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The many meanings of gross photosynthesis and their implication for photosynthesis research from leaf to globe

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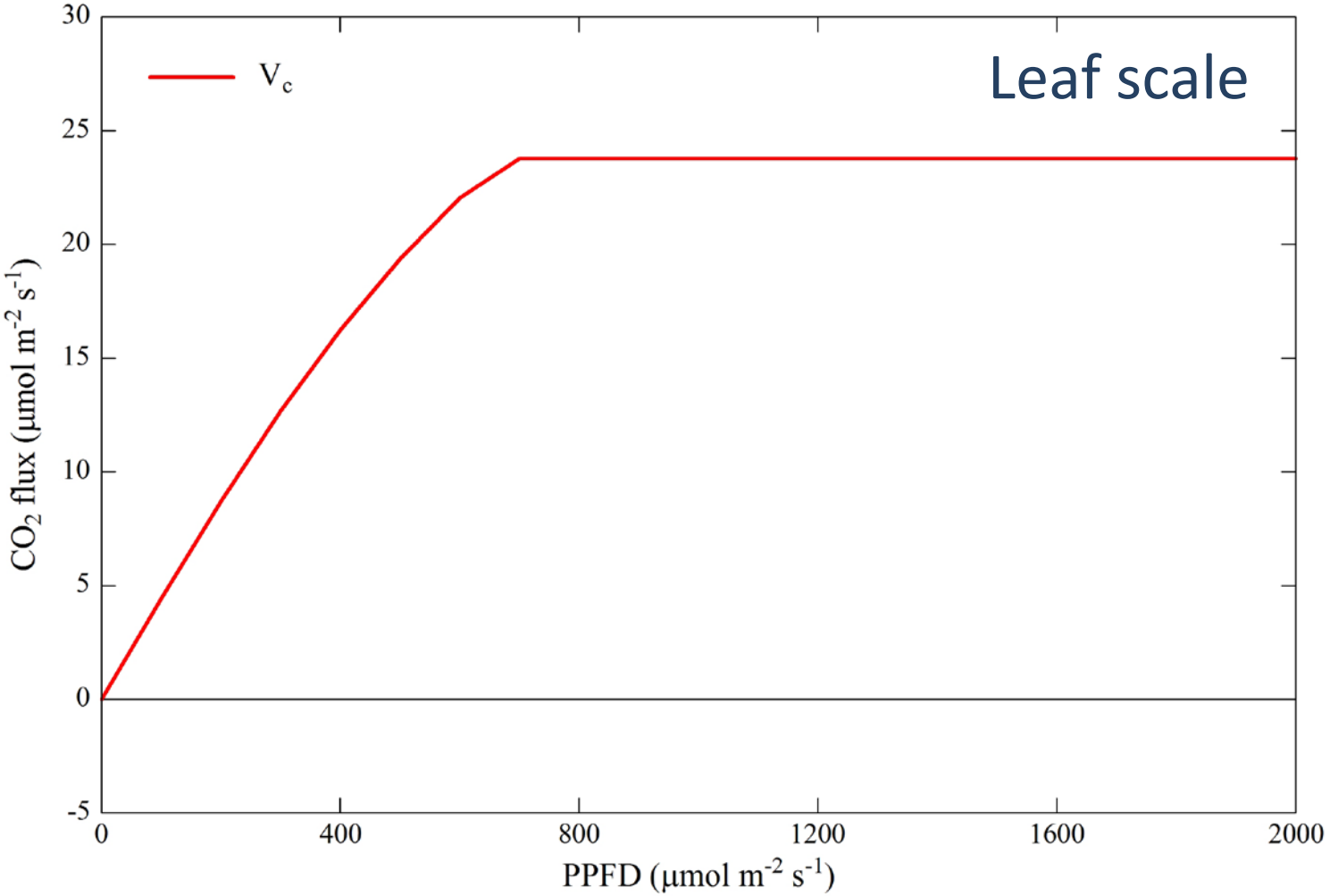
Ice breaker

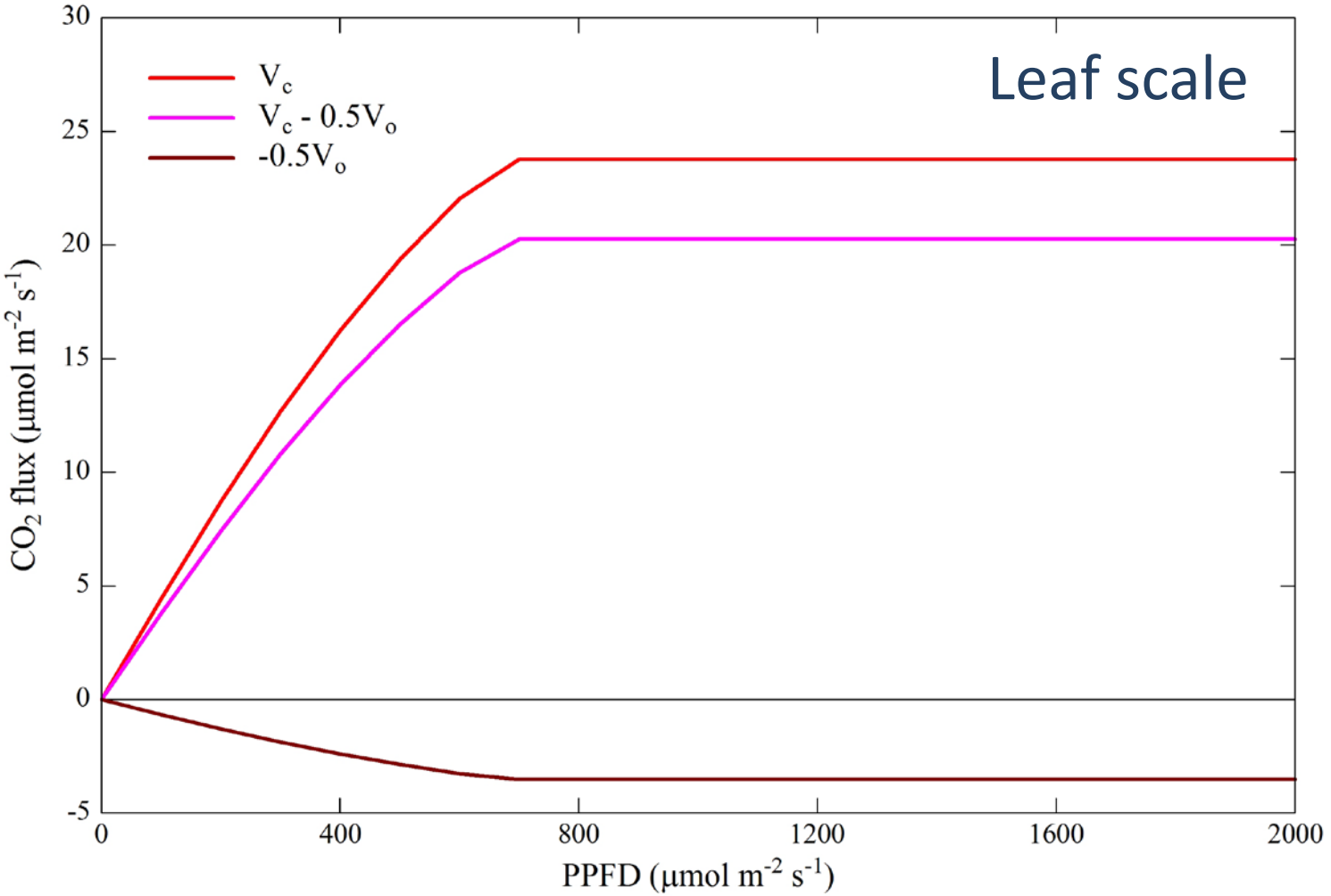
Expose yourself!

Put up your hands up if you think you know the definition of gross photosynthesis.

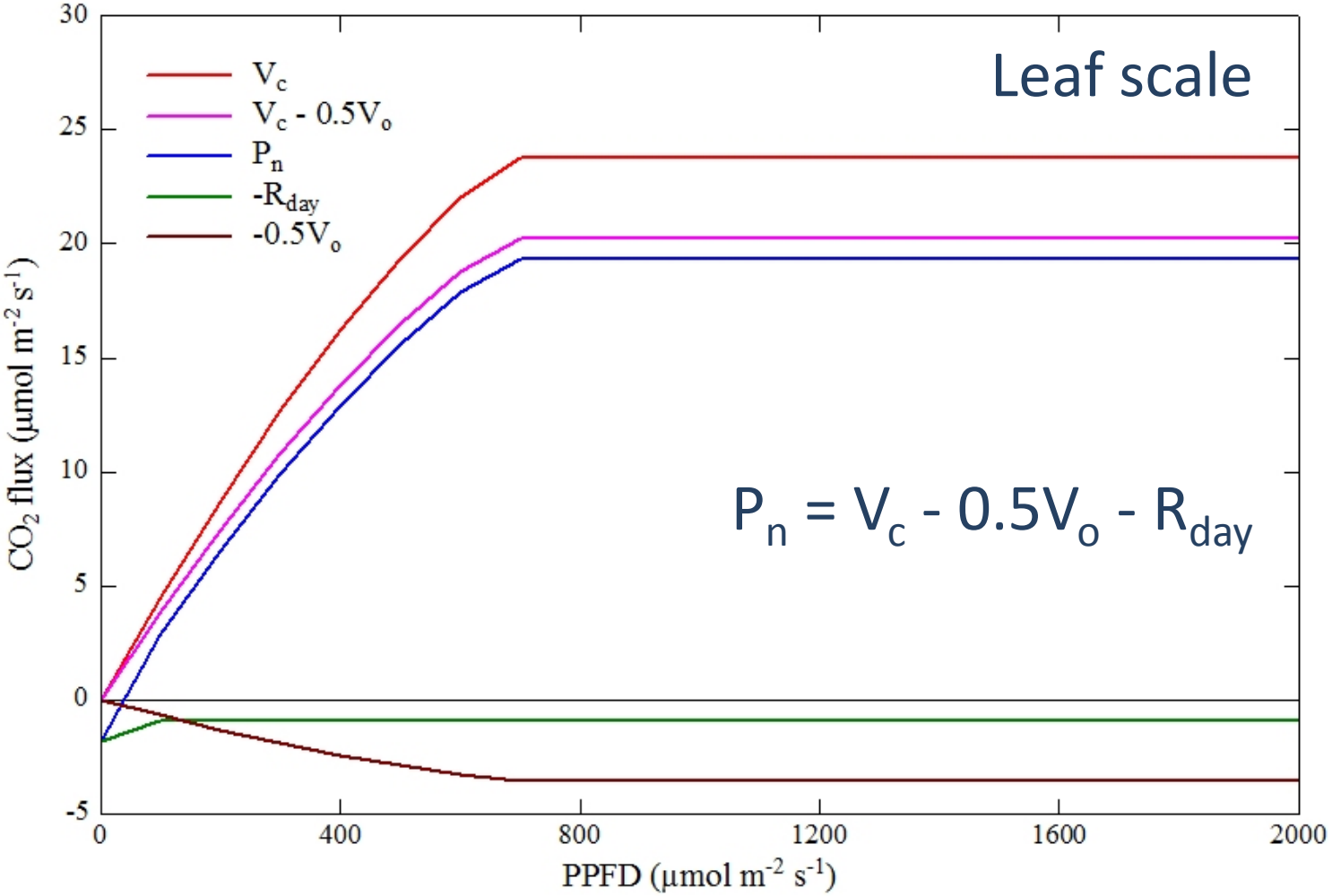
Background


Leaf scale
V_c
CO_2 flux (µmol m^{-2} s^{-1})
PPFD (µmol m^{-2} s^{-1})
30
25
20
15
10
5
0
-5
0
400
800
1200
1600
2000

Background


Leaf scale
V_c
V_c - 0.5V_o
-0.5V_o
CO_2 flux (µmol m^{-2} s^{-1})
PPFD (µmol m^{-2} s^{-1})
30
25
20
15
10
5
0
-5
0
400
800
1200
1600
2000

Background


Leaf scale
V_c
V_c - 0.5V_o
P_n
-R_{day}
-0.5V_o
$P_n = V_c - 0.5V_o - R_{day}$
CO_2 flux (µmol m^{-2} s^{-1})
PPFD (µmol m^{-2} s^{-1})
30
25
20
15
10
5
0
-5
0
400
800
1200
1600
2000

Definitions

$$P_n = V_c - 0.5V_o - R_{day}$$

(a)

(b)

Gross photosynthesis is defined as

(a) V_c (i.e. carboxylation only) or

(b) V_c-$0.5V_o$ (i.e. carboxylation minus photorespiration)

Which definition is correct?

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Definitions

Ecosystems (2006) 9: 1041–1050
DOI: 10.1007/s10021-005-0105-7

ECOSYSTEMS

Reconciling Carbon-cycle Concepts, Terminology, and Methods

F. S. Chapin III,[1]* G. M. Woodwell,[2] J. T. Randerson,[3] E. B. Rastetter,[4] G. M. Lovett,[5] D. D. Baldocchi,[6] D. A. Clark,[7] M. E. Harmon,[8] D. S. Schimel,[9] R. Valentini,[10] C. Wirth,[11] J. D. Aber,[12] J. J. Cole,[5] M. L. Goulden,[3] J. W. Harden,[13] M. Heimann,[11] R. W. Howarth,[14] P. A. Matson,[15] A. D. McGuire,[16] J. M. Melillo,[4] H. A. Mooney,[17] J. C. Neff,[18] R. A. Houghton,[2] M. L. Pace,[5] M. G. Ryan,[18] S. W. Running,[19] O. E. Sala,[20] W. H. Schlesinger,[21] and E.-D. Schulze[11]

"… gross photosynthesis is the sum of gross carbon fixation by autotrophic carbon-fixing tissues per unit area and time …"

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Definitions

Journal of Experimental Botany, Vol. 65, No. 15, pp. 4065–4095, 2014
doi:10.1093/jxb/eru191 Advance Access publication 27 May, 2014

Journal of Experimental Botany
www.jxb.oxfordjournals.org

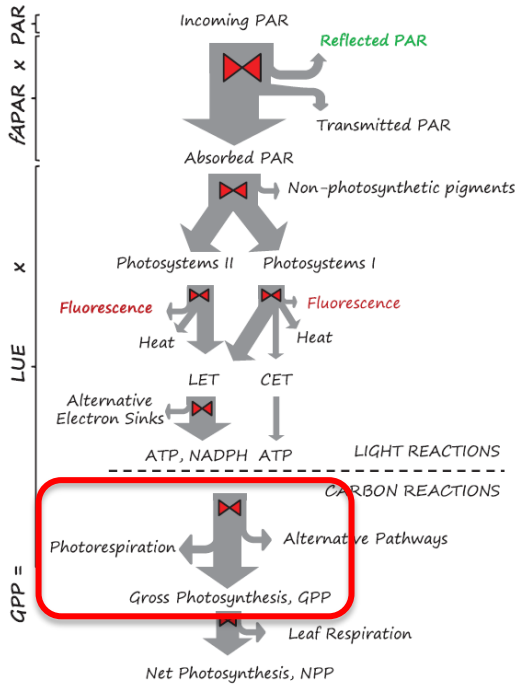
DARWIN REVIEW

Linking chlorophyll *a* fluorescence to photosynthesis for remote sensing applications: mechanisms and challenges

Albert Porcar-Castell[1,*], Esa Tyystjärvi[2], Jon Atherton[1], Christiaan van der Tol[3], Jaume Flexas[4], Erhard E. Pfündel[5], Jose Moreno[6], Christian Frankenberg[7] and Joseph A. Berry[8]

Definitions

$GPP = V_c - 0.5V_o$



$GPP = V_c$

The ATP and NADPH generated by the light reactions are utilized by the Calvin–Benson cycle to synthesize sugars by assimilating CO_2 (gross photosynthetic assimilation or A_G) (Fig. 1). Net photosynthetic assimilation (A_N) is the quantity that is measurable by gas exchange systems and relates to 'true' or gross photosynthesis (A_G) as:

$$A_N = A_G - PR - R_d \quad (2)$$

where R_d is the rate of mitochondrial day respiration and PR is the rate of photorespiration (Ogren, 1984). In photorespi-

two different definitions … in the same paper …

Definitions

$$P_n = V_c - 0.5V_o - R_{day}$$

(a)

(b)

Older definitions

(a) V_c : 'true' photosynthesis

(b) V_c-0.5V_o: 'apparent' photosynthesis

Results

Eddy covariance flux partitioning

$$NEP_n = -(R_{dark} + R_{non\text{-}leaf})$$

$$NEP_d = V_c - 0.5V_o - (R_{day} + R_{non\text{-}leaf})$$

f(T)

Problem #1: because $R_{day} < R_{dark}$, NEP_n overestimates daytime ecosystem respiration

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Results

Available online at www.sciencedirect.com

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Agricultural and Forest Meteorology 130 (2005) 13–25

AGRICULTURAL AND FOREST METEOROLOGY

www.elsevier.com/locate/agrformet

Estimation of daytime ecosystem respiration to determine gross primary production of a mountain meadow

Georg Wohlfahrt *, Michael Bahn, Alois Haslwanter, Christian Newesely, Alexander Cernusca

"… suggests an overestimation of RECO by 11-17% …"

Results

Eddy covariance flux partitioning

$NEP_n = -(R_{dark} + R_{non\text{-}leaf})$

$NEP_d = V_c\text{-}0.5V_o - (R_{day} + R_{non\text{-}leaf})$

f(T)

Problem #2: NEP_n carries no information about photorespiration - we thus can only estimate $V_c\text{-}0.5V_o$, but not V_c, i.e.

$V_c\text{-}0.5V_o = NEP_d + (R_{day} + R_{non\text{-}leaf})$

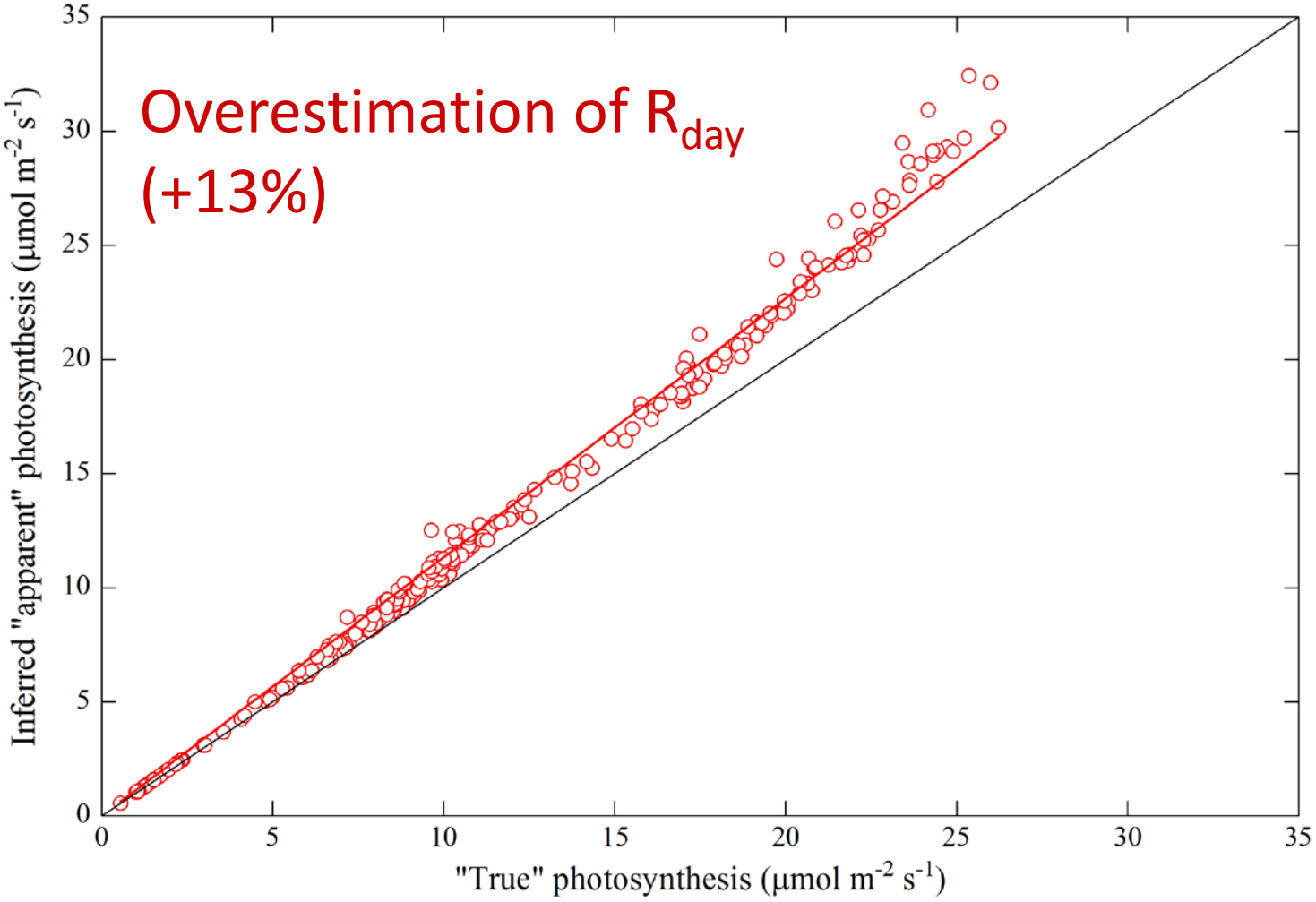
Eddy covariance flux partitioning

#1: NEP_n overestimates daytime ecosystem respiration

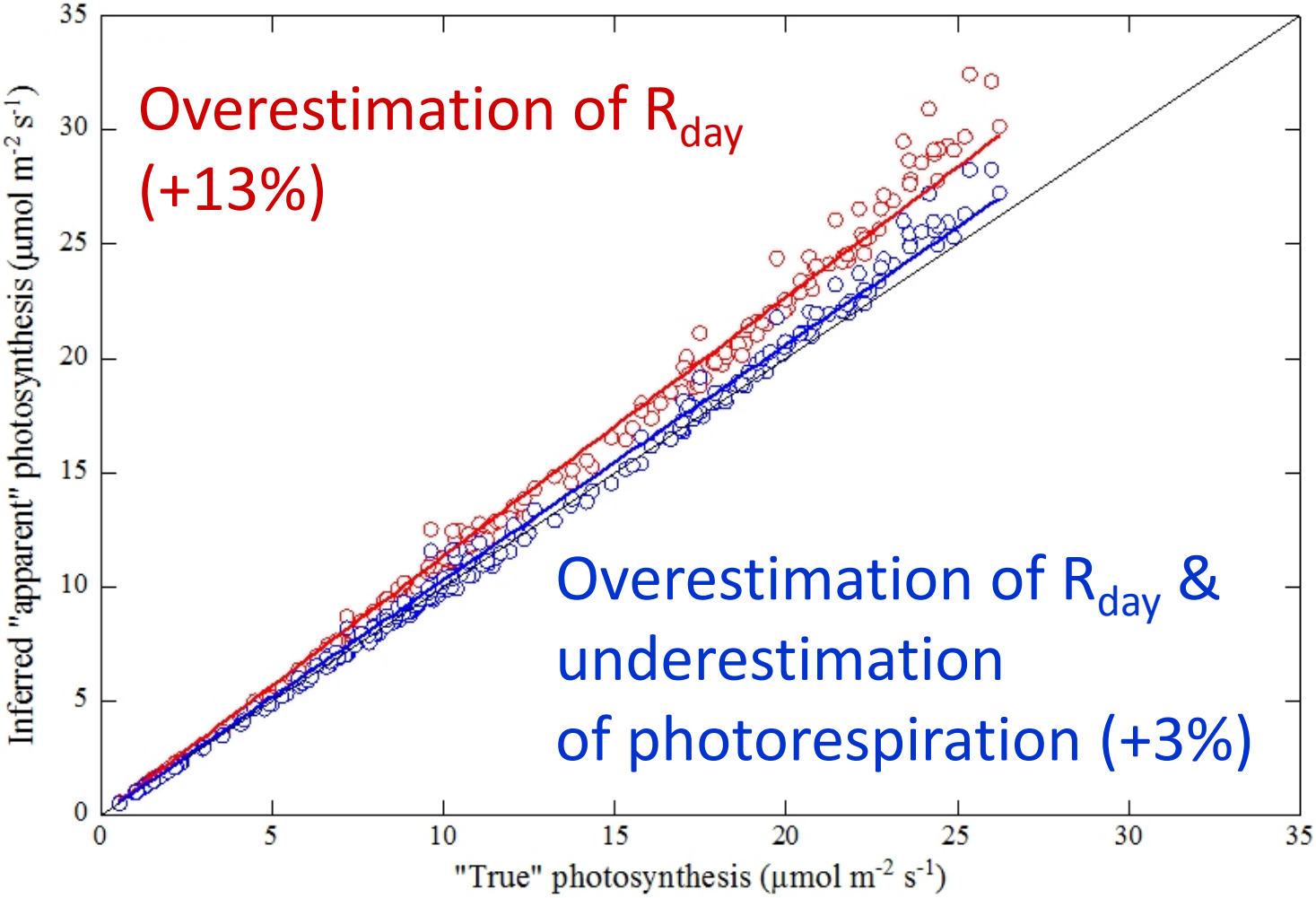
#2: NEP_n carries no information about photorespiration

=> Inferred GPP may be closer to true (V_c) than apparent (V_c-0.5V_o) photosynthesis

Results


Overestimation of R_{day}
(+13%)
Inferred "apparent" photosynthesis (µmol m^{-2} s^{-1})
"True" photosynthesis (µmol m^{-2} s^{-1})
0
5
10
15
20
25
30
35

Results


Overestimation of R_{day} (+13%)
Overestimation of R_{day} & underestimation of photorespiration (+3%)
Inferred "apparent" photosynthesis (µmol m^{-2} s^{-1})
"True" photosynthesis (µmol m^{-2} s^{-1})
0
5
10
15
20
25
30
35

Take-home messages

- The term gross photosynthesis has been and is used with different meanings by different communities.
- Eddy covariance flux partitioning conceptually allows estimating the ‘apparent’ photosynthesis, that is carboxylation minus photorespiration.
- However, the resulting estimate is closer to the ‘true’ photosynthesis, that is carboxylation only.
- Given these and other complications, alternative ways of exploiting the strong contrast between nighttime and daytime CO_2 exchange should be explored.
- Finally, we advocate to use the term gross photosynthesis and GPP for carboxylation minus photorespiration.