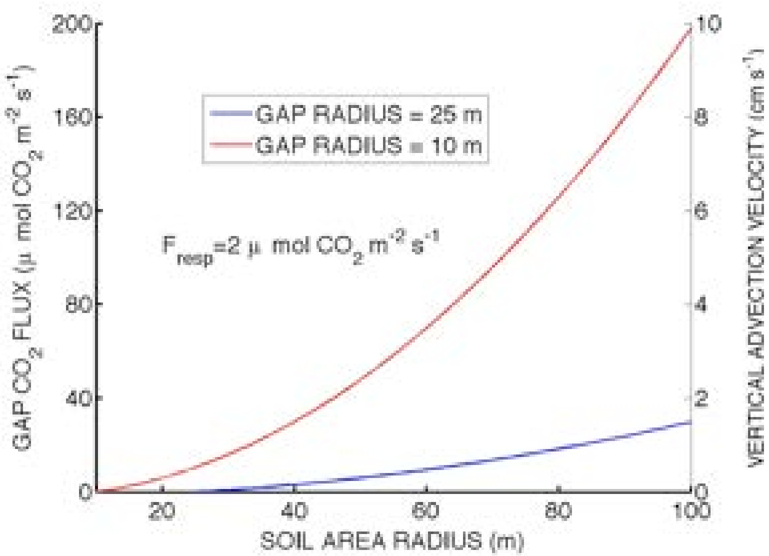




rough venting flux estimates

1. soil respiration

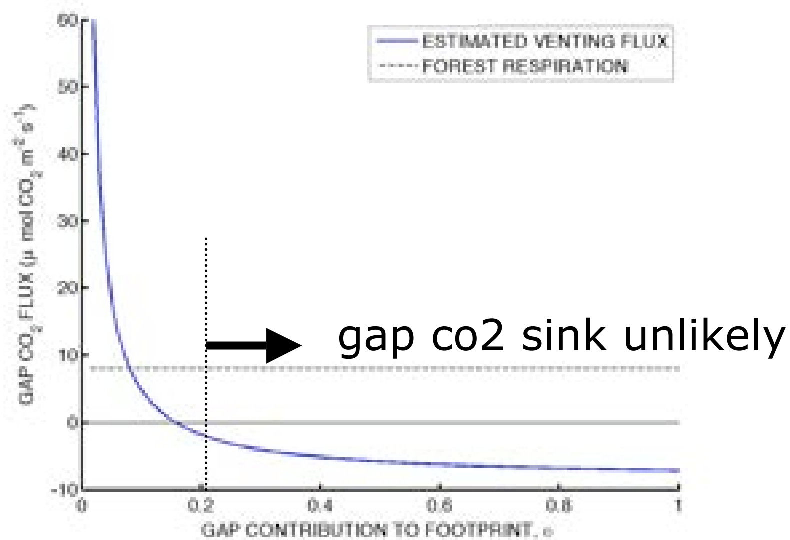
$$F_{VENTING} = F_{RESP}\left(\frac{r^2}{R_G^2} - 1\right)$$



2. flux differences

$$F_{GAP,MEAS} = (1-\alpha)F_{INTACT} + \alpha F_{VENTING}$$

α = fraction of footprint carried by gap



- potential for large fluxes
- high sensitivity to contribution of gap to footprint

more understanding of the contribution of the gap to the flux footprint is required.

ways forward

•Measurements of 3D flow to capture horizontal CO_2 advection into gap, and upward advection through gap (modified DRAINO)

•modeling of forest/atm exchange for complex canopies (eg, Acevedo)

Conclusions

•Even for small amount of canopy removal the subcanopy was warmer and more dry after logging

•flux and profile measurements consistent with preferential venting of subcanopy air upward through canopy gaps, though magnitude of flux uncertain

•field data set to stimulate further measurement, modeling efforts

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