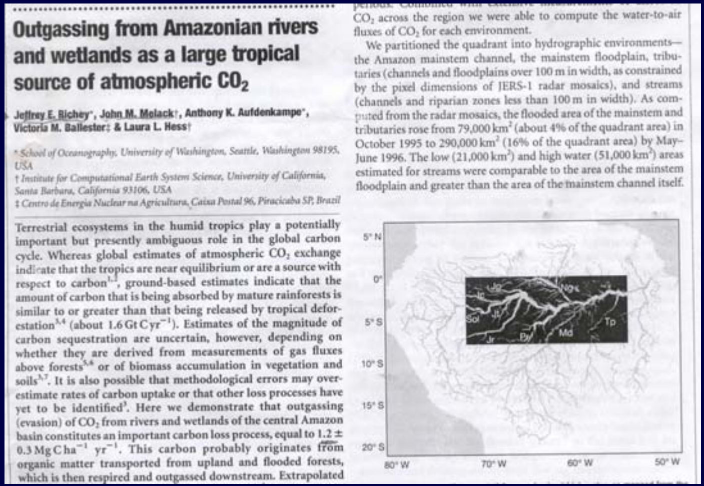
Boat-Based Eddy Covariance Measurements of CO_2 Exchange Over Amazon and Tapajos Rivers and Lakes

UC IRVINE: SCOTT MILLER, ED READ, CHRIS DOUGHTY, MIKE GOULDEN
USP: HELBER FREITAS , HUMBERTO DA ROCHA

Motivation for measuring river-air CO2 exchange

Richey et al, April 2002, Nature Letter



Outgassing from Amazonian rivers and wetlands as a large tropical source of atmospheric CO_2

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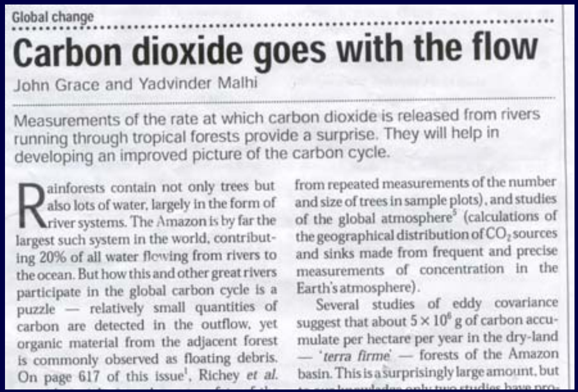
Terrestrial ecosystems in the humid tropics play a potentially important but presently ambiguous role in the global carbon cycle. Whereas global estimates of atmospheric CO_2 exchange indicate that the tropics are near equilibrium or are a source with respect to carbon[1,2], ground-based estimates indicate that the amount of carbon that is being absorbed by mature rainforests is similar to or greater than that being released by tropical deforestation[3,4] (about 1.6 Gt C yr^{-1}). Estimates of the magnitude of carbon sequestration are uncertain, however, depending on whether they are derived from measurements of gas fluxes above forests[5,6] or of biomass accumulation in vegetation and soils[3,7]. It is also possible that methodological errors may overestimate rates of carbon uptake or that other loss processes have yet to be identified[3]. Here we demonstrate that outgassing (evasion) of CO_2 from rivers and wetlands of the central Amazon basin constitutes an important carbon loss process, equal to 1.2 ± 0.3 Mg C ha^{-1} yr^{-1}. This carbon probably originates from organic matter transported from upland and flooded forests, which is then respired and outgassed downstream. Extrapolated

... CO_2 across the region we were able to compute the water-to-air fluxes of CO_2 for each environment.

We partitioned the quadrant into hydrographic environments—the Amazon mainstem channel, the mainstem floodplain, tributaries (channels and floodplains over 100 m in width, as constrained by the pixel dimensions of JERS-1 radar mosaics), and streams (channels and riparian zones less than 100 m in width). As computed from the radar mosaics, the flooded area of the mainstem and tributaries rose from 79,000 km^2 (about 4% of the quadrant area) in October 1995 to 290,000 km^2 (16% of the quadrant area) by May–June 1996. The low (21,000 km^2) and high water (51,000 km^2) areas estimated for streams were comparable to the area of the mainstem floodplain and greater than the area of the mainstem channel itself.

Grace and Malhi, Nature News & Views



Global change

Carbon dioxide goes with the flow

John Grace and Yadvinder Malhi

Measurements of the rate at which carbon dioxide is released from rivers running through tropical forests provide a surprise. They will help in developing an improved picture of the carbon cycle.

Rainforests contain not only trees but also lots of water, largely in the form of river systems. The Amazon is by far the largest such system in the world, contributing 20% of all water flowing from rivers to the ocean. But how this and other great rivers participate in the global carbon cycle is a puzzle — relatively small quantities of carbon are detected in the outflow, yet organic material from the adjacent forest is commonly observed as floating debris. On page 617 of this issue[1], Richey *et al.* ...

... from repeated measurements of the number and size of trees in sample plots), and studies of the global atmosphere[5] (calculations of the geographical distribution of CO_2 sources and sinks made from frequent and precise measurements of concentration in the Earth's atmosphere).

Several studies of eddy covariance suggest that about 5×10^6 g of carbon accumulate per hectare per year in the dry-land — '*terra firme*' — forests of the Amazon basin. This is a surprisingly large amount, but ...

connection to tower-based NEE results of large CO_2 uptake?

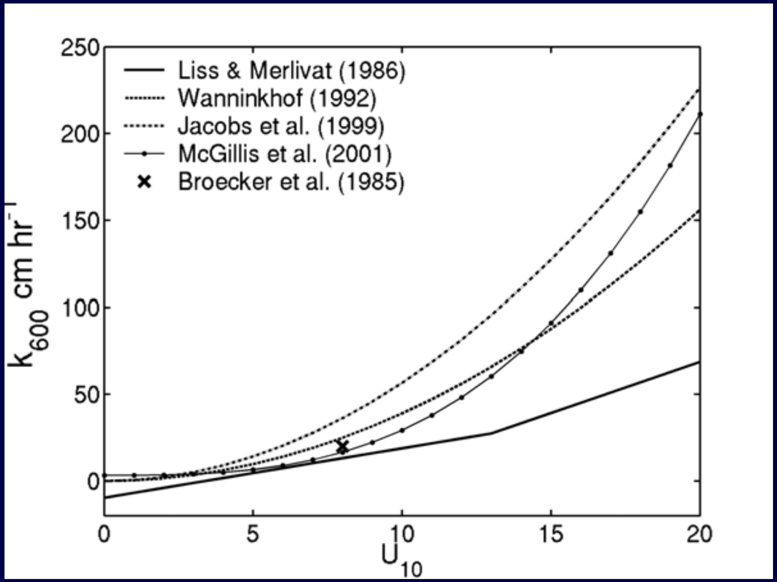
River-Atmosphere flux ~ 1.2 T C ha^{-1} yr^{-1}

Forest NEE ~ 1-2 T C ha^{-1} yr^{-1}

Opportunity →

Estimating river-air CO_2 flux, F_C

Piston Velocity verus Wind Speed



$$F_c = k\left(\mathrm{pCO}_{2w} - \mathrm{pCO}_{2a}\right)$$

$k =$ piston velocity (cm hr^{-1})

$\mathrm{pCO}_{2w} =$ water-side CO_2 partial pressure

$\mathrm{pCO}_{2a} =$ air-side CO_2 partial pressure

1. Typically, the air-water CO2 gradient is measured and the piston velocity, ***k*** is parameterized.

2. ***k*** is (at least) wind speed dependent (linear?, quadratic?, cubic?)

Methods to "measure" piston velocity, *k*

1. **chambers** (small scales, order 1 m)

   PRO: local measure of flux, short time scale

   CON: chamber disturbs airflow

2. **tracer** techniques (larger scales, order 10^3 km)

   PRO: integrated measurement

   CON: coarse resolution

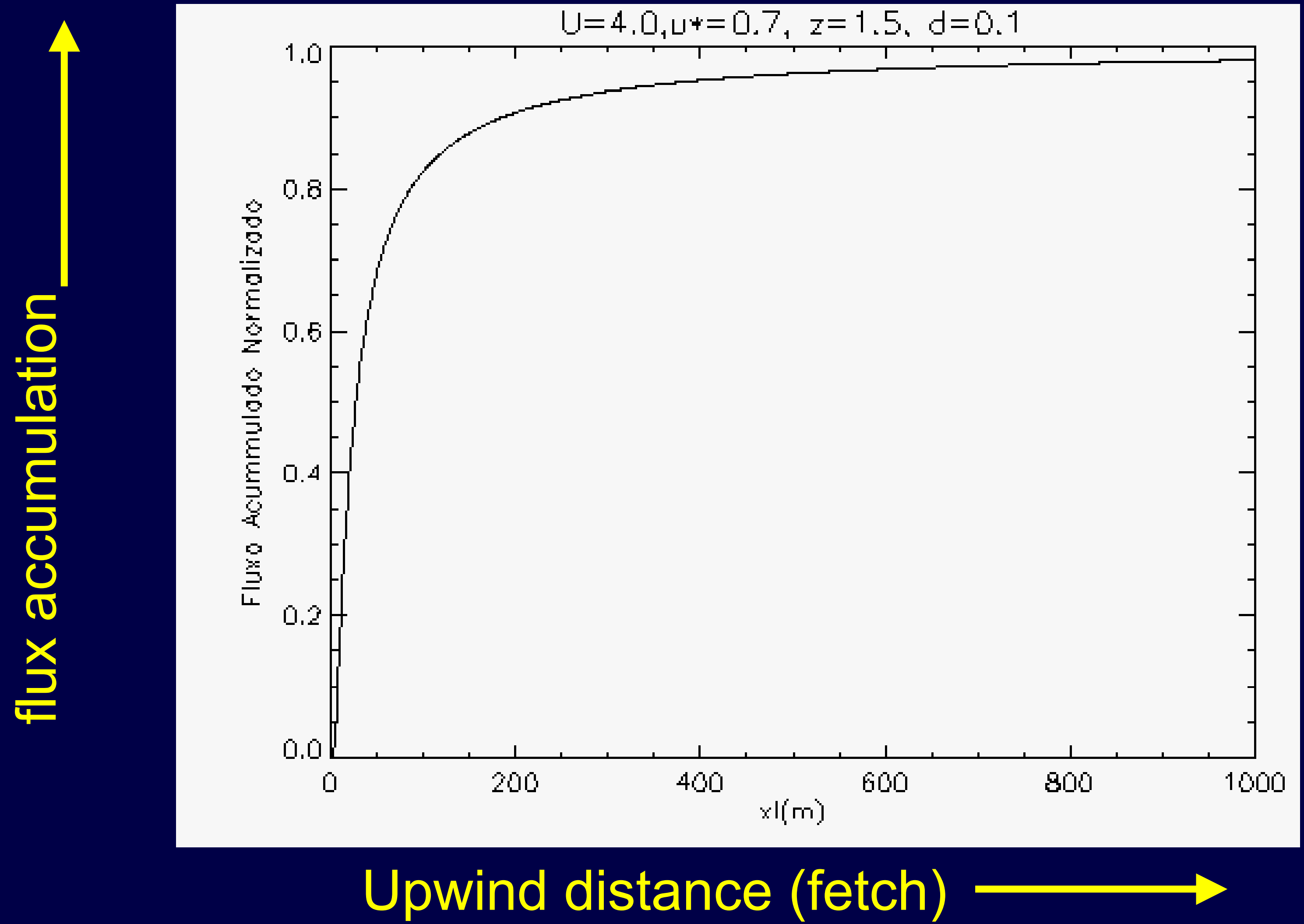
3. **eddy covariance** (intermediate scales, order 10^2 m)

   PRO: good time resolution, direct flux

   CON: relatively small fluxes, flux footprint, motion corrections, density corrections

Flux Footprint

For U=4m/s, z=1.5 m, 90% of flux with 200m fetch.



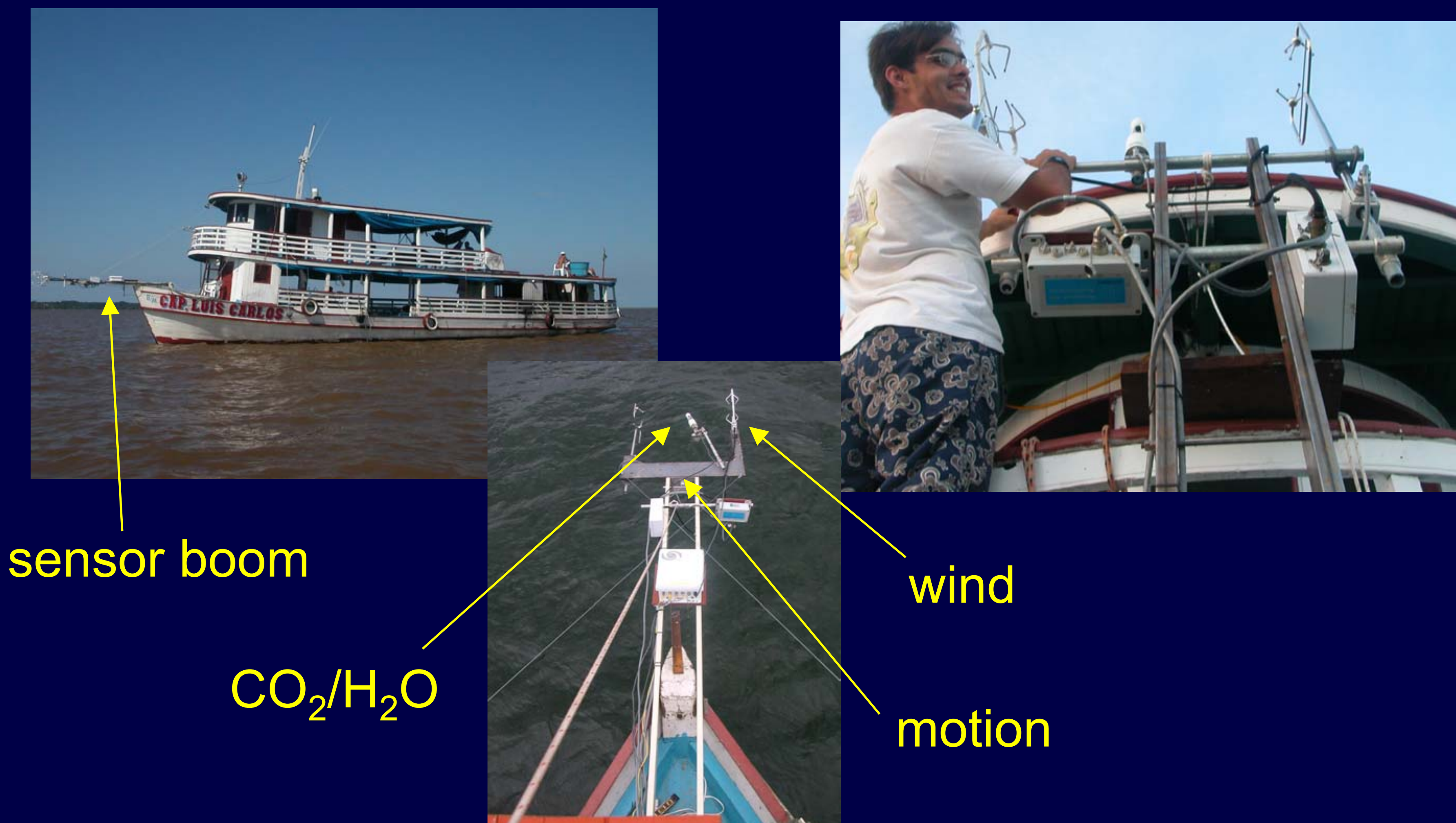
Goals: Direct measurements of CO_2 flux using eddy covariance, and air-water CO_2 gradient

1. Calculate ***k*** from direct measurements

$$k = \frac{F_c}{\text{pCO}_{2w} - \text{pCO}_{2a}}$$

2. Compare simultaneous eddy covariance and chamber-based estimates of ***k***

Air-side CO_2 and H_2O Flux Measurement



Water-side pCO_2 Measurement

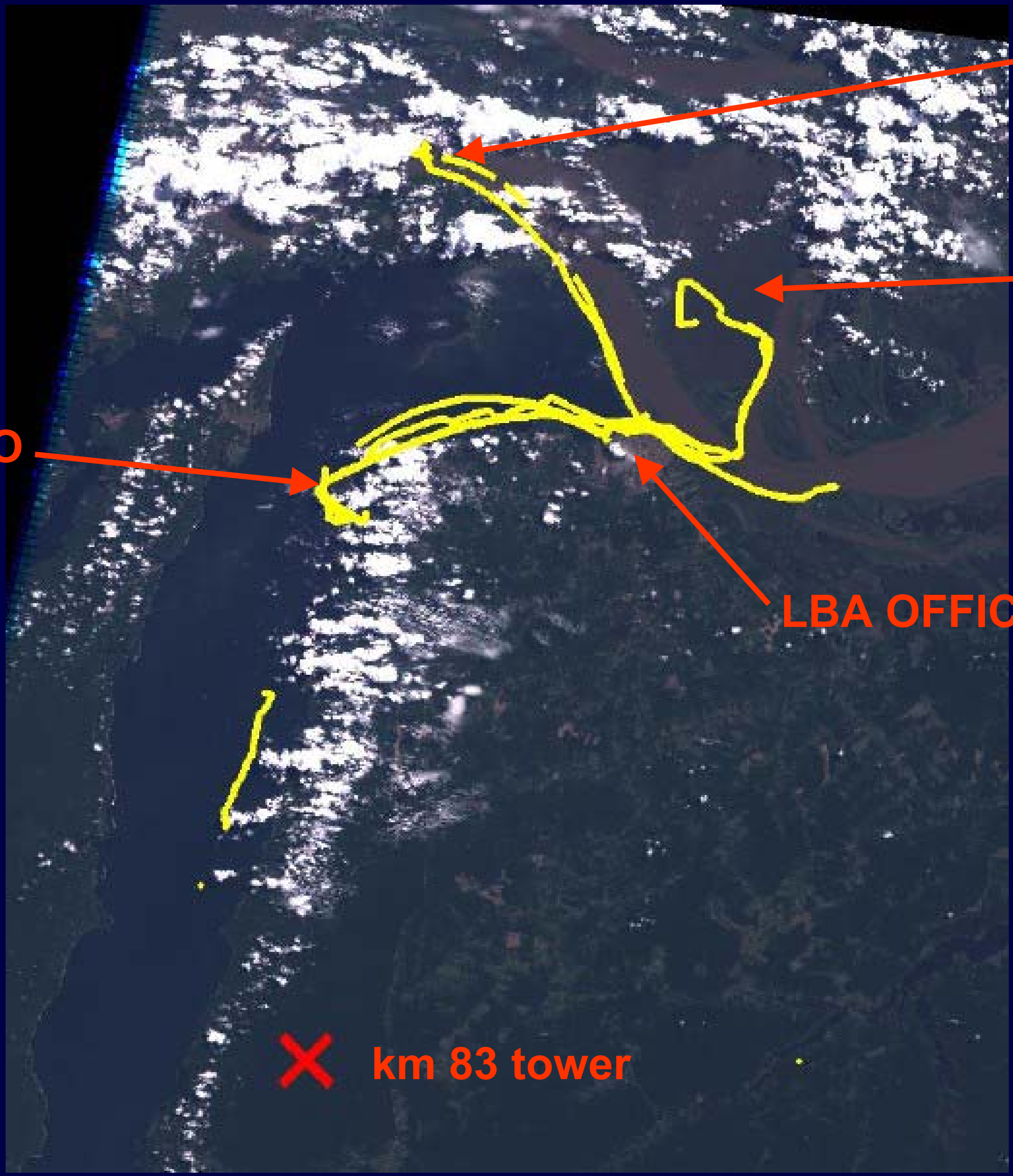
Teflon tubing equilibrator

shower head equilibrator

Closed path
IRGA

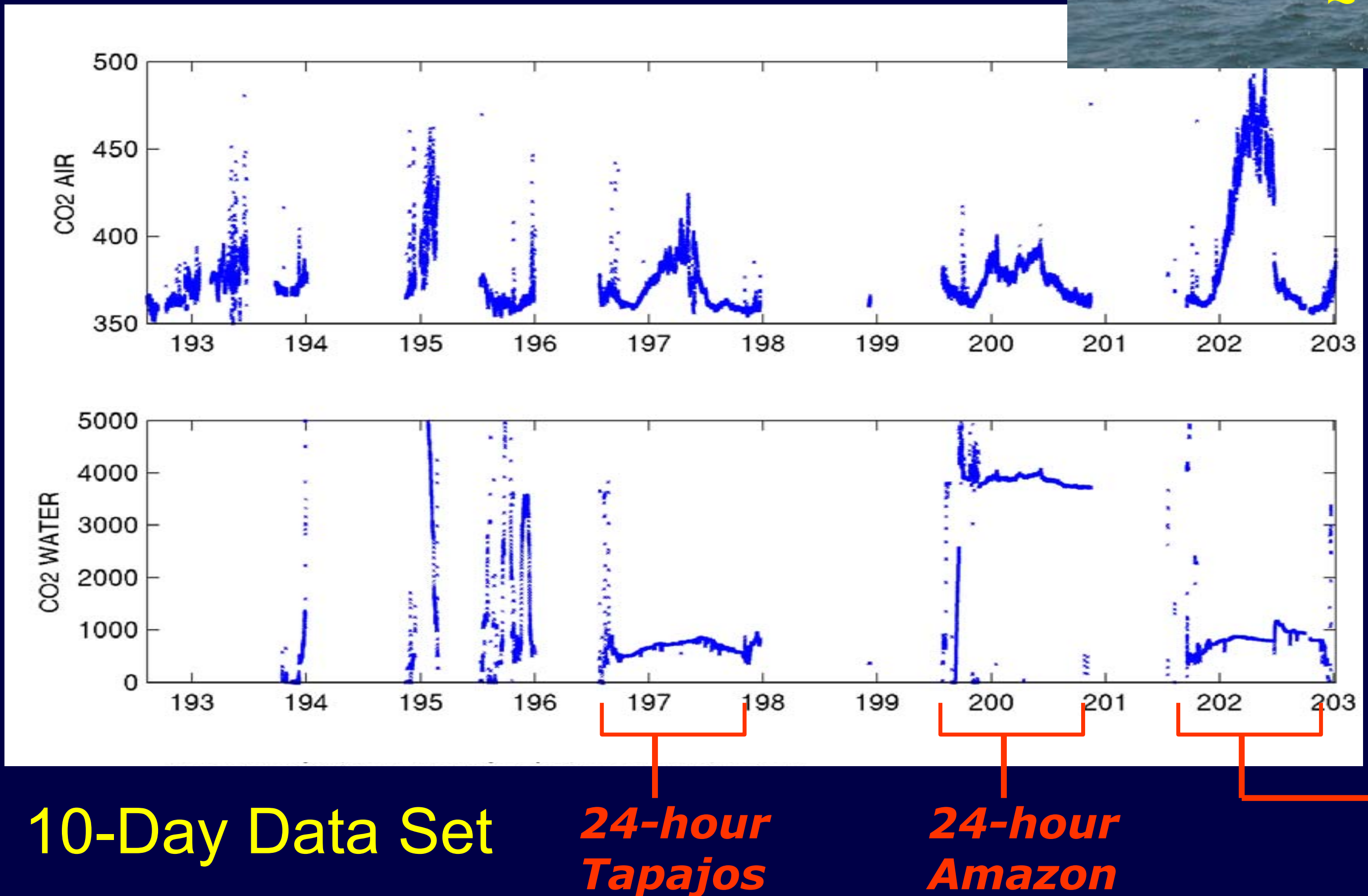
Sampling Strategy: Moving and Moored

10 day
ship track



Air and Water CO_2 Concentrations

Atmospheric CO2 ~ 380-500 ppm
Surface ocean CO2 ~300-450 ppm



10-Day Data Set

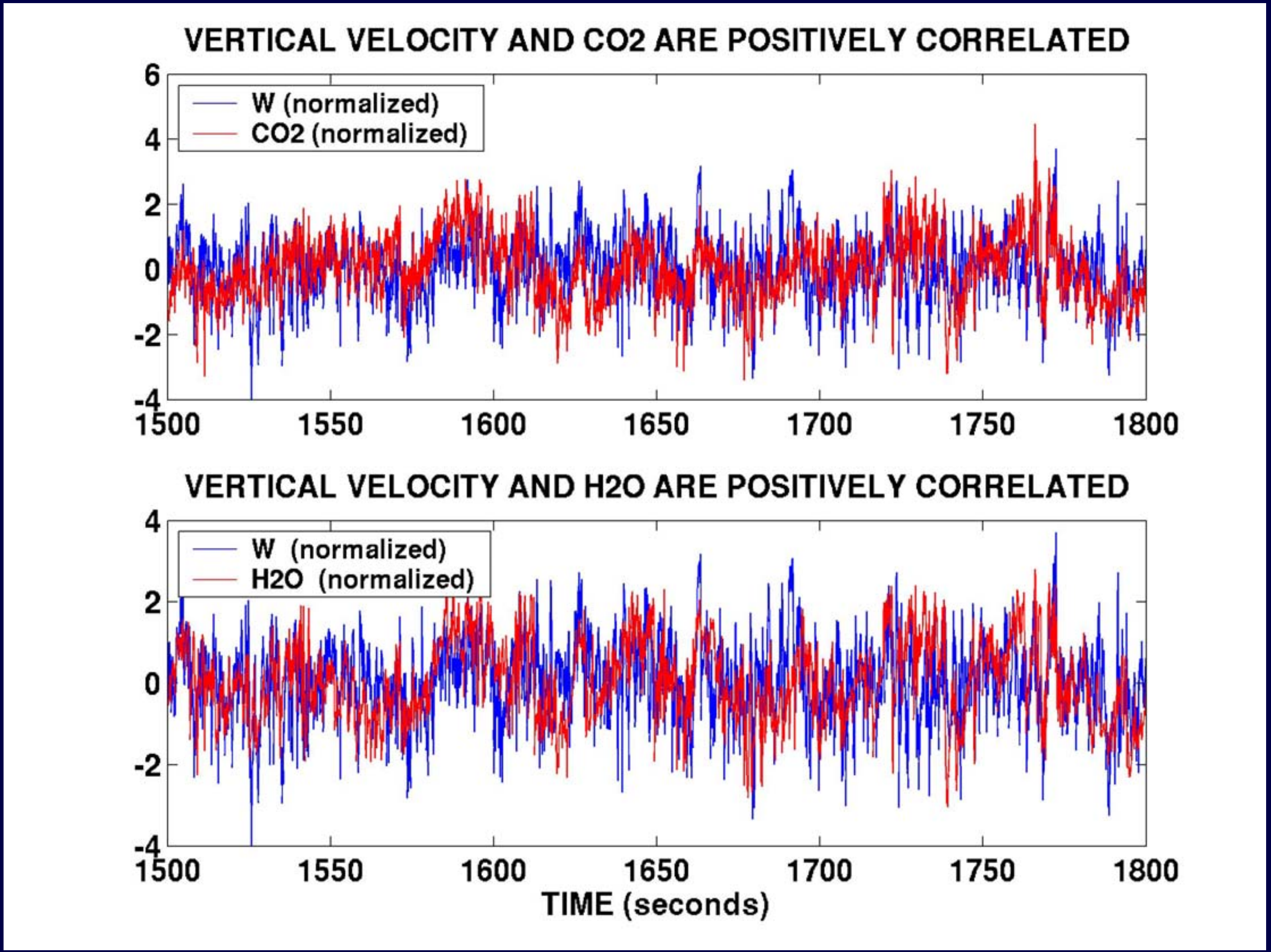
Raw Data

upward heat flux

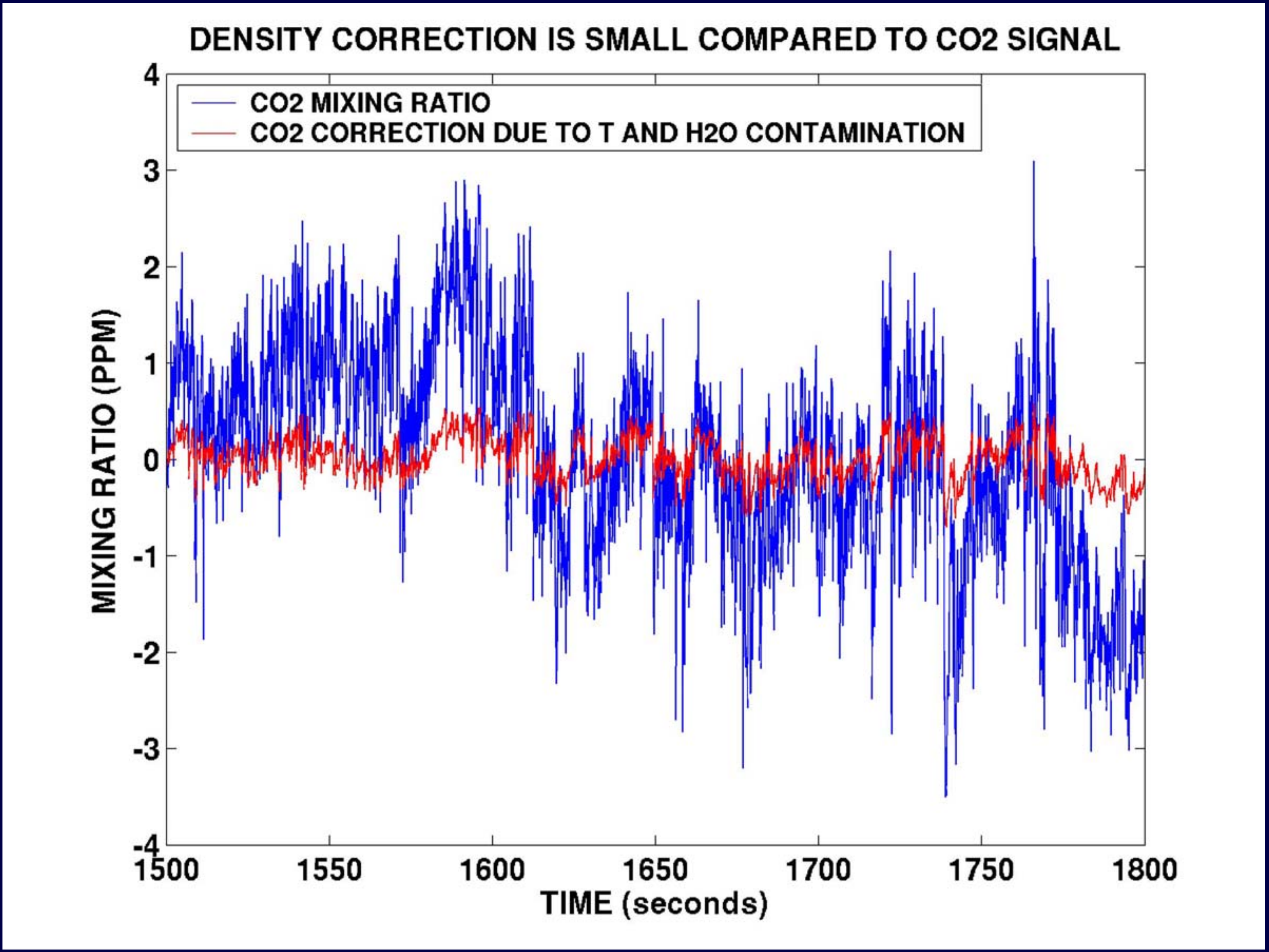
$$\overline{w'T'} > 0$$

upward CO_2 flux

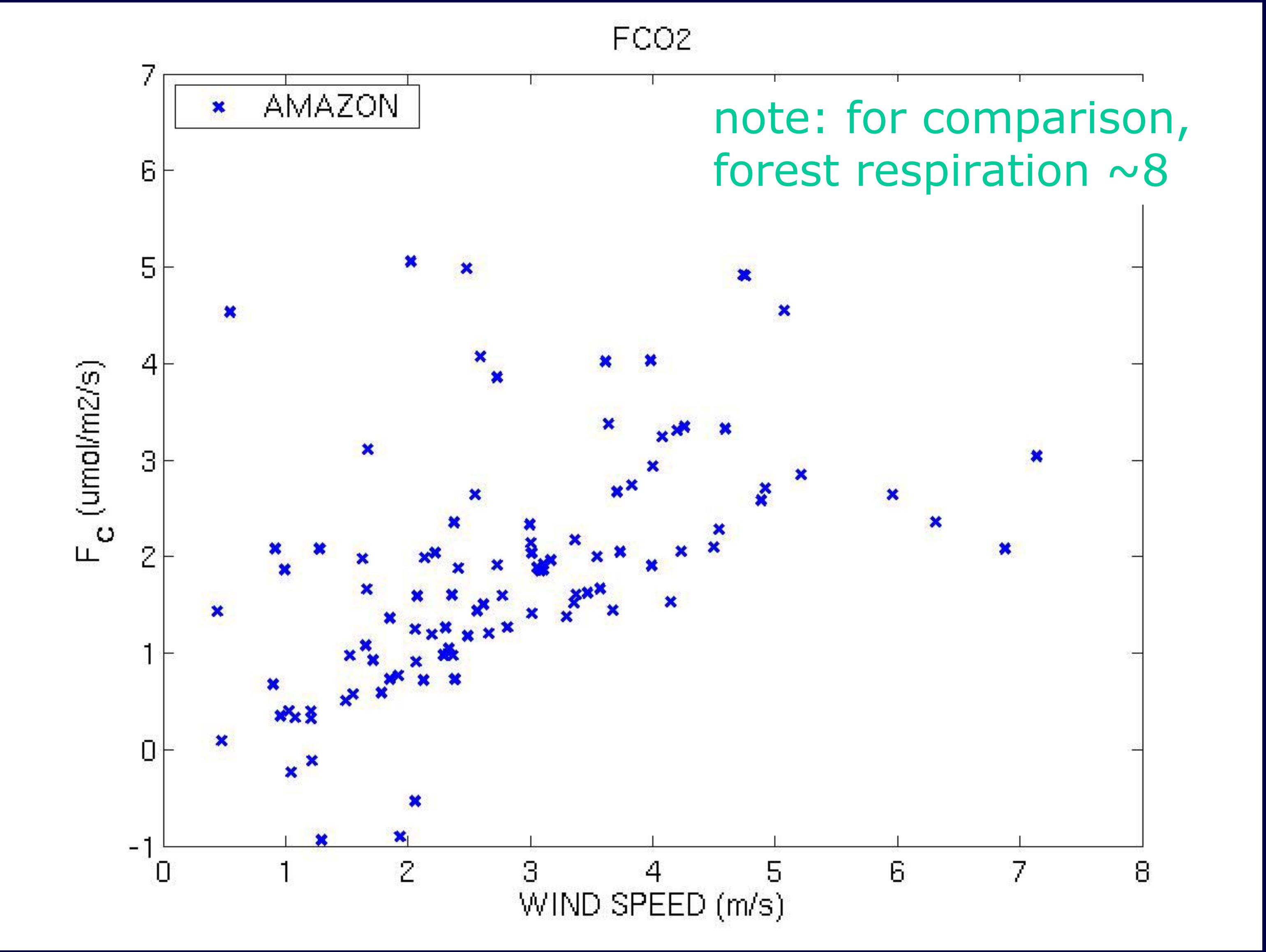
$$\overline{w'c'} > 0$$



Flux Corrections

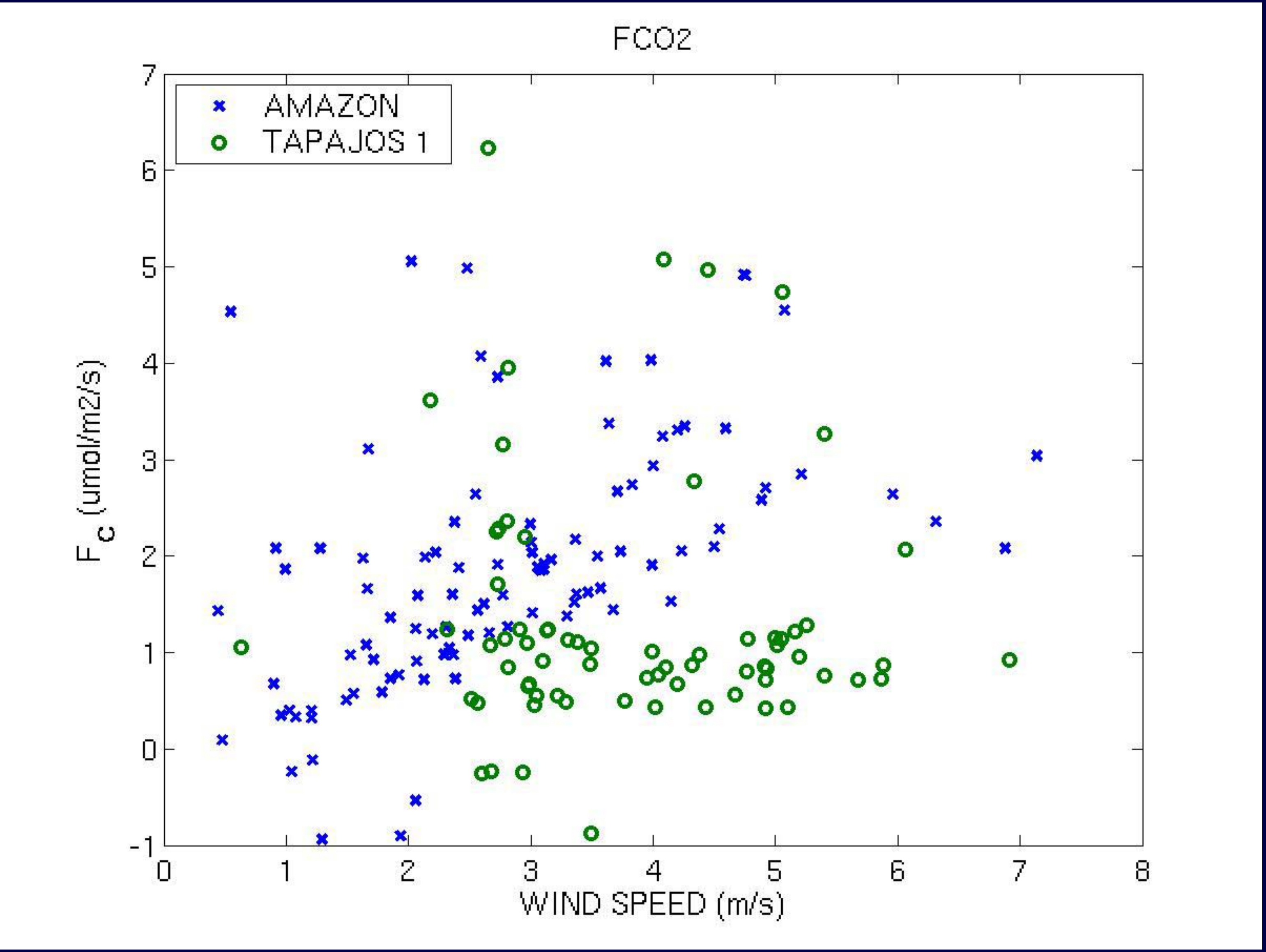


CO_2 Flux versus Wind Speed

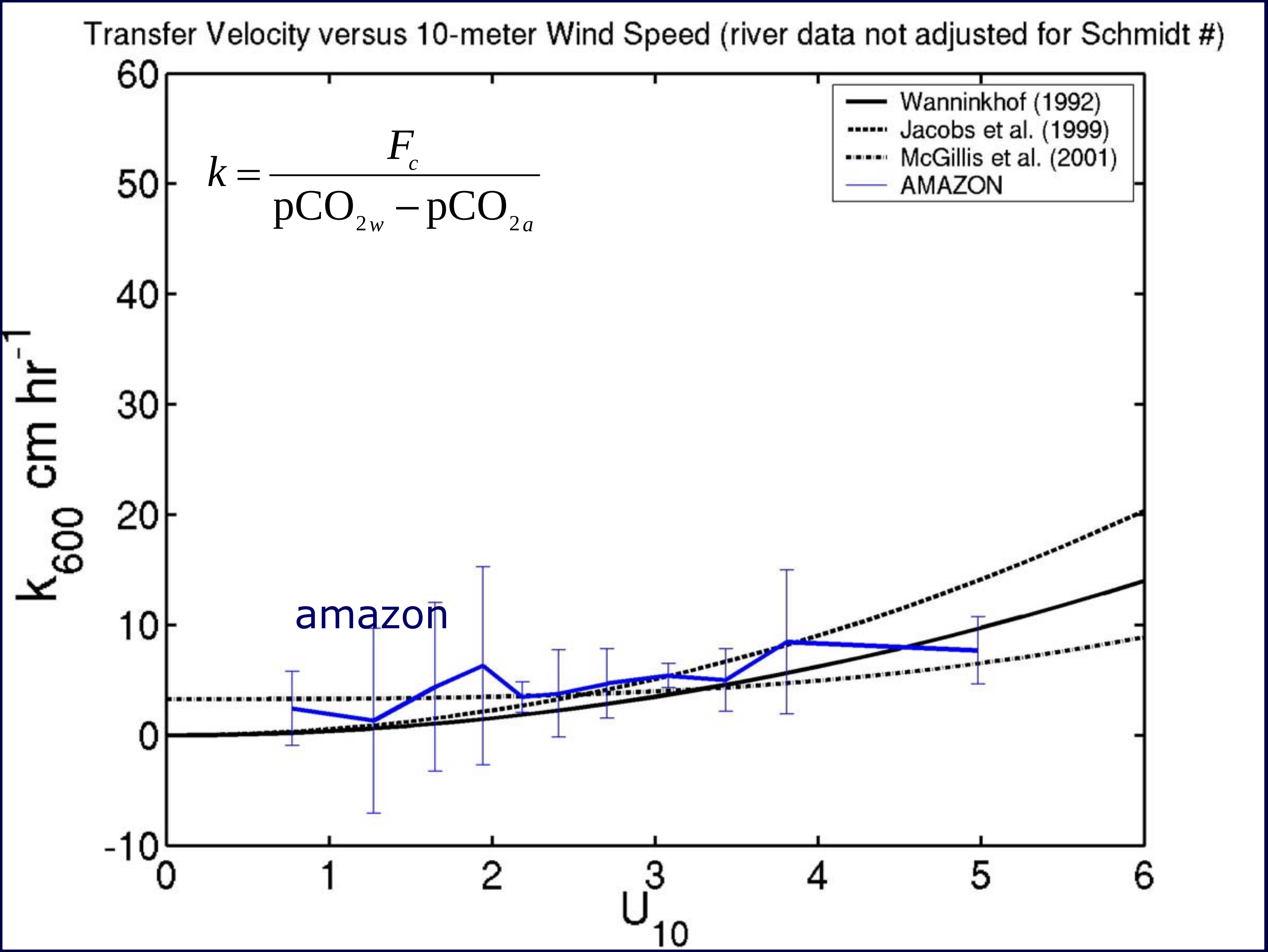


note: for comparison, forest respiration ~8

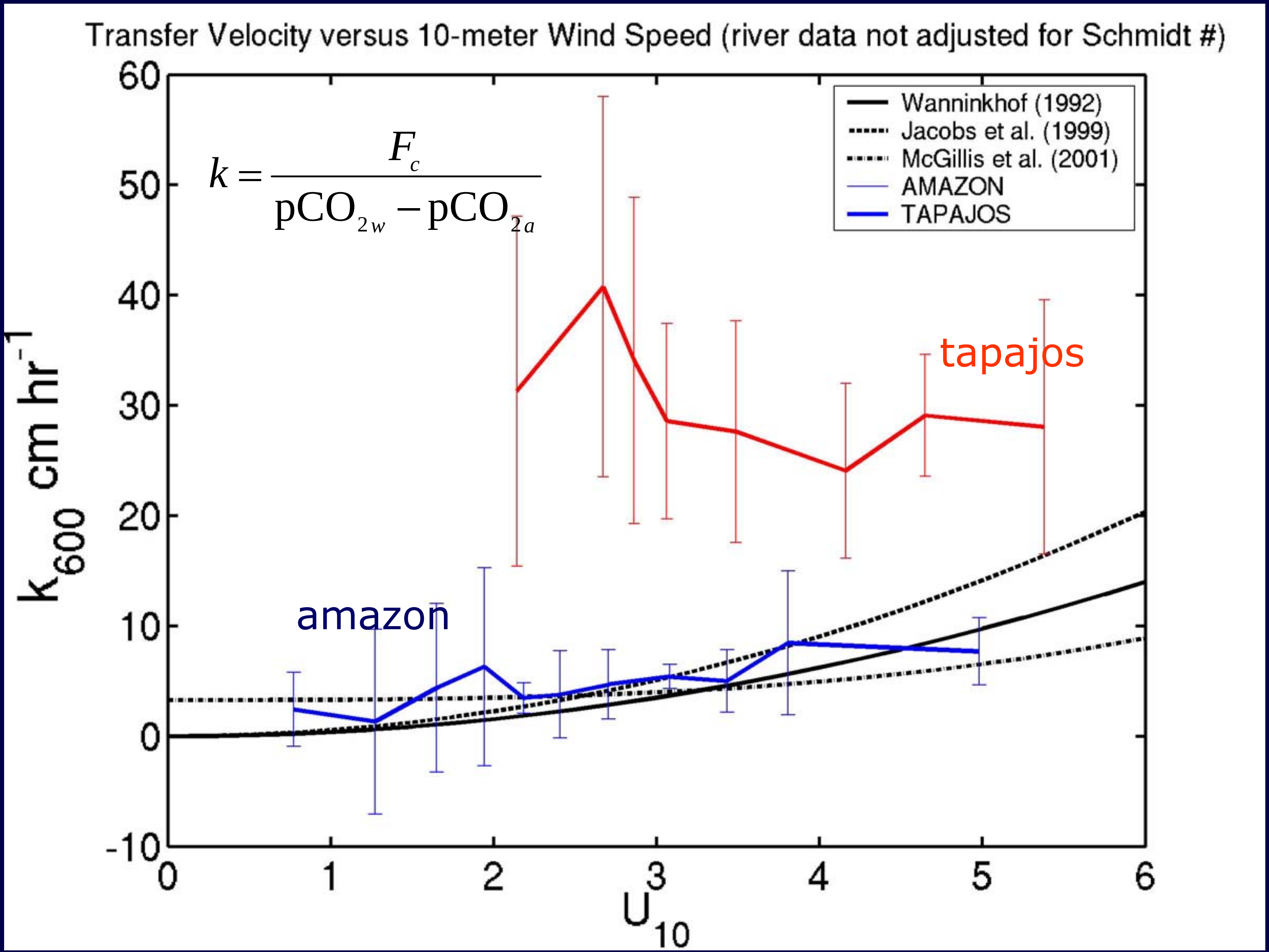
CO_2 Flux versus Wind Speed



Piston Velocity: Amazon only



Piston Velocity: Amazon & Tapajos



Tapajos- Amazon difference: Shallow-water fetch may have contributed to higher piston velocities on the Tapajos

Conclusions

- Boat-based eddy covariance facilitated by the high CO2 gradient across the air-water interface, and large rivers.
- ***k*** for Amazon consistent with other methods and environments.
- ***k*** appears to vary spatially (preliminary).

Thanks: Boat Crew, Bethany Reed, Daniel Amarral.