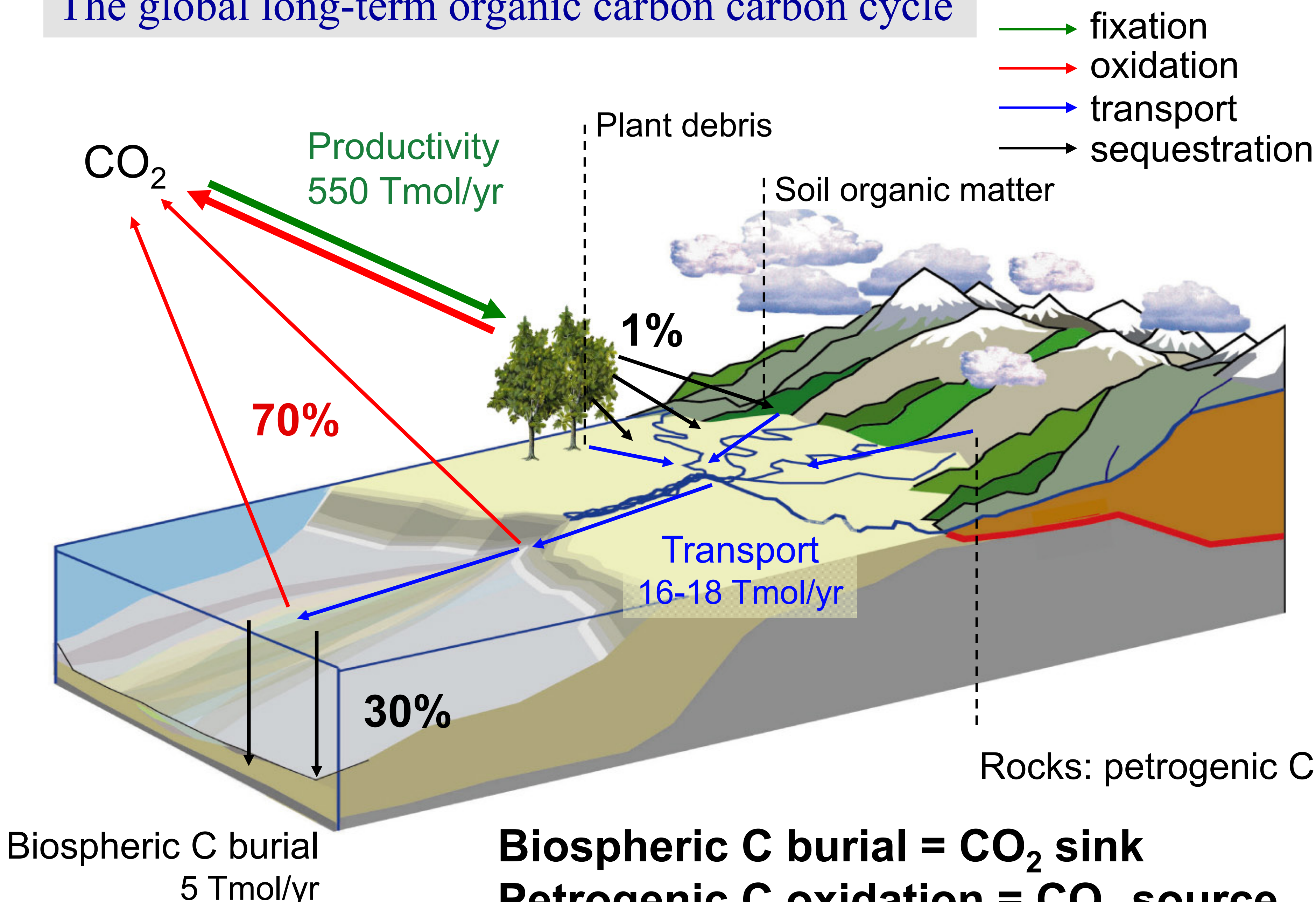
Dynamics of particulate organic carbon transfer to the ocean: a source to sink perspective

Valier Galy – Woods Hole Oceanographic Institution

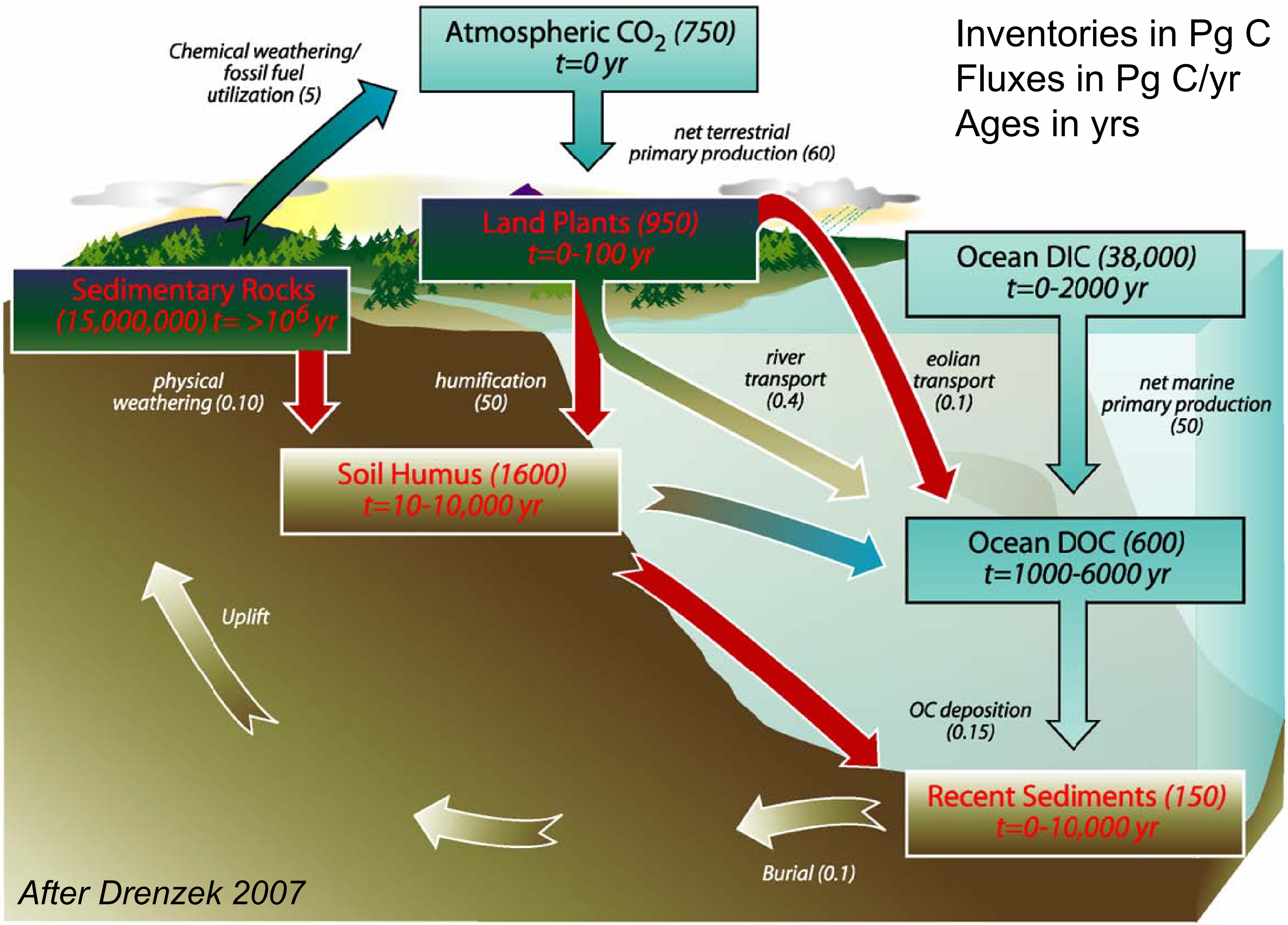
The global long-term organic carbon carbon cycle



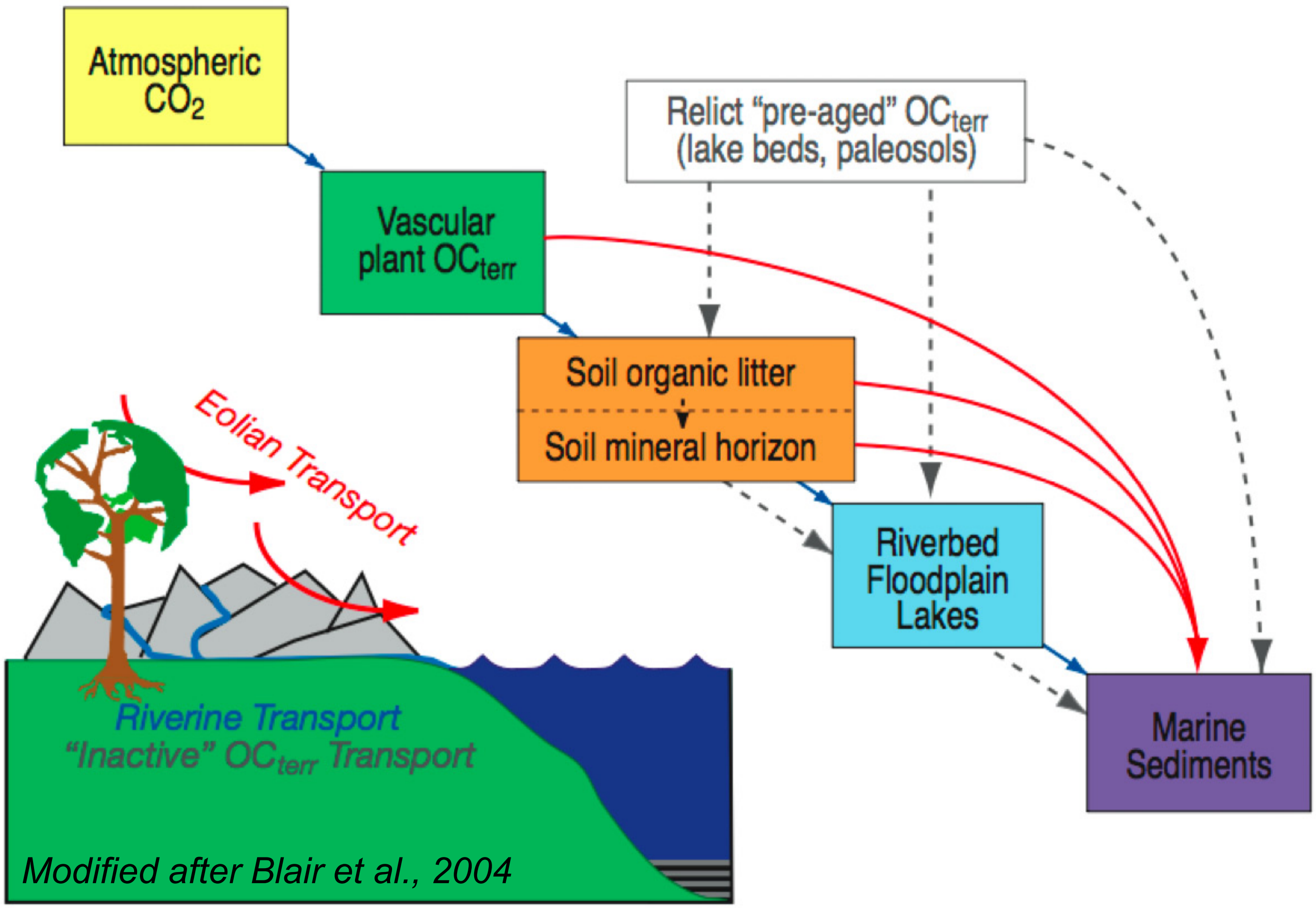
Biospheric C burial = CO_2 sink

Petrogenic C oxidation = CO_2 source

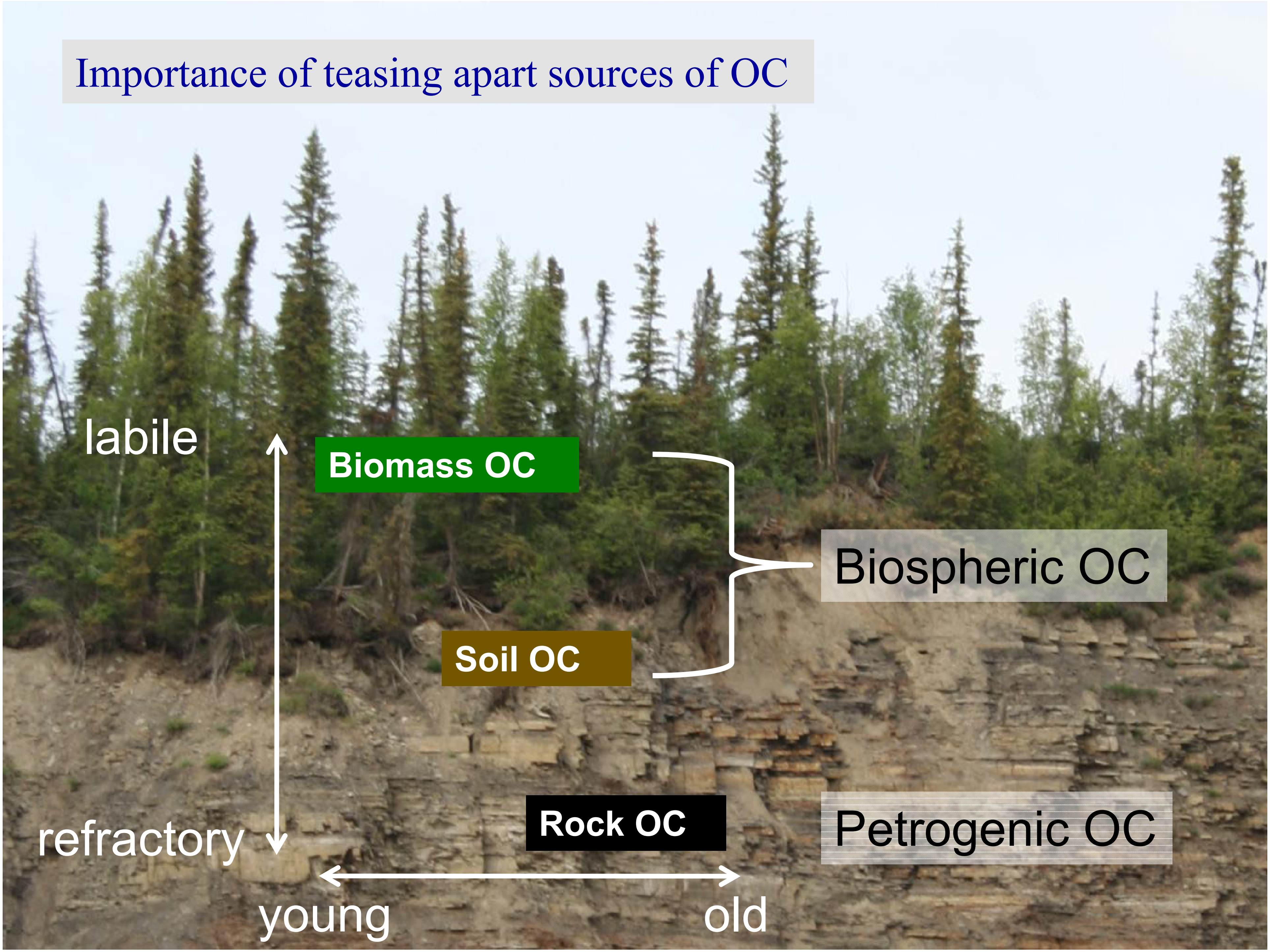
The short term C cycle: sensitivity of the atmospheric reservoir



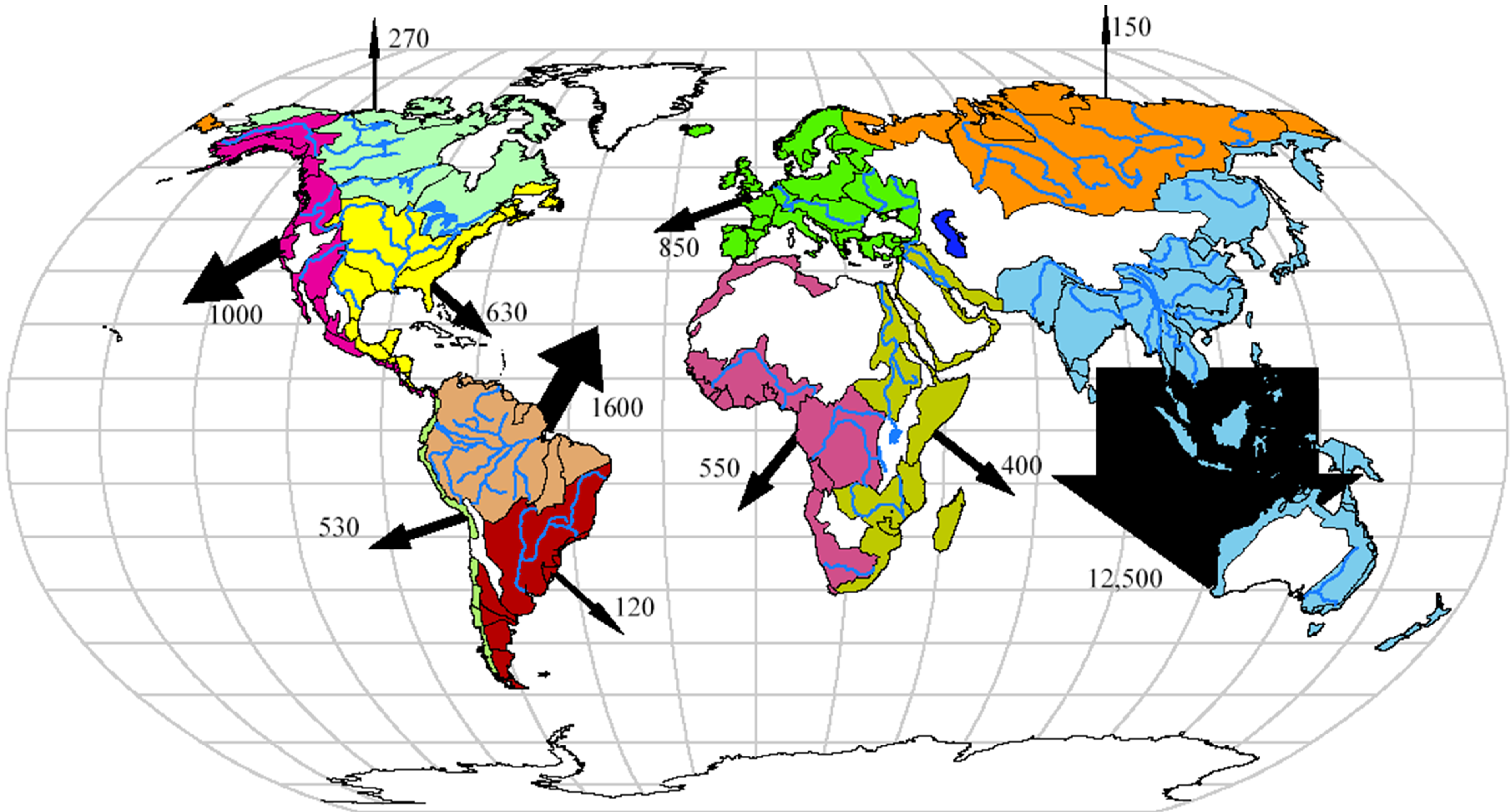
Continental processes of OC recycling



Terrestrial OC is affected by several exchange process on its way to the ocean
Consequences for C budget and OC based environmental reconstructions

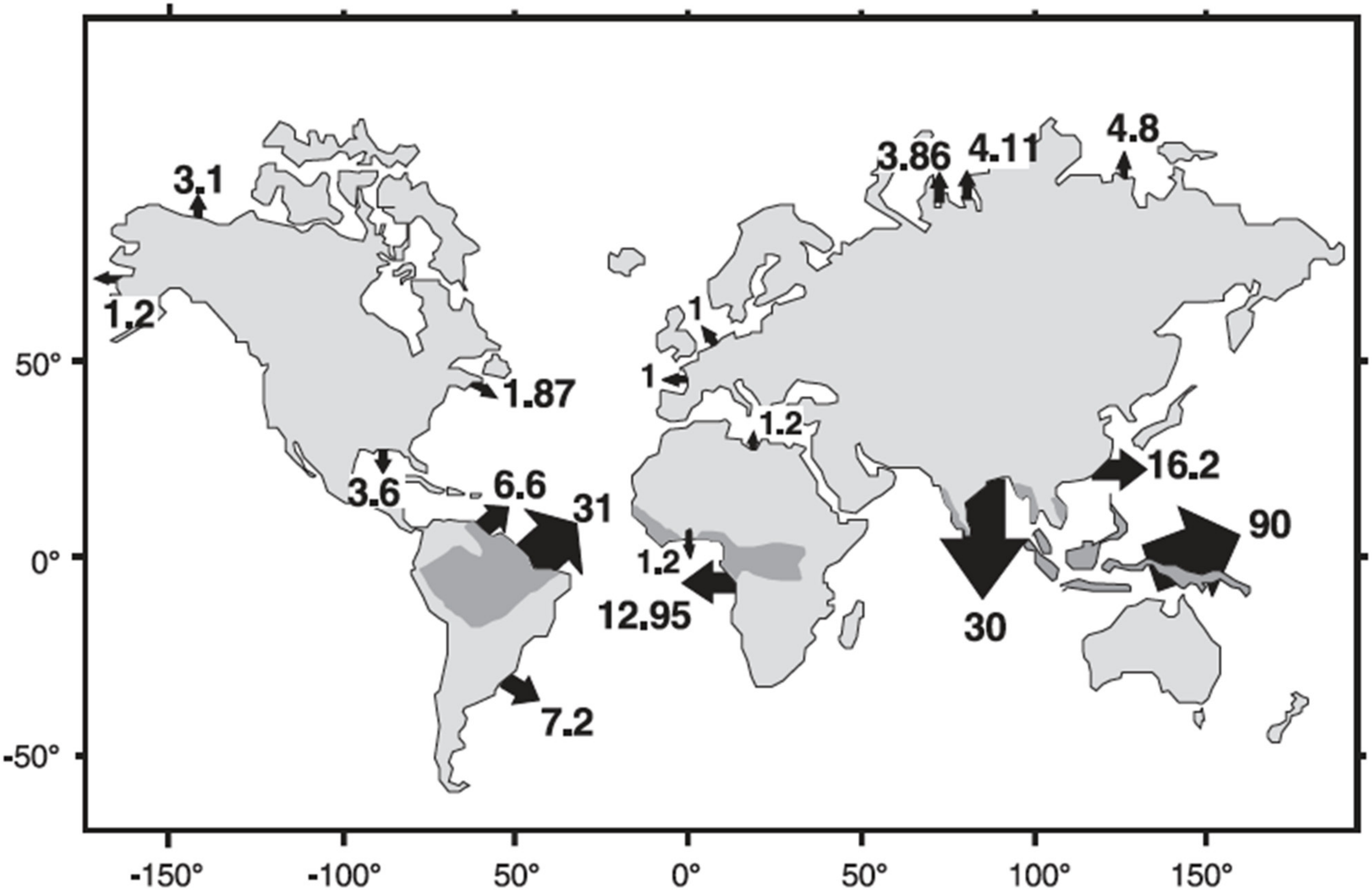

Importance of teasing apart sources of OC
labile
Biomass OC
Soil OC
Biospheric OC
Rock OC
Petrogenic OC
refractory
young
old

Sediment flux to the Ocean



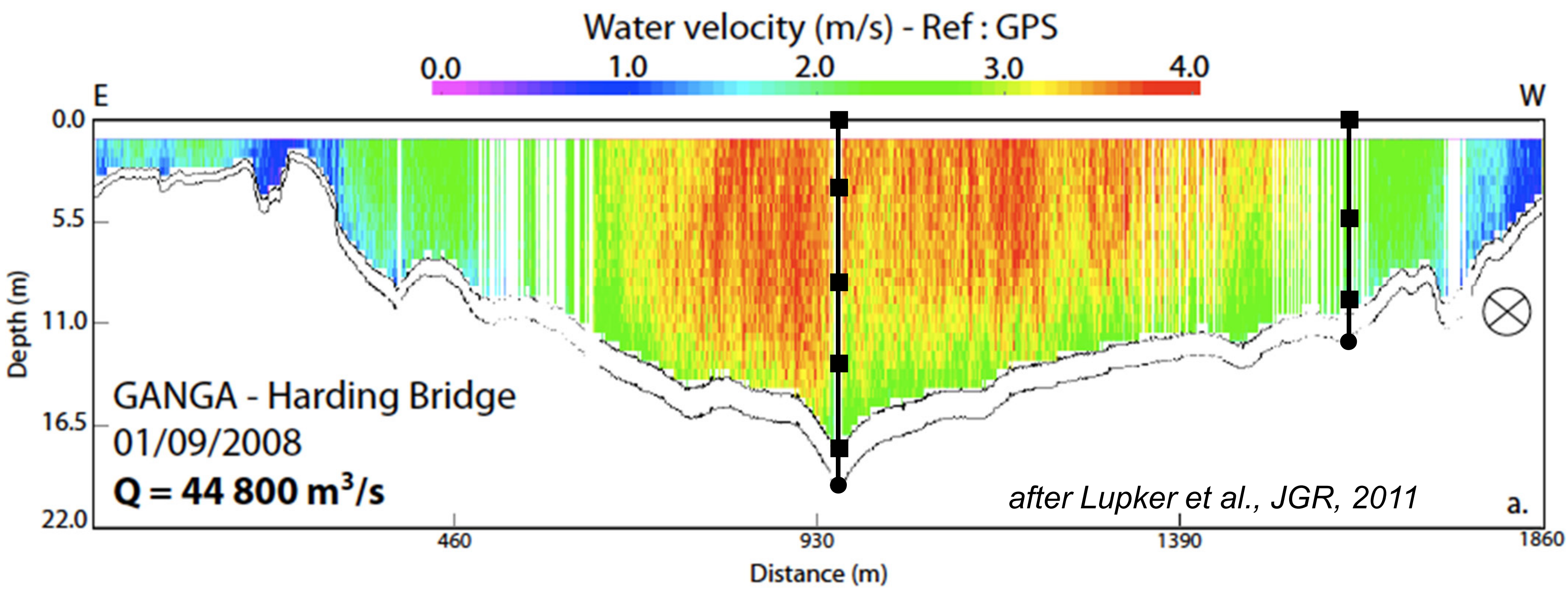
Milliman and Farnsworth, 2011

POC flux to the Ocean: large tropical systems & SMRI

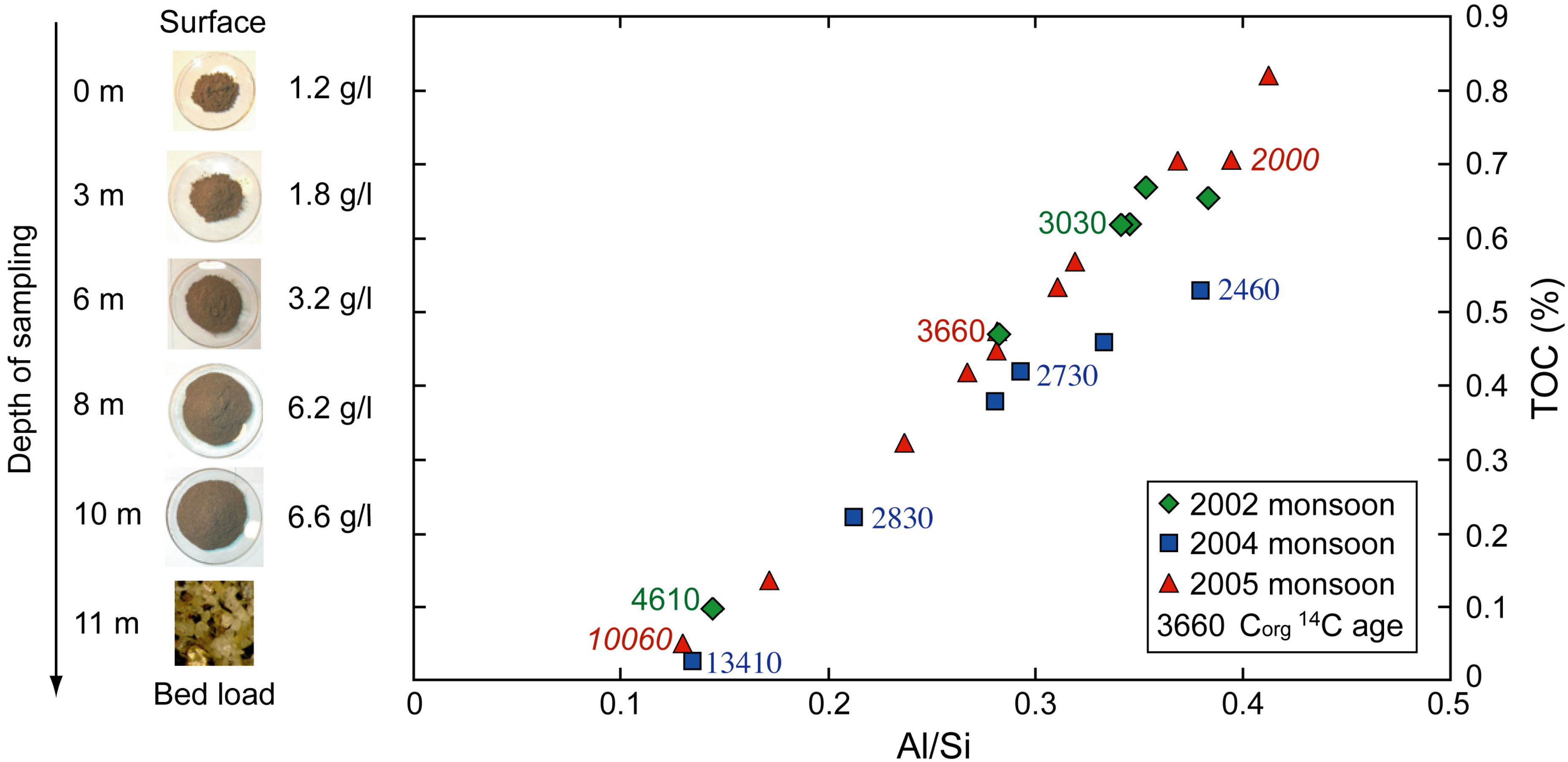


Schlunz and Schneider, 2000, IJES

Large Rivers: the depth sampling approach

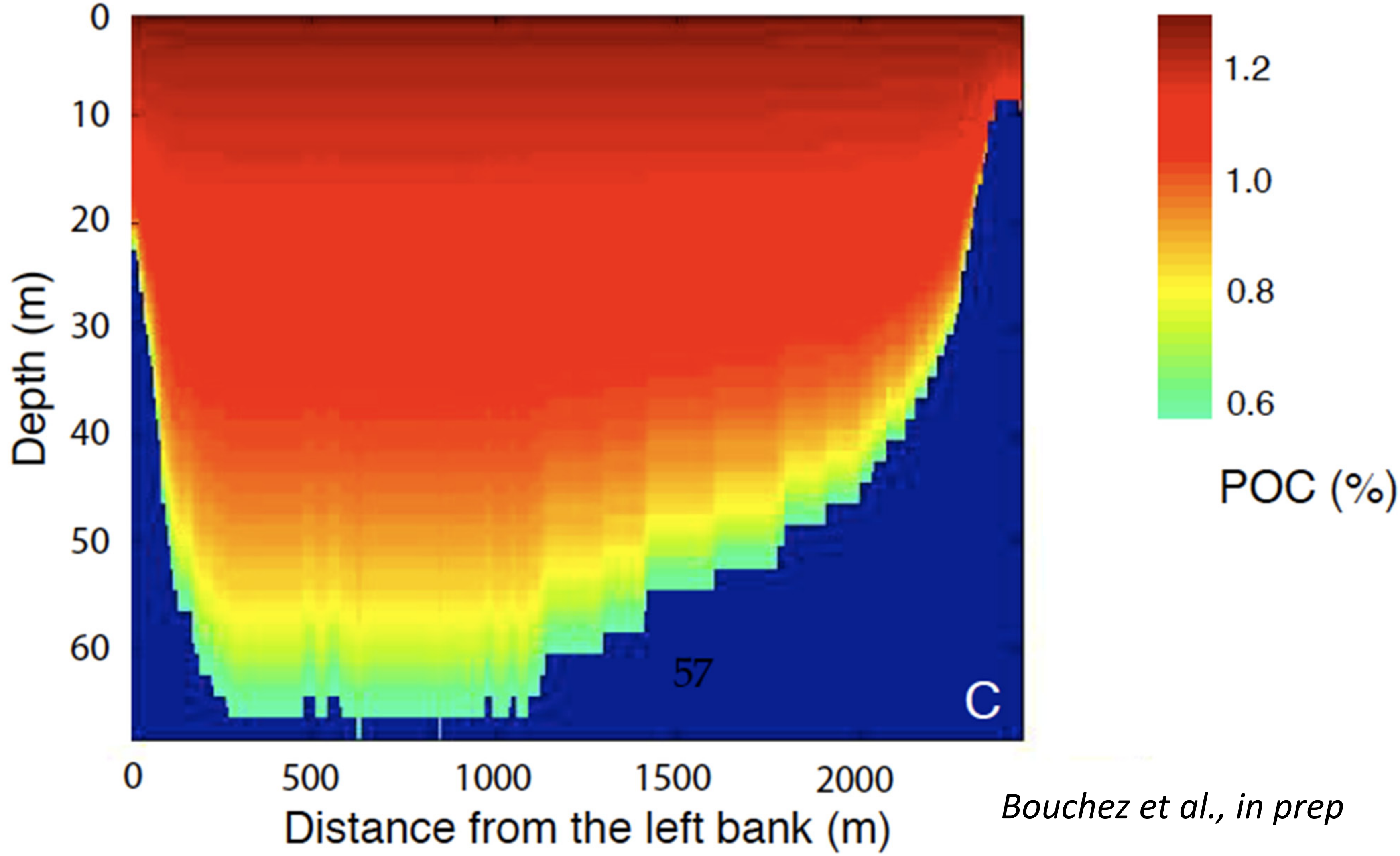


Depth variations of POC concentration and composition



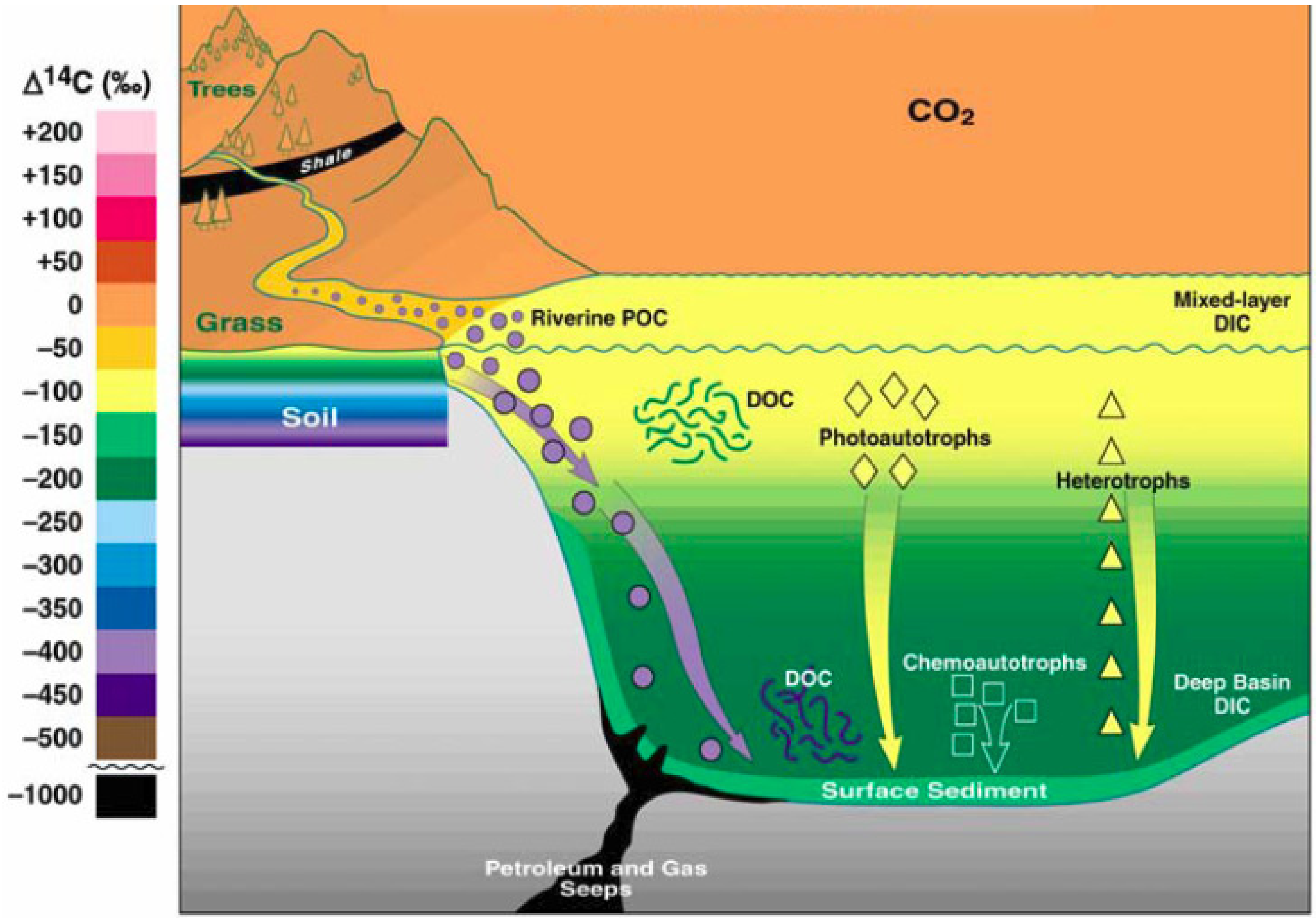
Galy et al., 2007 nature
Galy et al., 2008 GCA

Depth integrated POC concentration



Bouchez et al., in prep

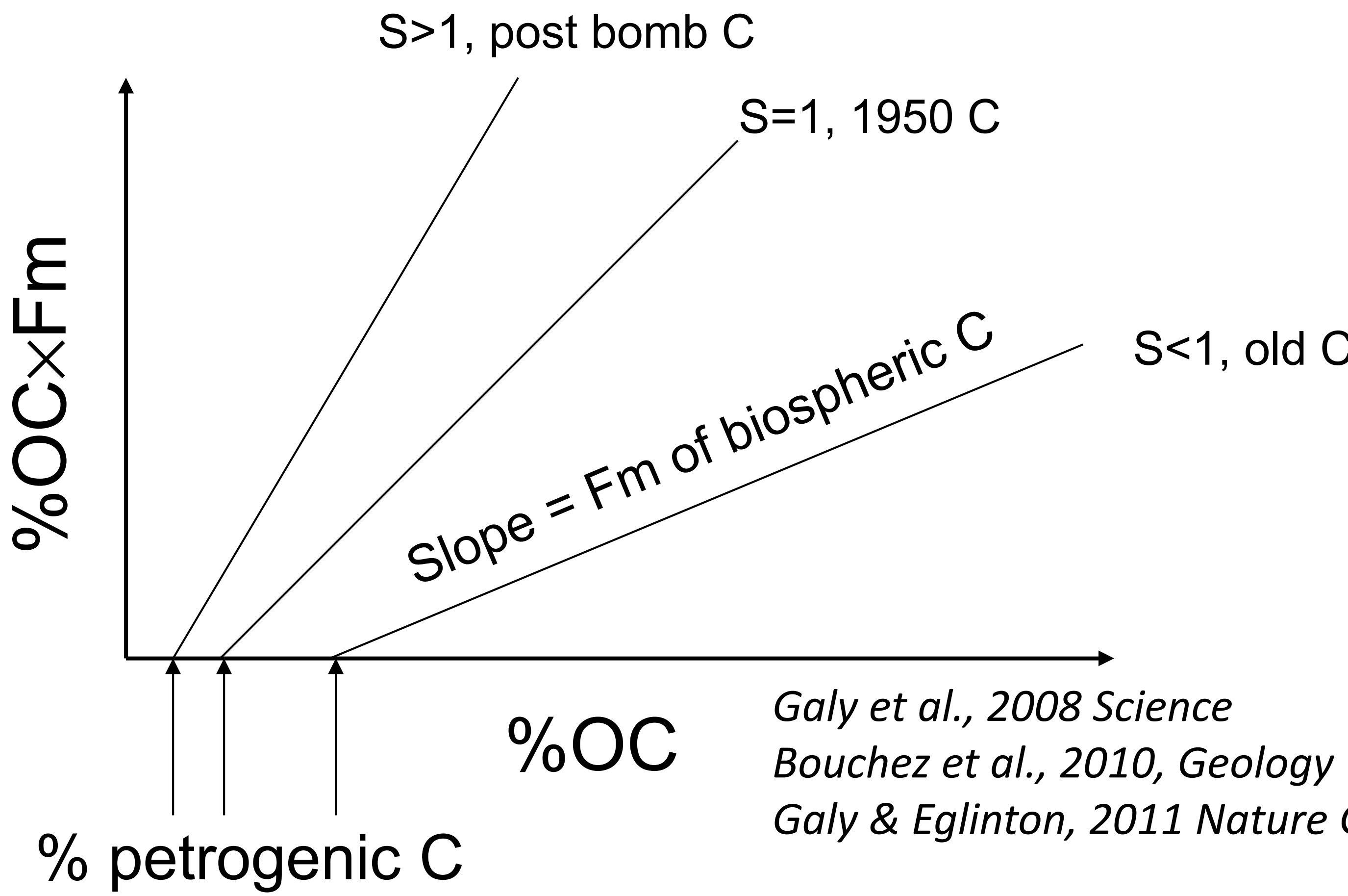
The ^{14}C jumble



Petrogenic C is ^{14}C dead whereas biospheric C has some ^{14}C

^{14}C = clock for biospheric C ($t_{1/2}$ = 5730 yrs)

Using bulk ^{14}C data of depth profile sediments



Galy et al., 2008 Science
Bouchez et al., 2010, Geology
Galy & Eglinton, 2011 Nature Geosciences

$$\%OC \times Fm = \%OC \times Fm_{biospheric\,C} - \%OC_{petro} \times Fm_{biospheric\,C}$$

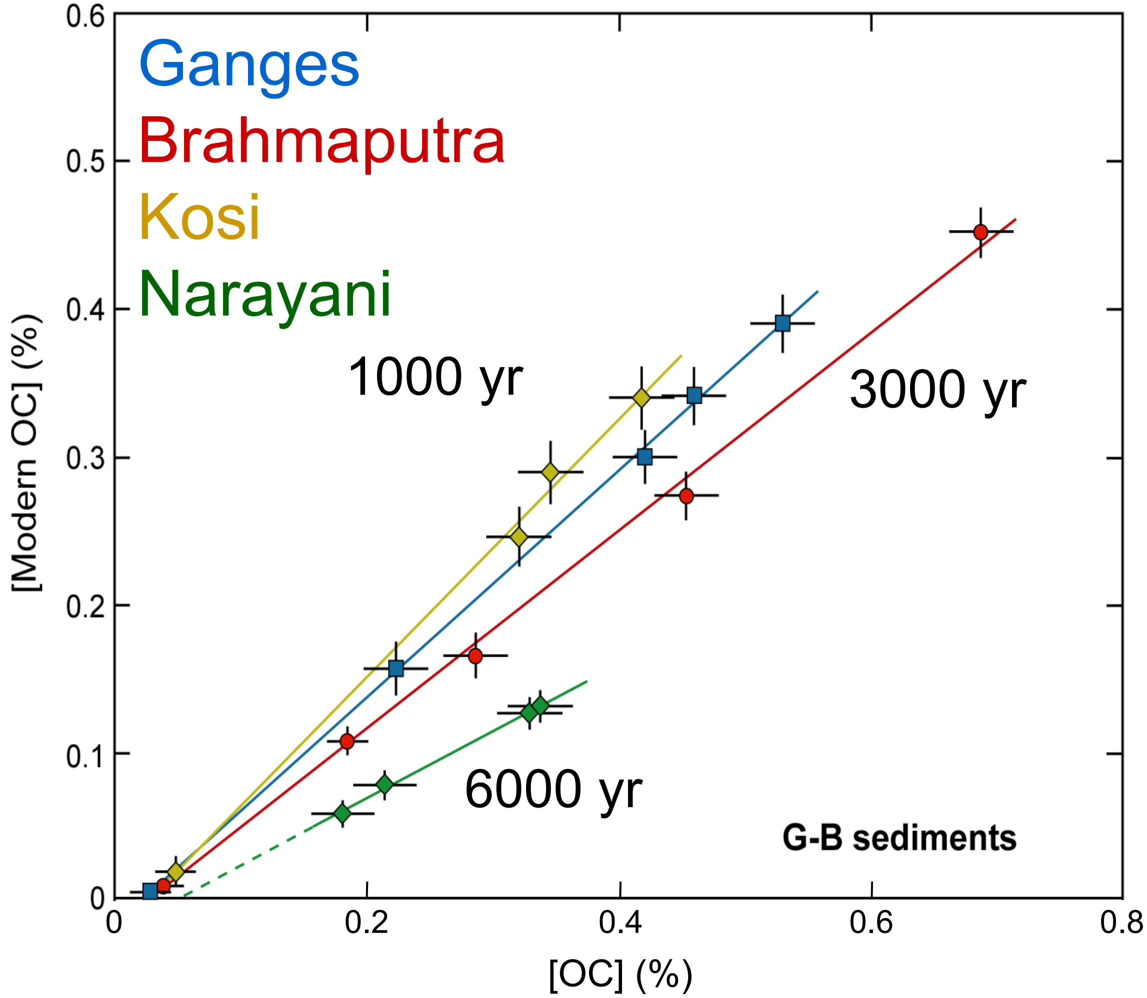
Sediments with same amount of petrogenic C and same age of biospheric C plot on linear trends

Residence time of biospheric C in the G-B system

Depth profiles allow the determination of the age of the biospheric OC

Long residence time of biospheric C

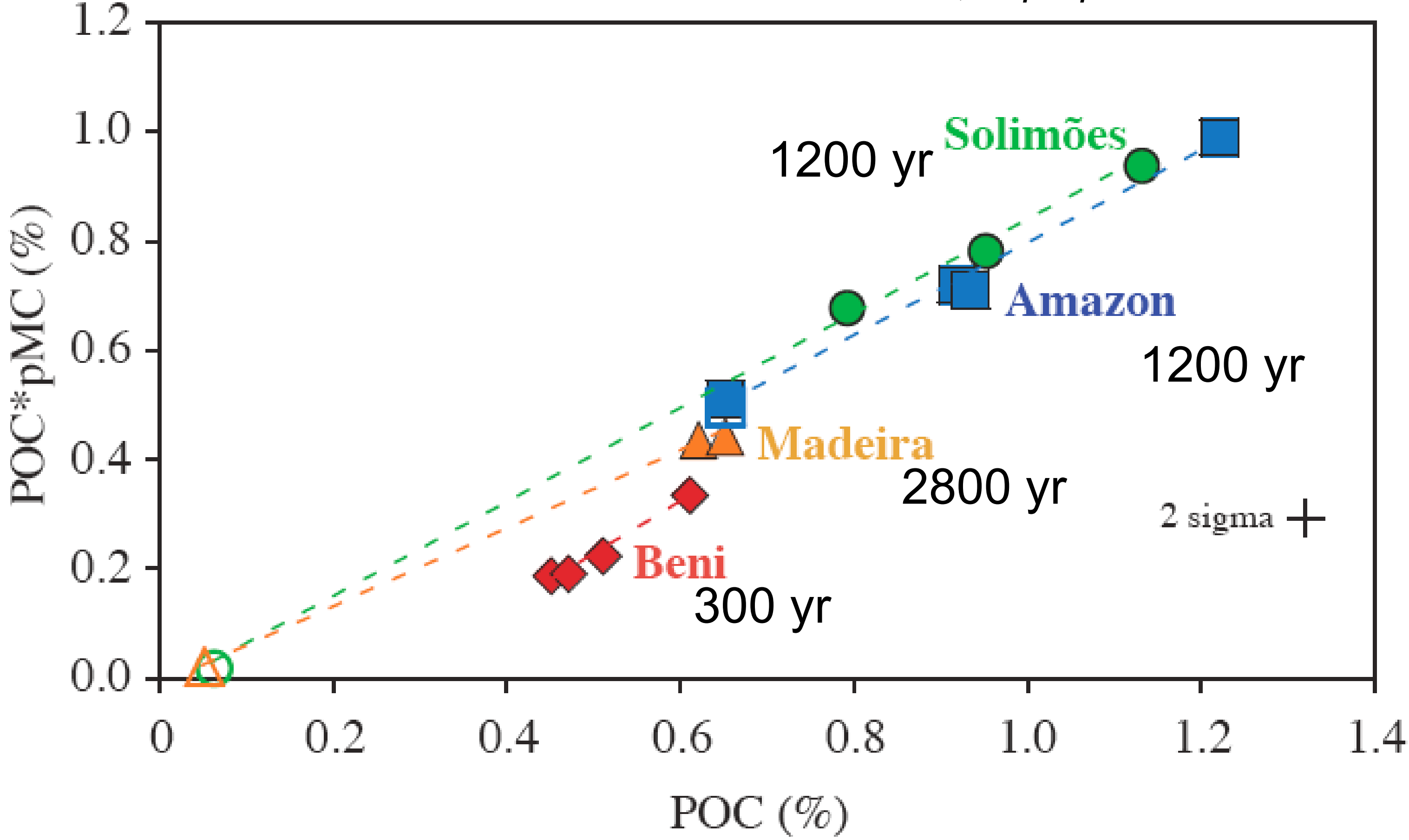
Contribution of pre-aged OC in soils



Galy & Eglinton, Nature geosciences, 2011

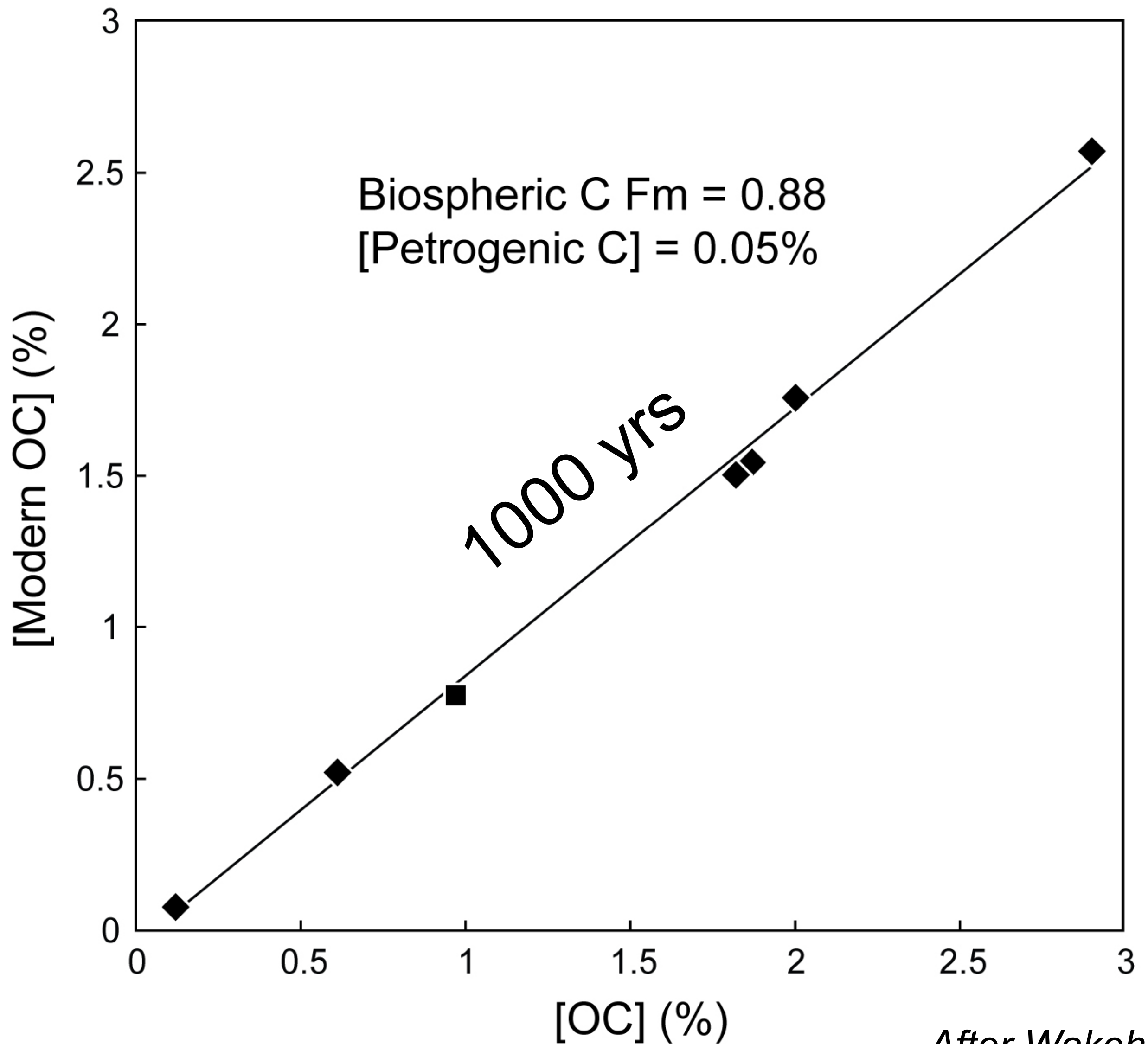
Residence time of biospheric C in the Amazon basin

Bouchez et al., Geology, 2010
Bouchez et al., in prep.



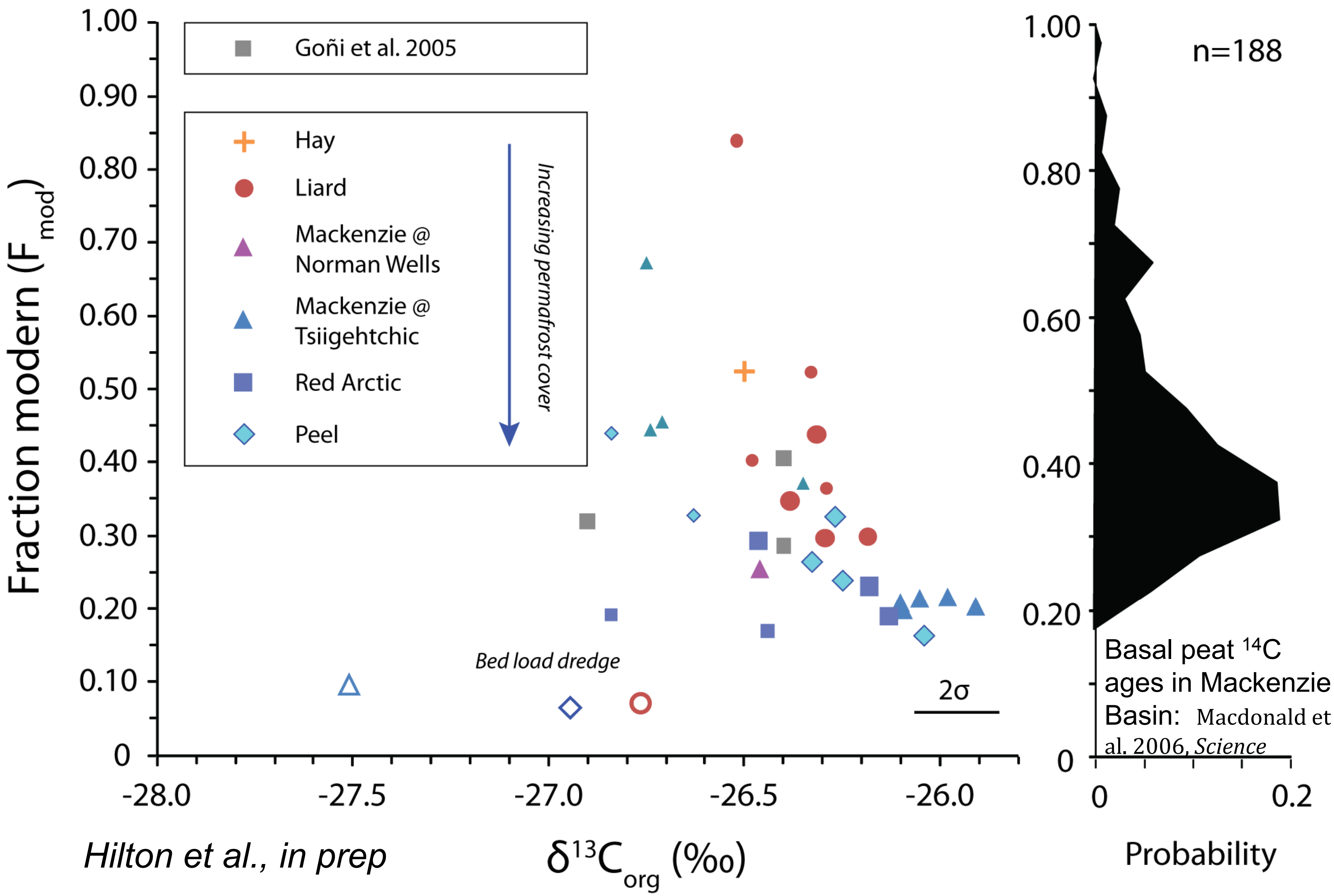
Fairly long residence time in the Amazon floodplain as well!

Residence time of biospheric C in the Mississippi basin

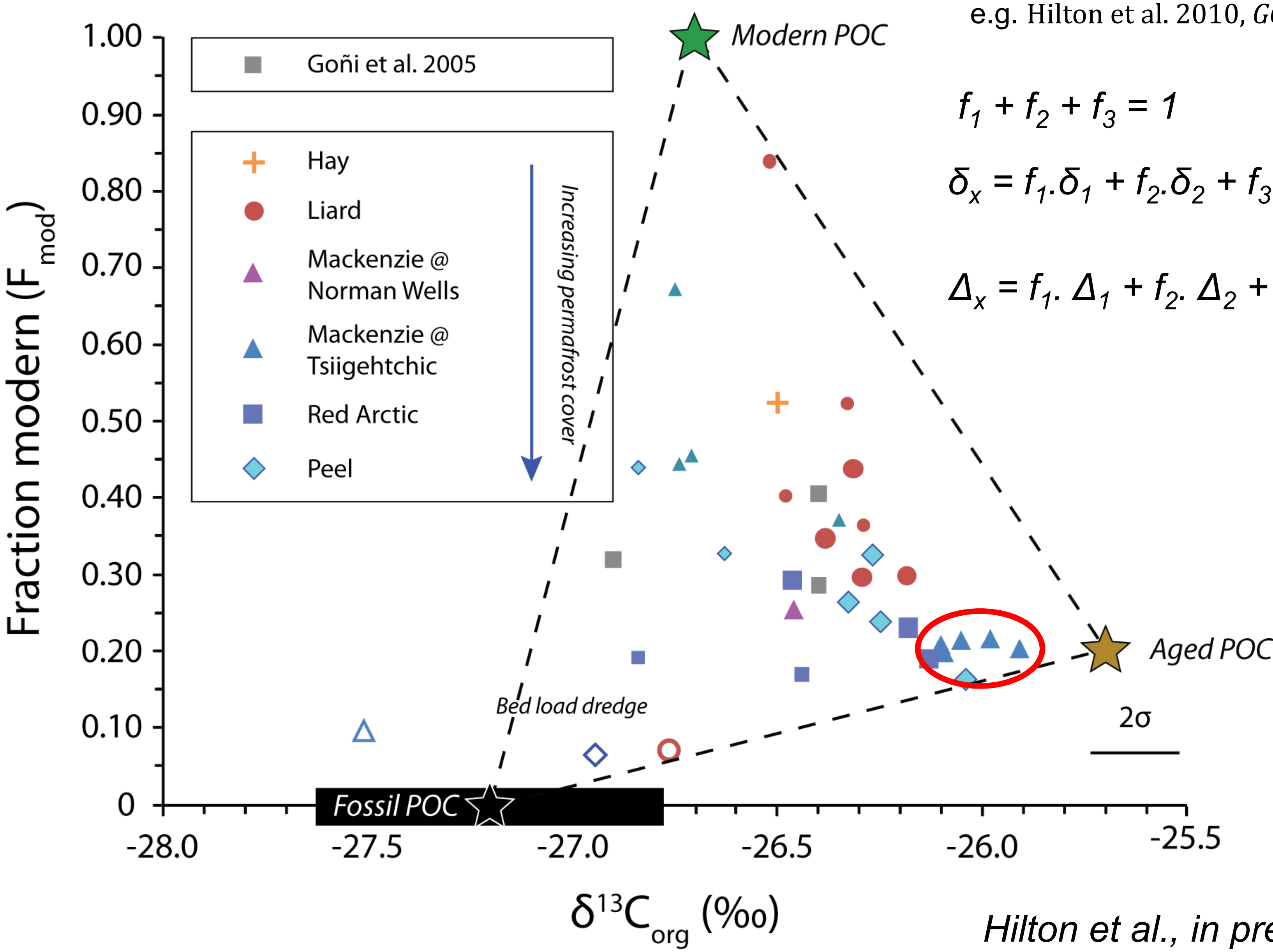


After Wakeham et al., 2009

Using Fm & $\delta^{13}C$ of bulk OC



3 end members mixing model



e.g. Hilton et al. 2010, *GCA*

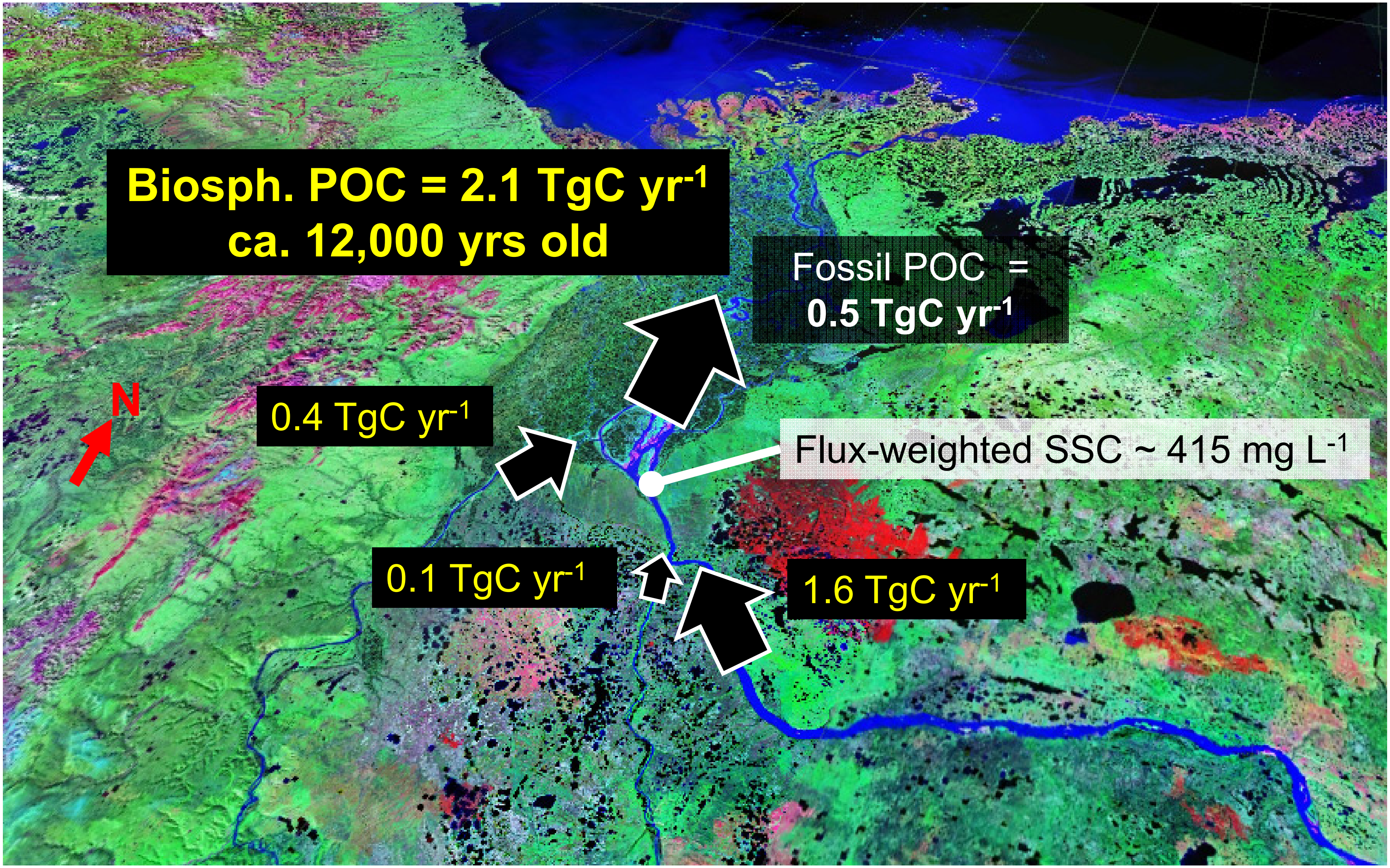
$$f_1 + f_2 + f_3 = 1$$

$$\delta_x = f_1.\delta_1 + f_2.\delta_2 + f_3.\delta_3$$

$$\Delta_x = f_1.\,\Delta_1 + f_2.\,\Delta_2 + f_3.\,\Delta_3$$

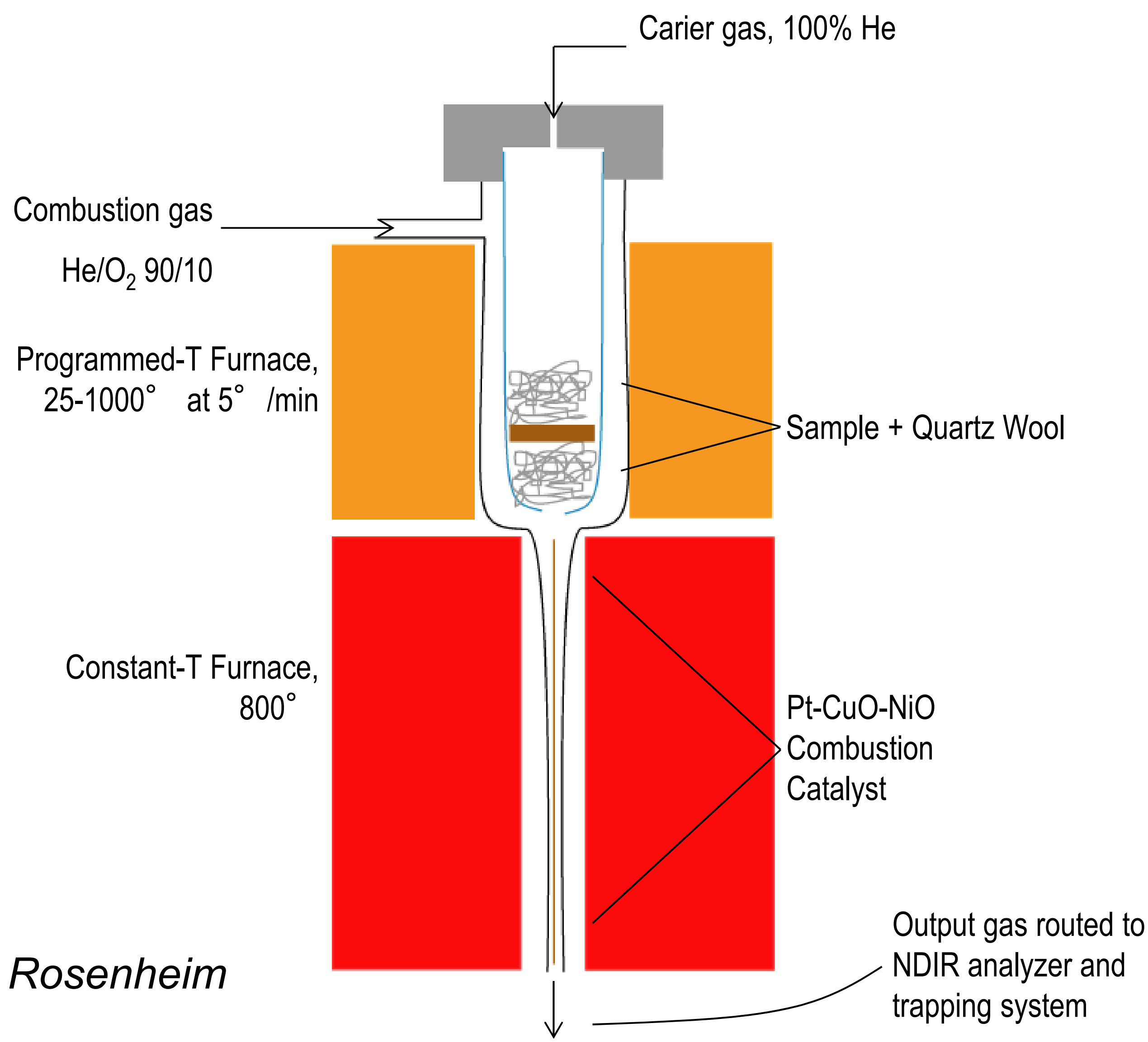
Hilton et al., in prep

Biospheric OC export in the Mackenzie River



Hilton et al., in prep

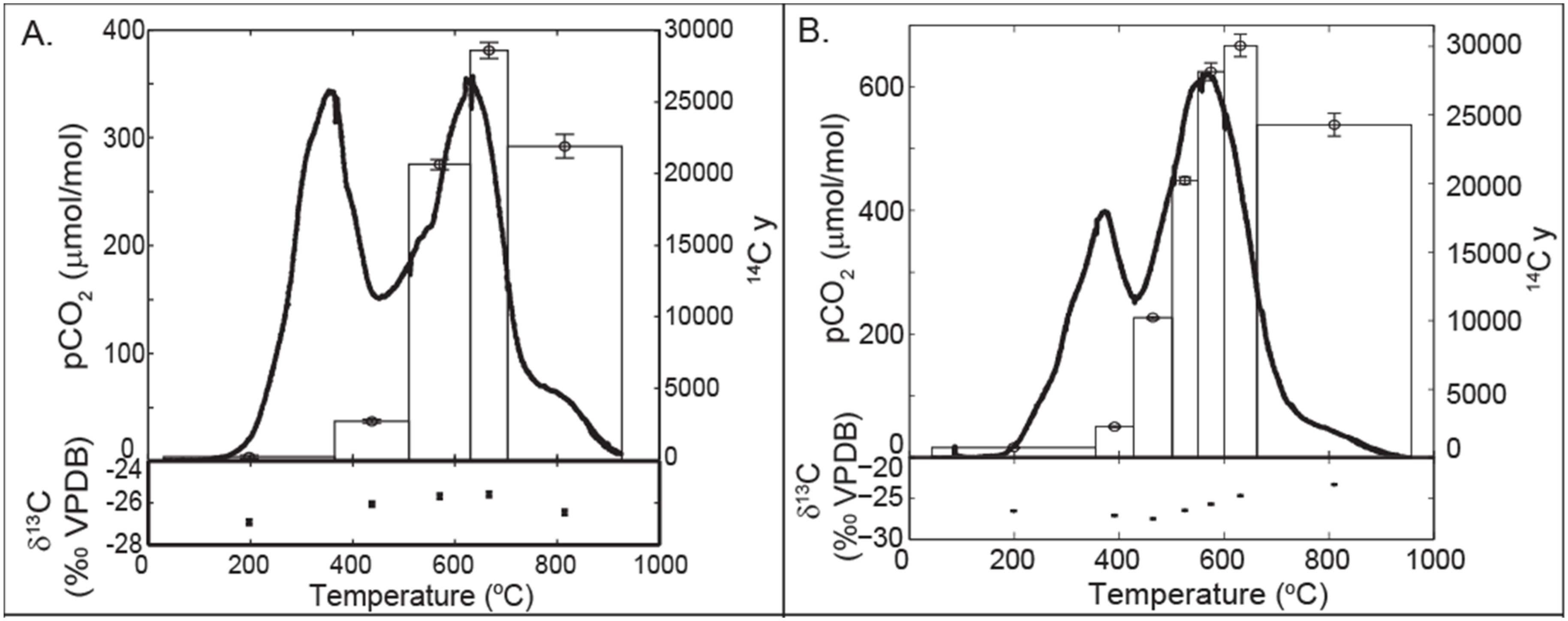
Programmed Temperature Pyrolysis (aka dirt burner)



courtesy B. Rosenheim

An approach to resolution of components of refractory mixtures

Narayani River

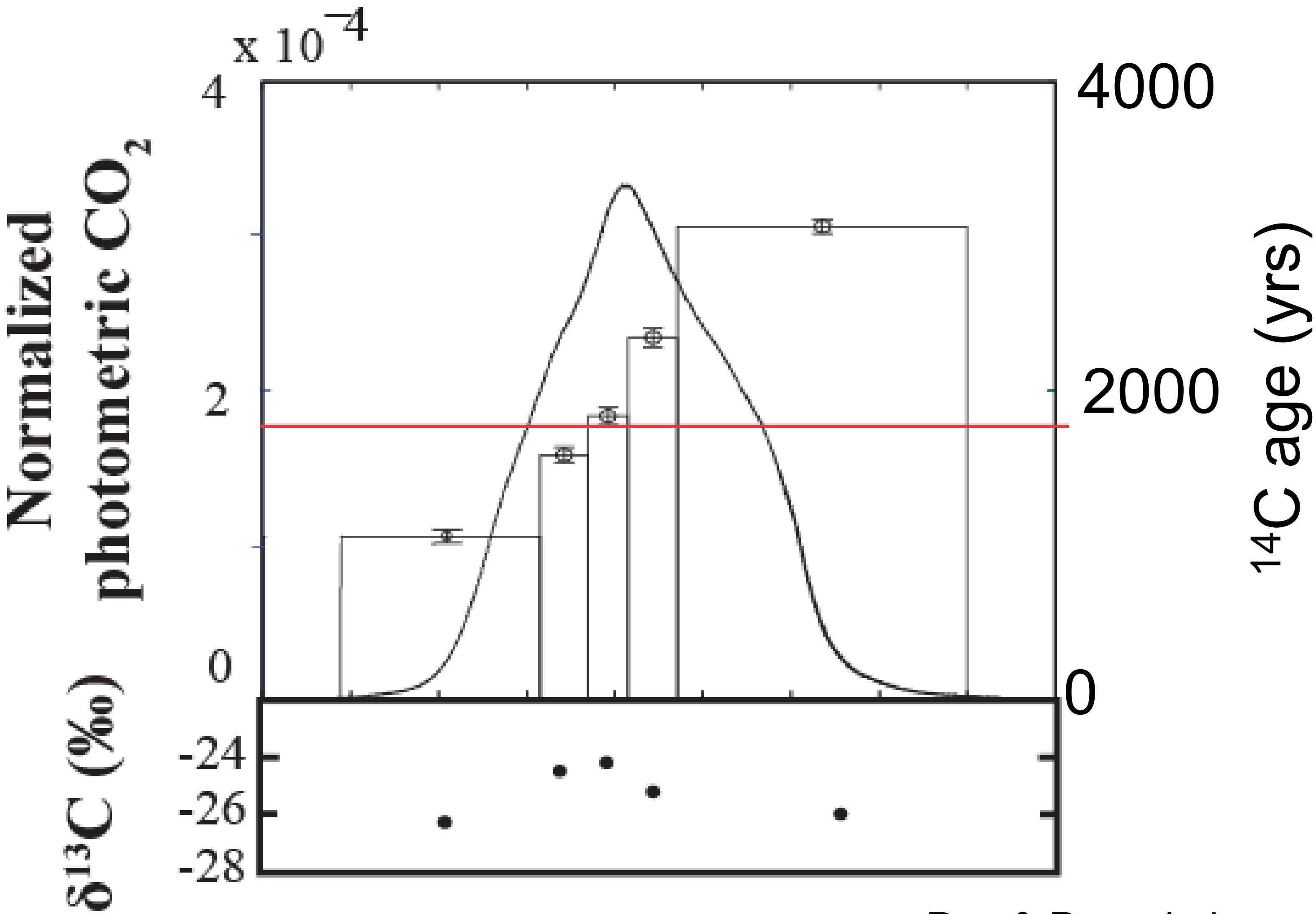


Rosenheim & Galy, in review

Complex mixture of components w/ different thermal reactivity

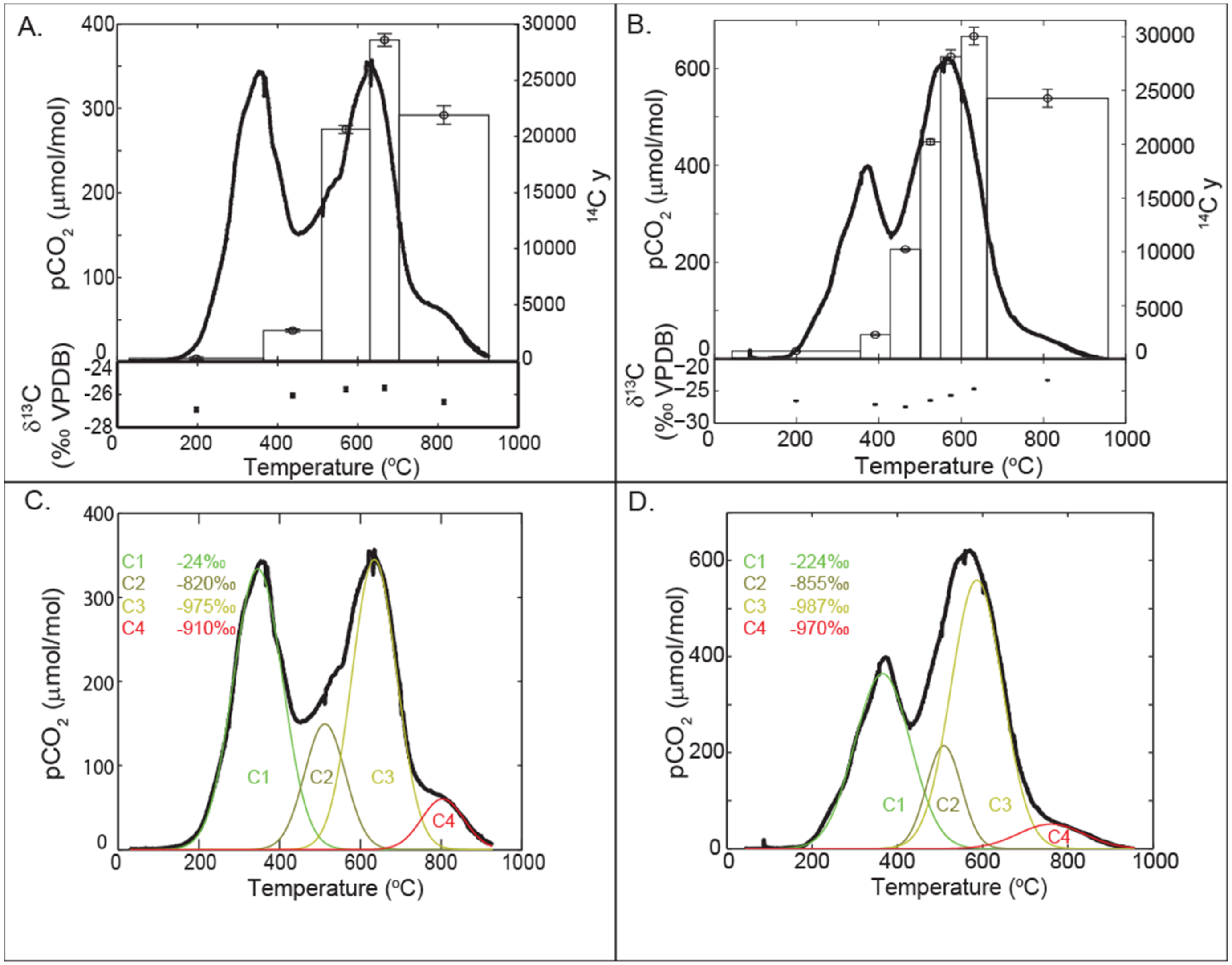
Corresponding variability of age spectrum (100 to 30000 yrs!)

Mississippi River



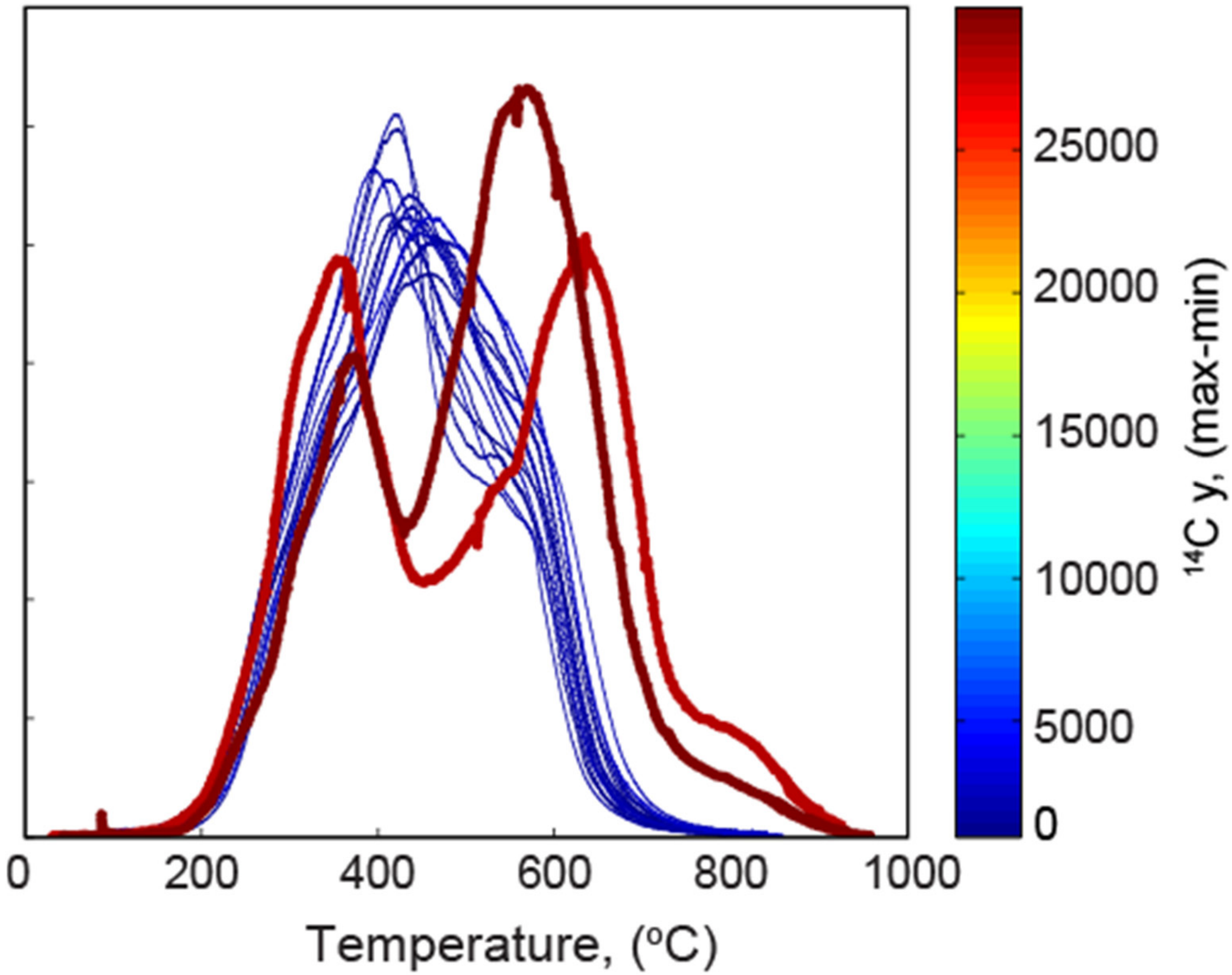
Roe & Rosenheim, accepted

Gaussian deconvolution



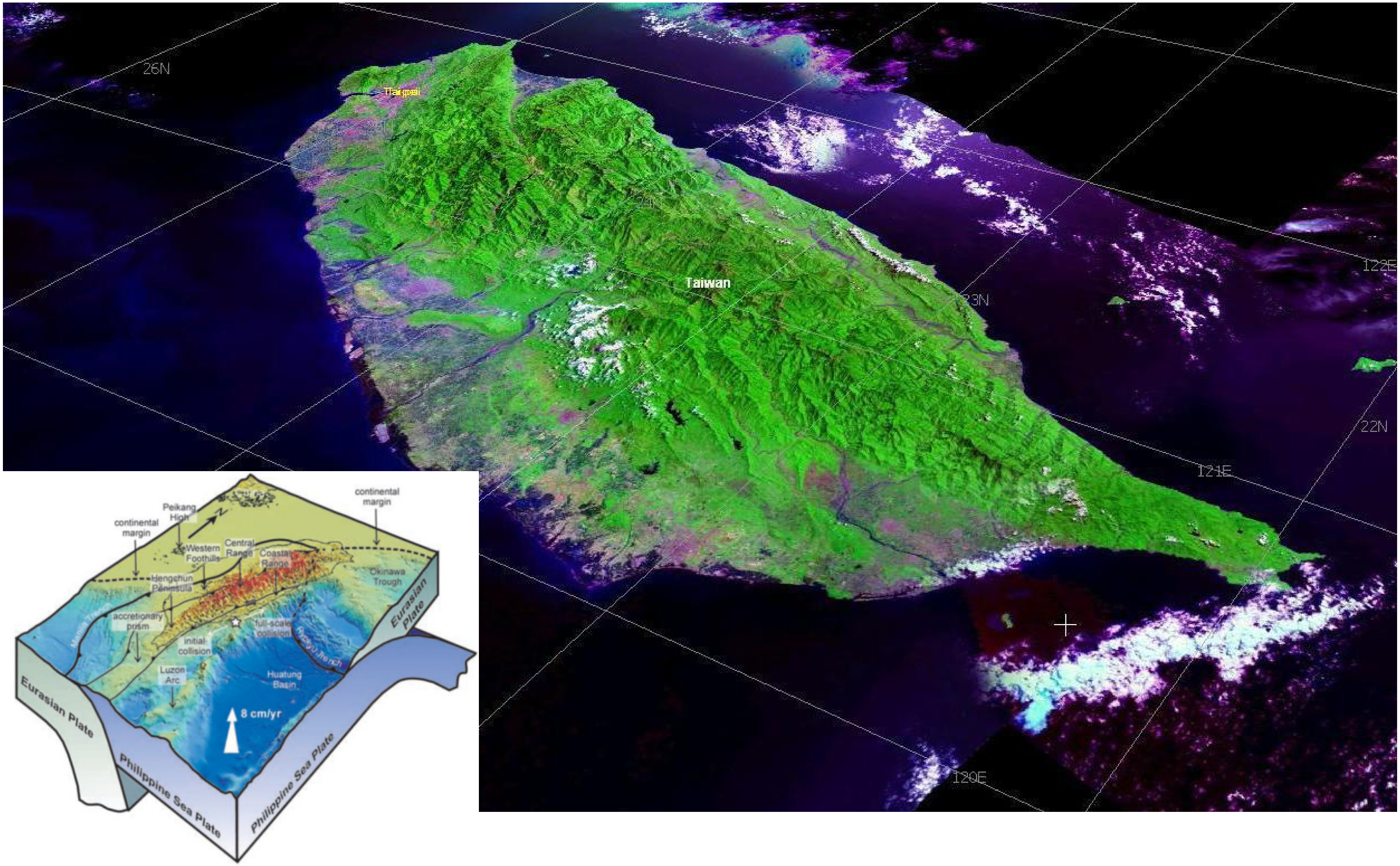
Rosenheim & Galy, in review

Comparing Narayani and Mississippi Rivers

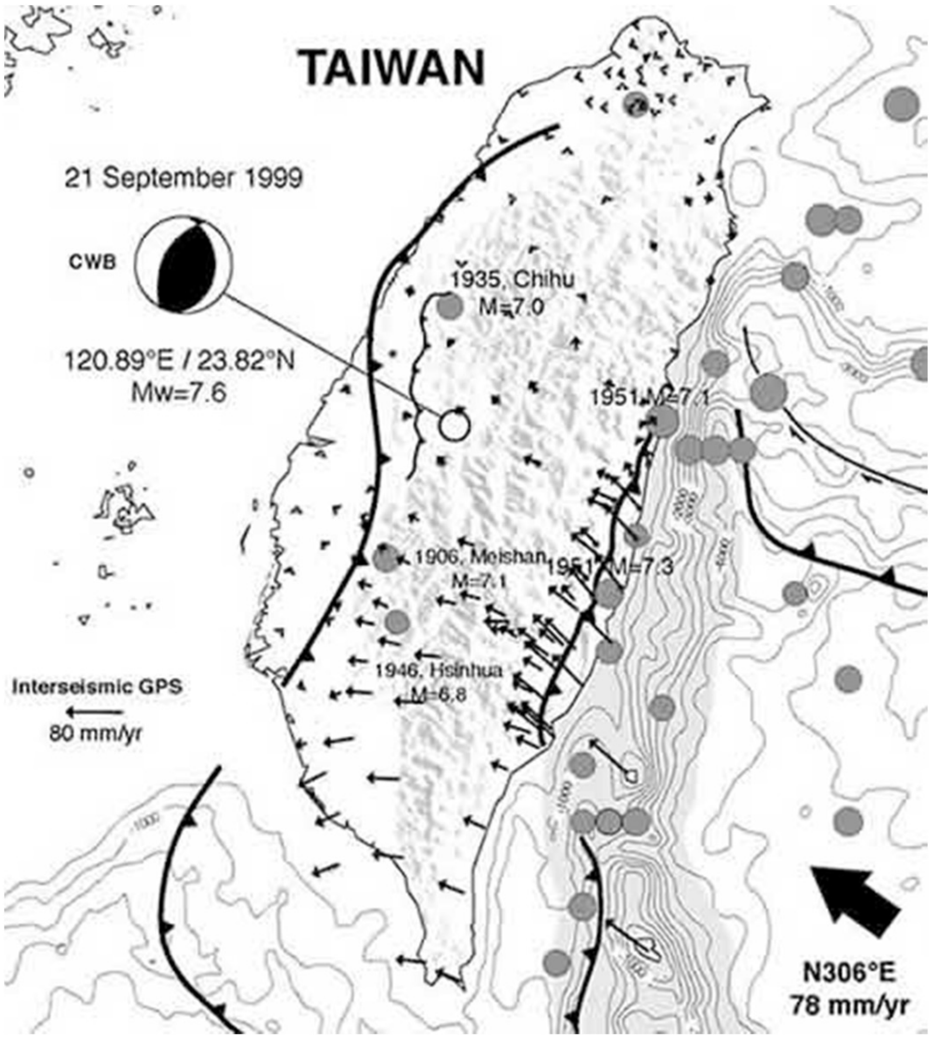


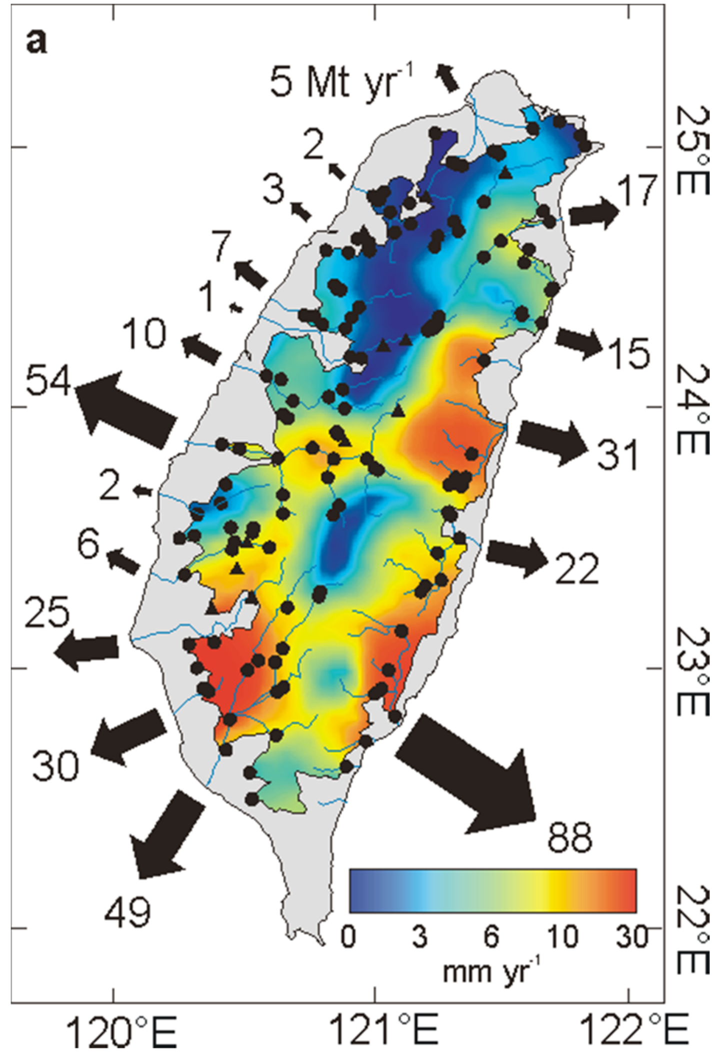
Rosenheim & Galy, in review

SMRI example: Taiwan



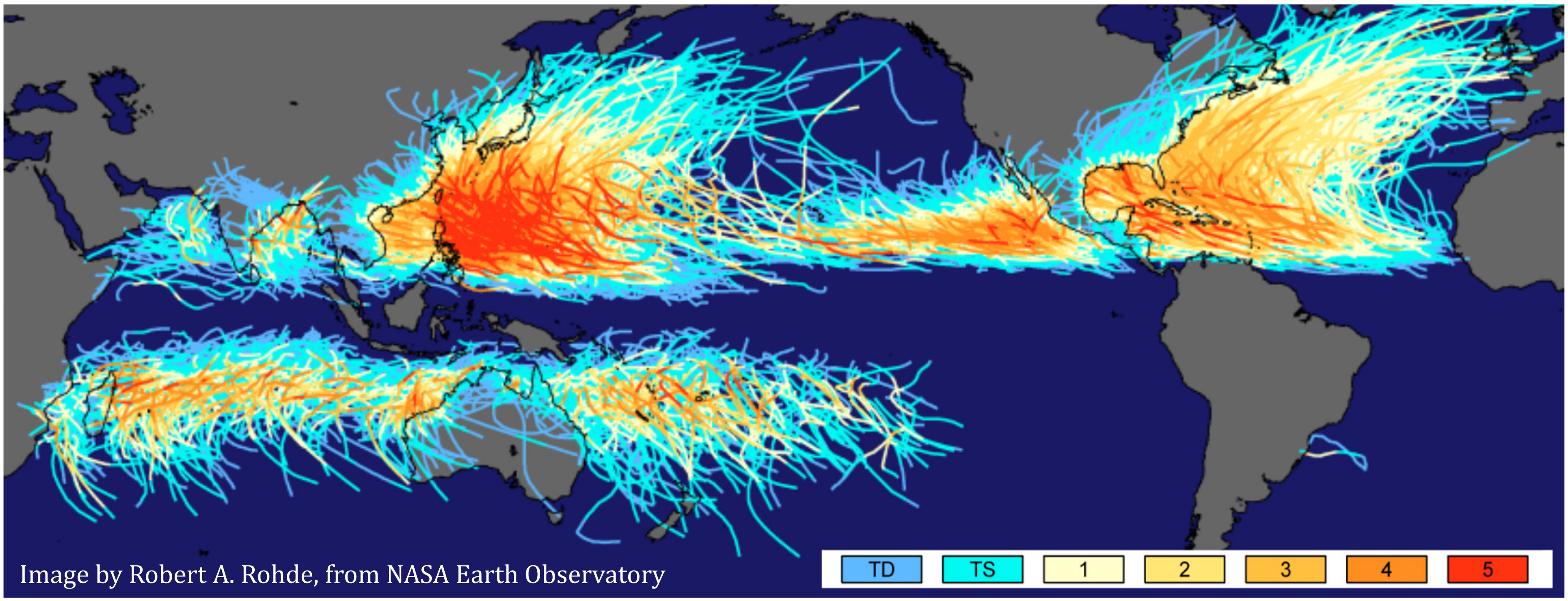
Taiwan: tectonic context





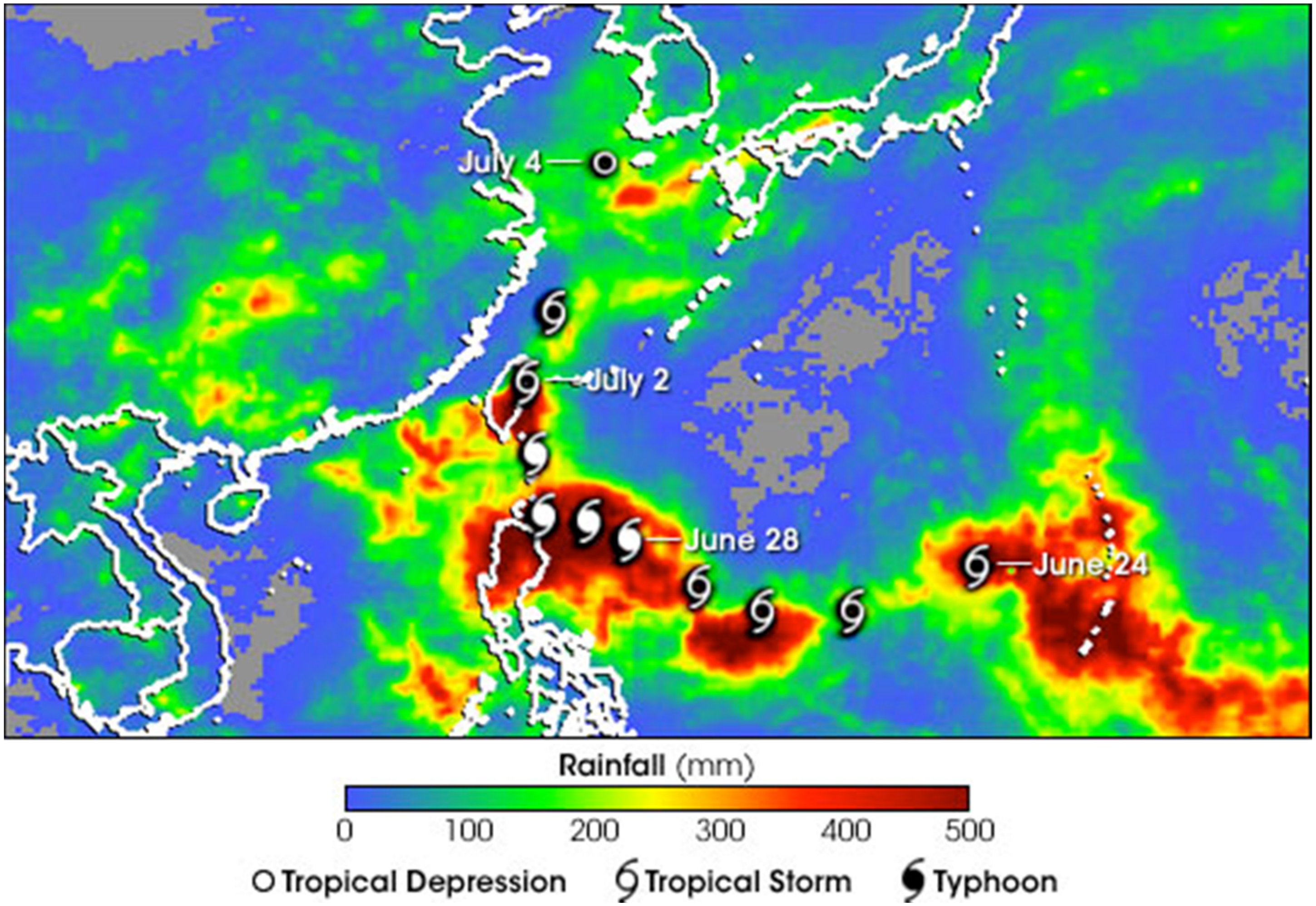
Fast convergence = high relief and fast physical erosion

Taiwan: a strong climate forcing

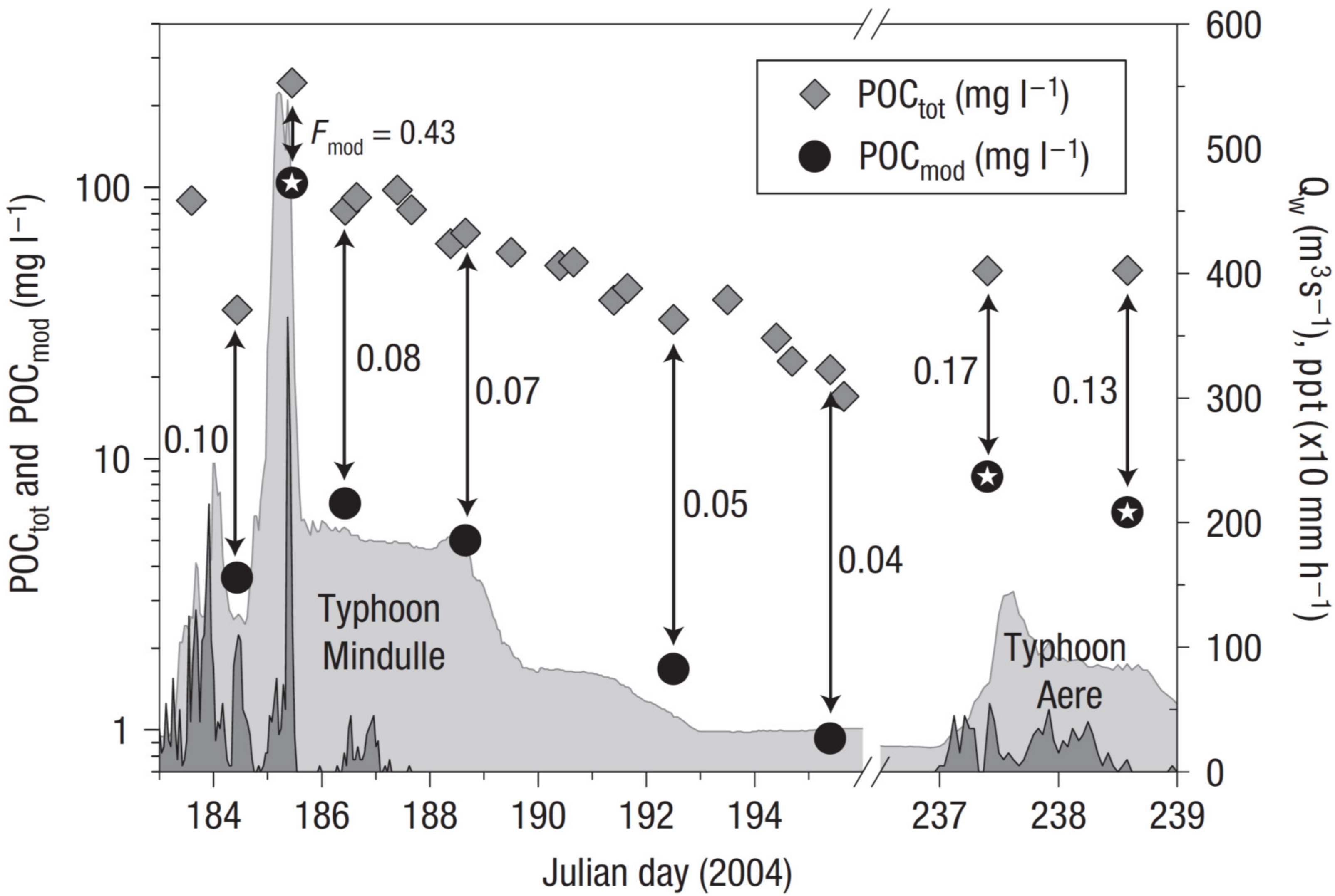


Hurricane pathway and intensity

OC export during extreme events: typhoon Mindulle

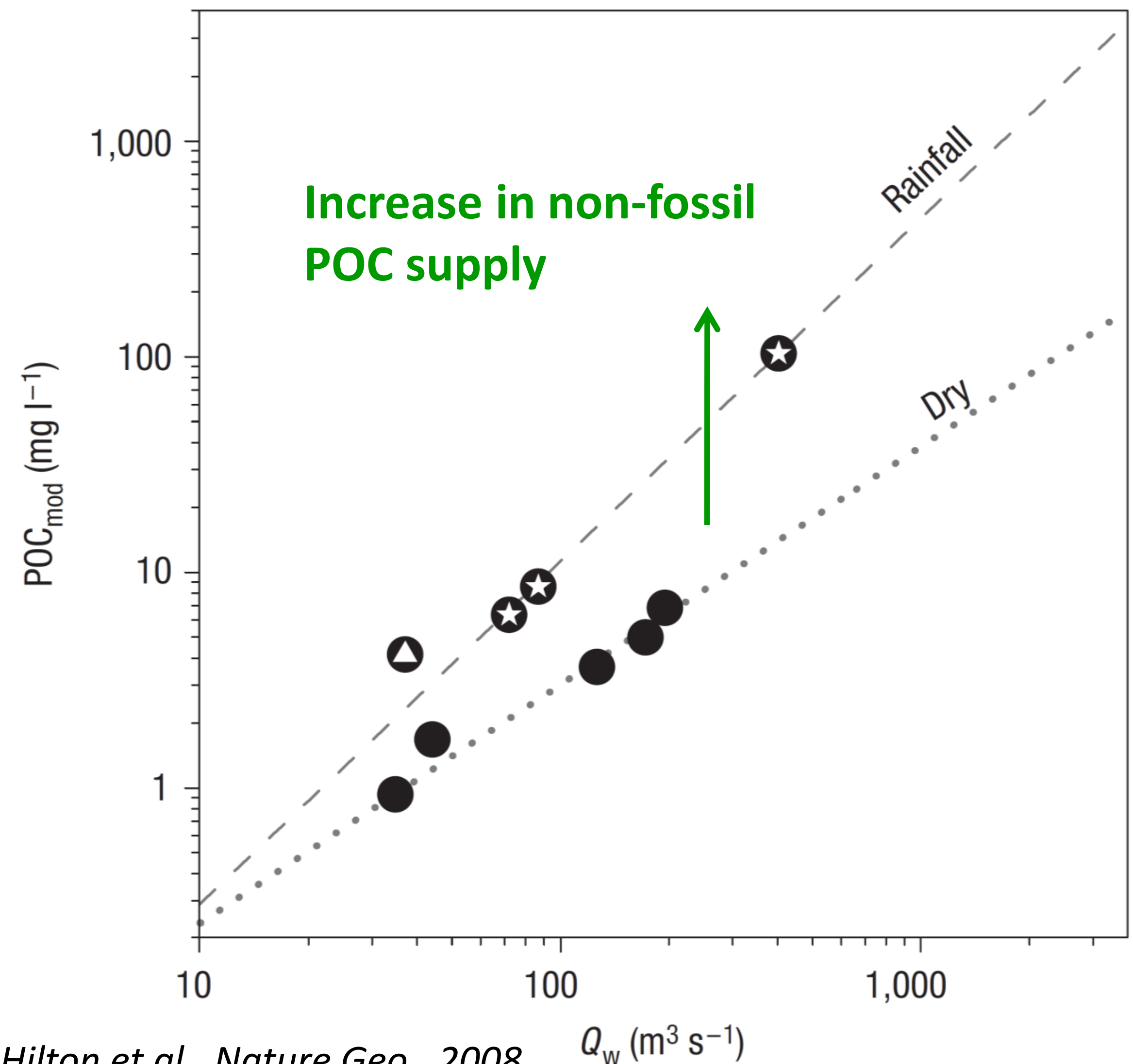


OC export during typhoon Mindulle



Hilton et al., Nature Geo., 2008

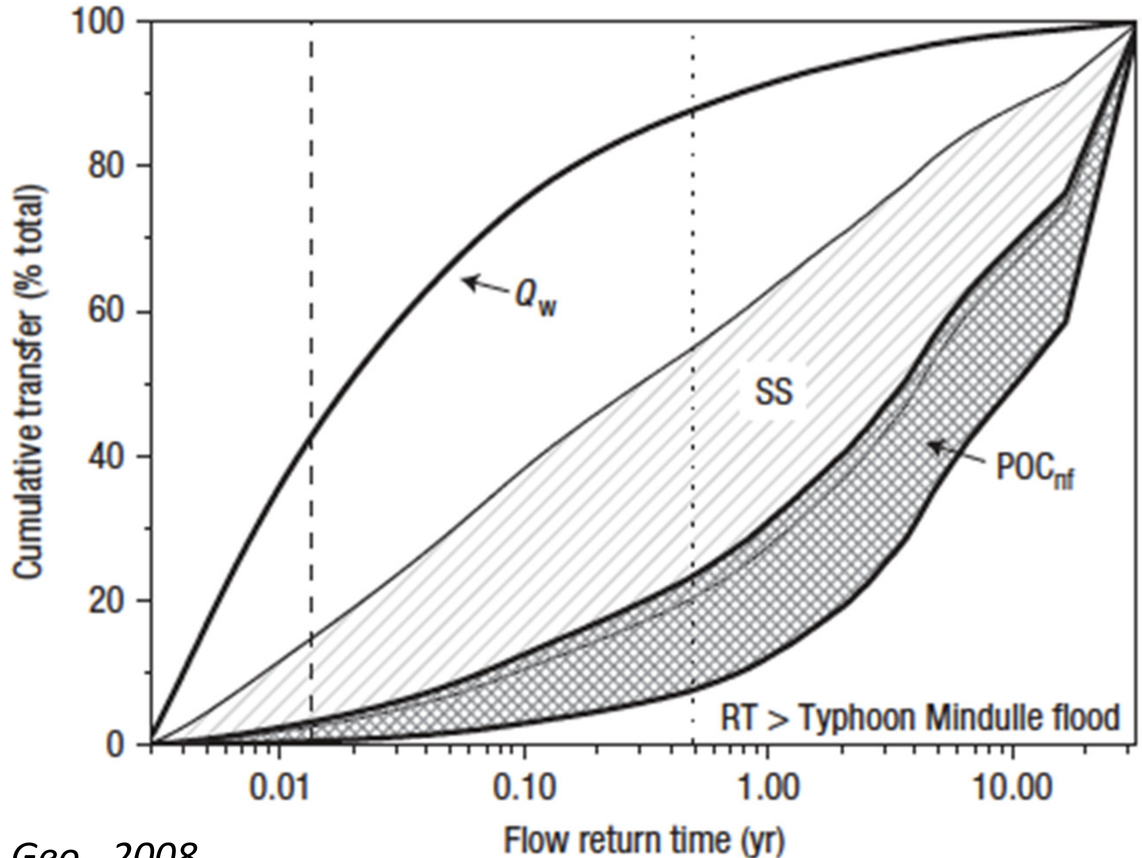
OC export during typhoons



Hilton et al., Nature Geo., 2008

- Water discharge (Q_w, m^3 s^{-1}) positively correlated with non-fossil POC load.
- Strong climate control on POC transfer

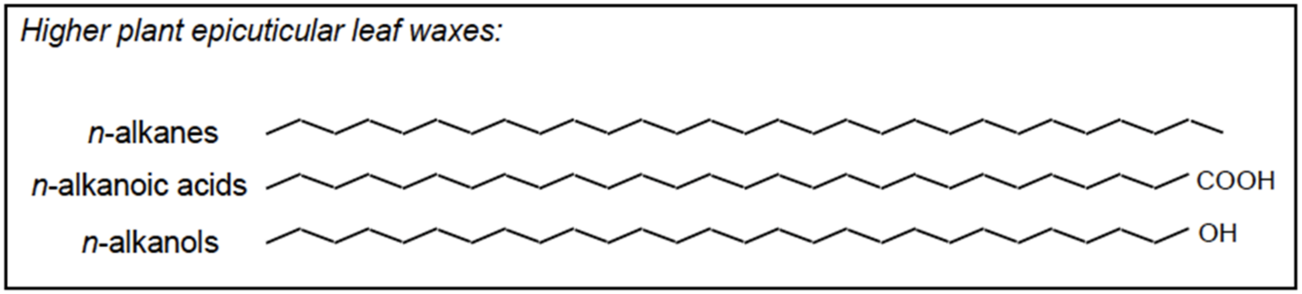
Overall significance of typhoons: a climate control of OC export

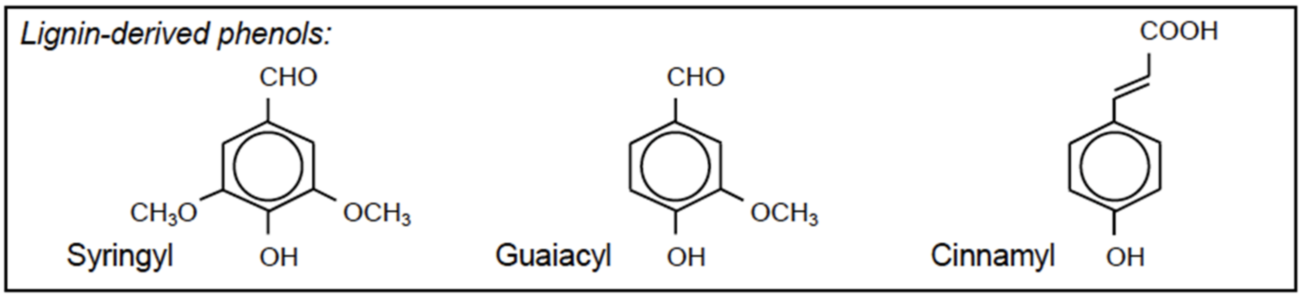


Hilton et al., Nature Geo., 2008

Large typhoons account for most of biospheric C export in Taiwan
Climate controls OC cycling

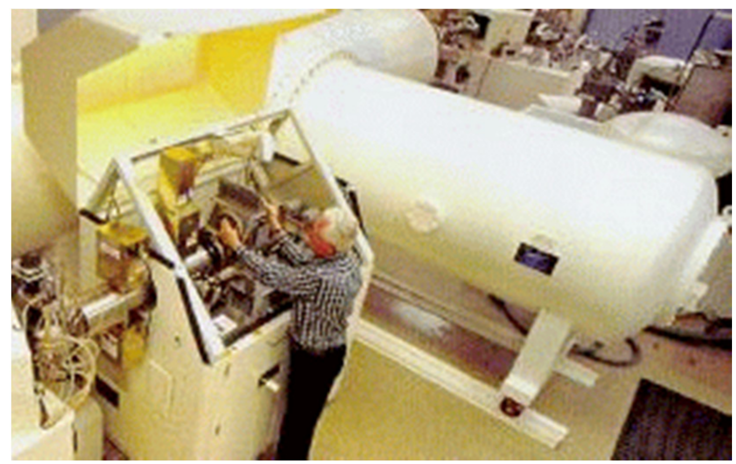
OC residence time: insights from isotopic analysis of biomarkers





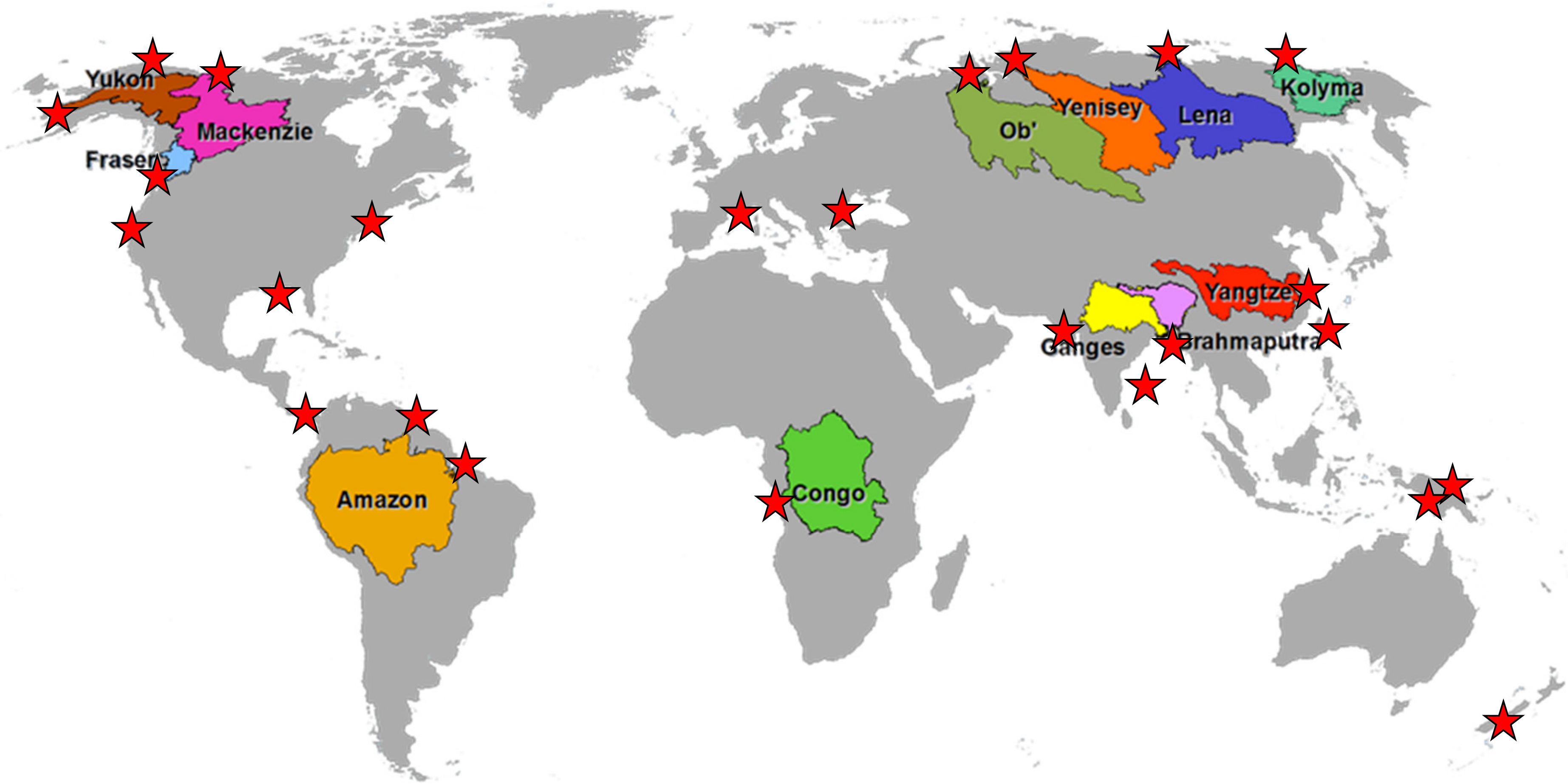
$\delta^{13}C$: source

δD: aridity proxy

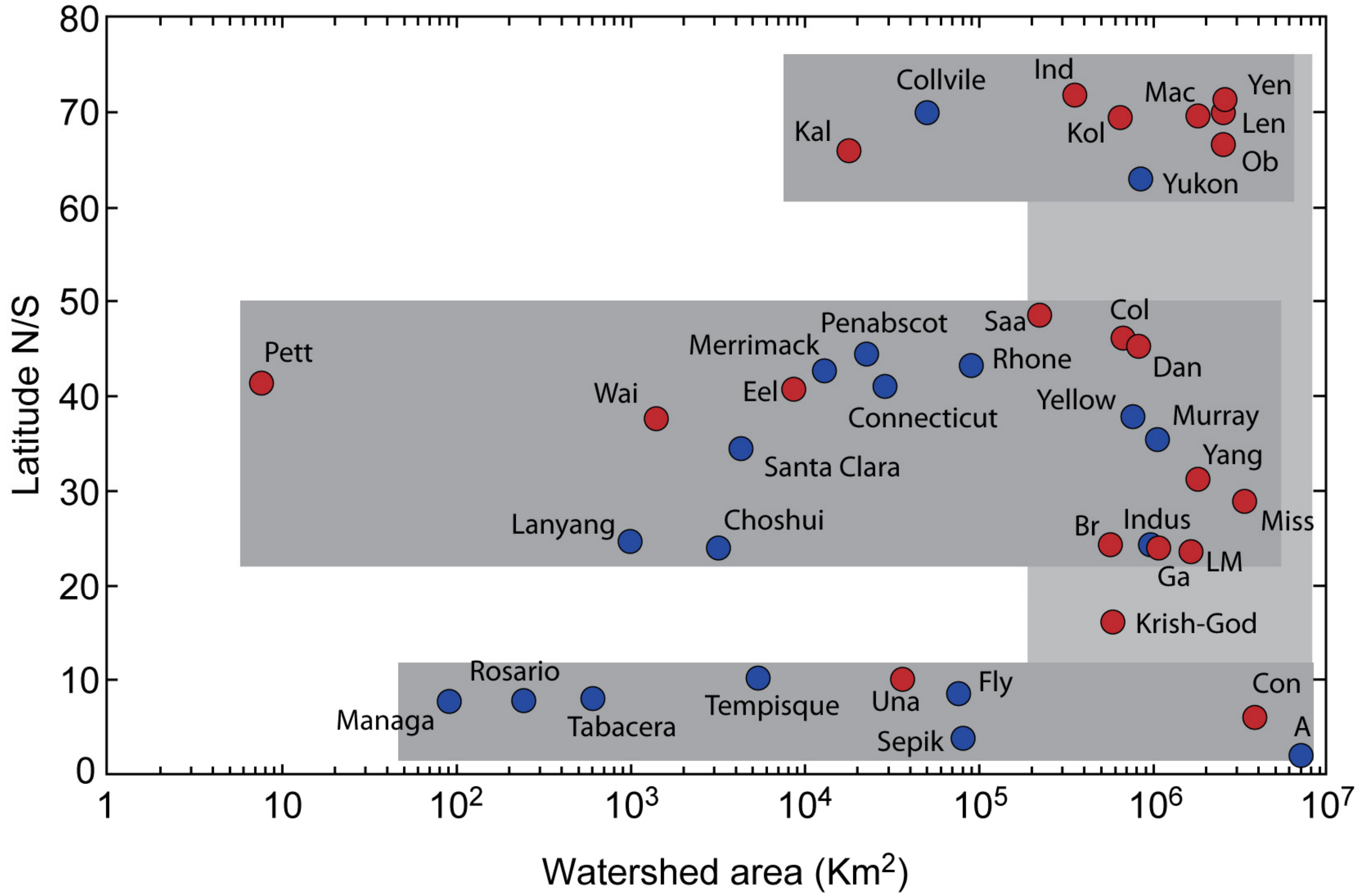


$\Delta^{14}C$: residence time

Global Rivers Observatory Network



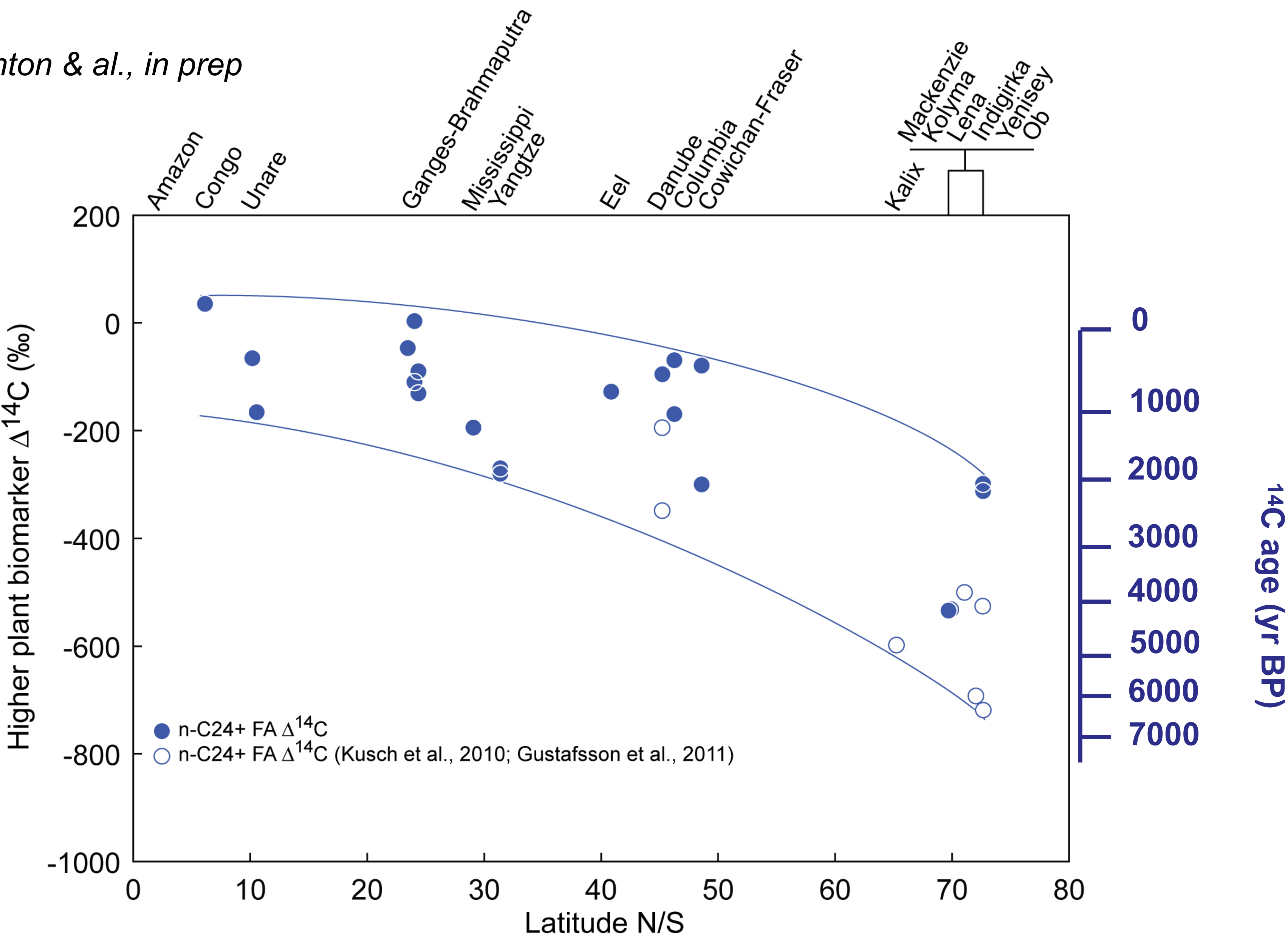
Spatial coverage



Kal = Kalix
Ind = Indigirka
Kol = Kolyma
Mac = Mackenzie
Yen = Yenisey
Len = Lena
Saa = Fraser + Cowishan (Saanich Inlet)
Col = Columbia
Dan = Danube
Wai = Waiapu
Pett = Petaquamscutt
Yang = Yangtze
Miss = Mississippi
LM = Lower Meghna
Ga = Ganges
Br = Brahamputra
Krish-God = Krishna + Godavari
Una = Unare
Con = Congo
A = Amazon

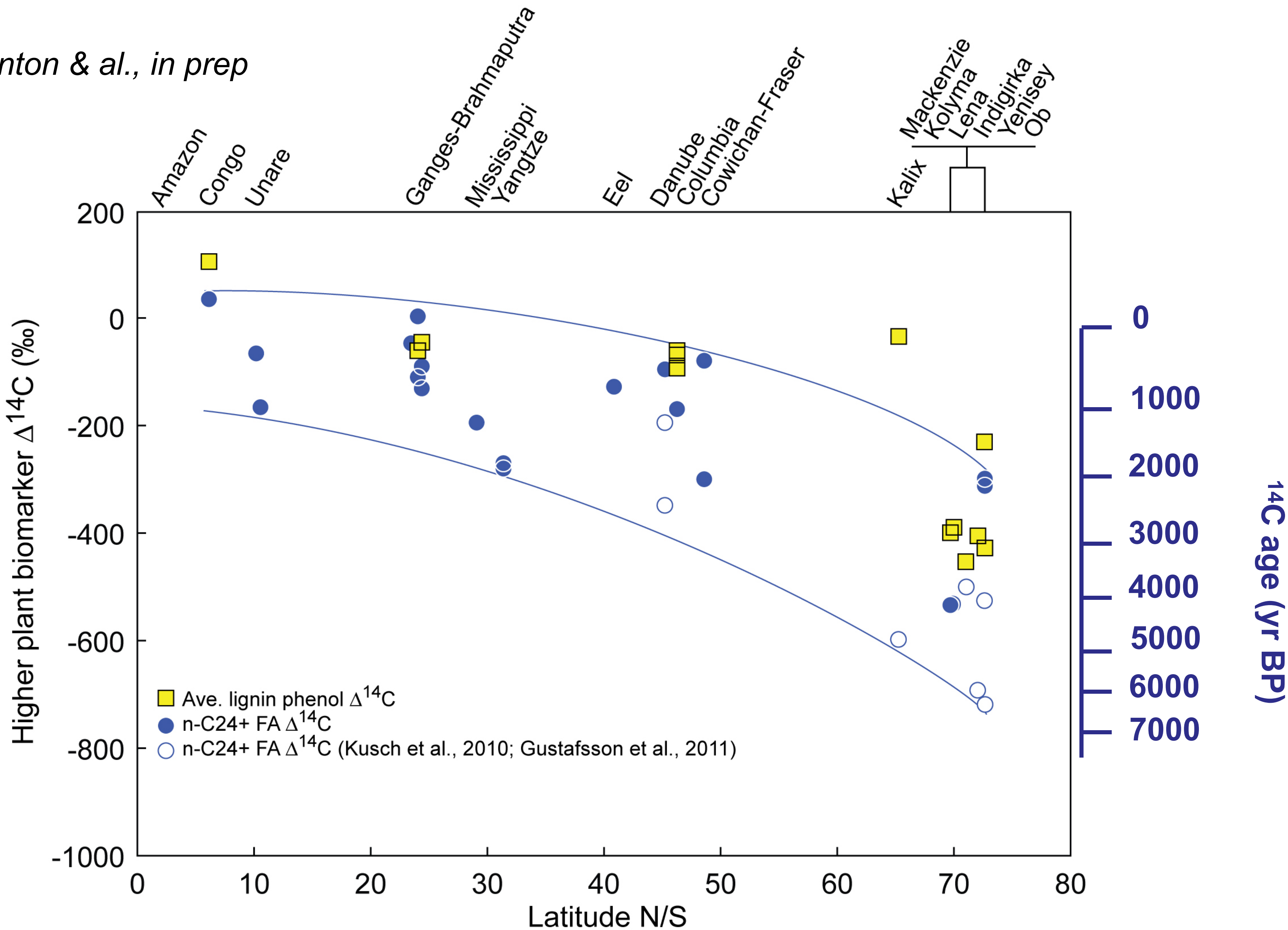
Latitudinal variation of terrestrial OC residence time

Eglinton & al., in prep

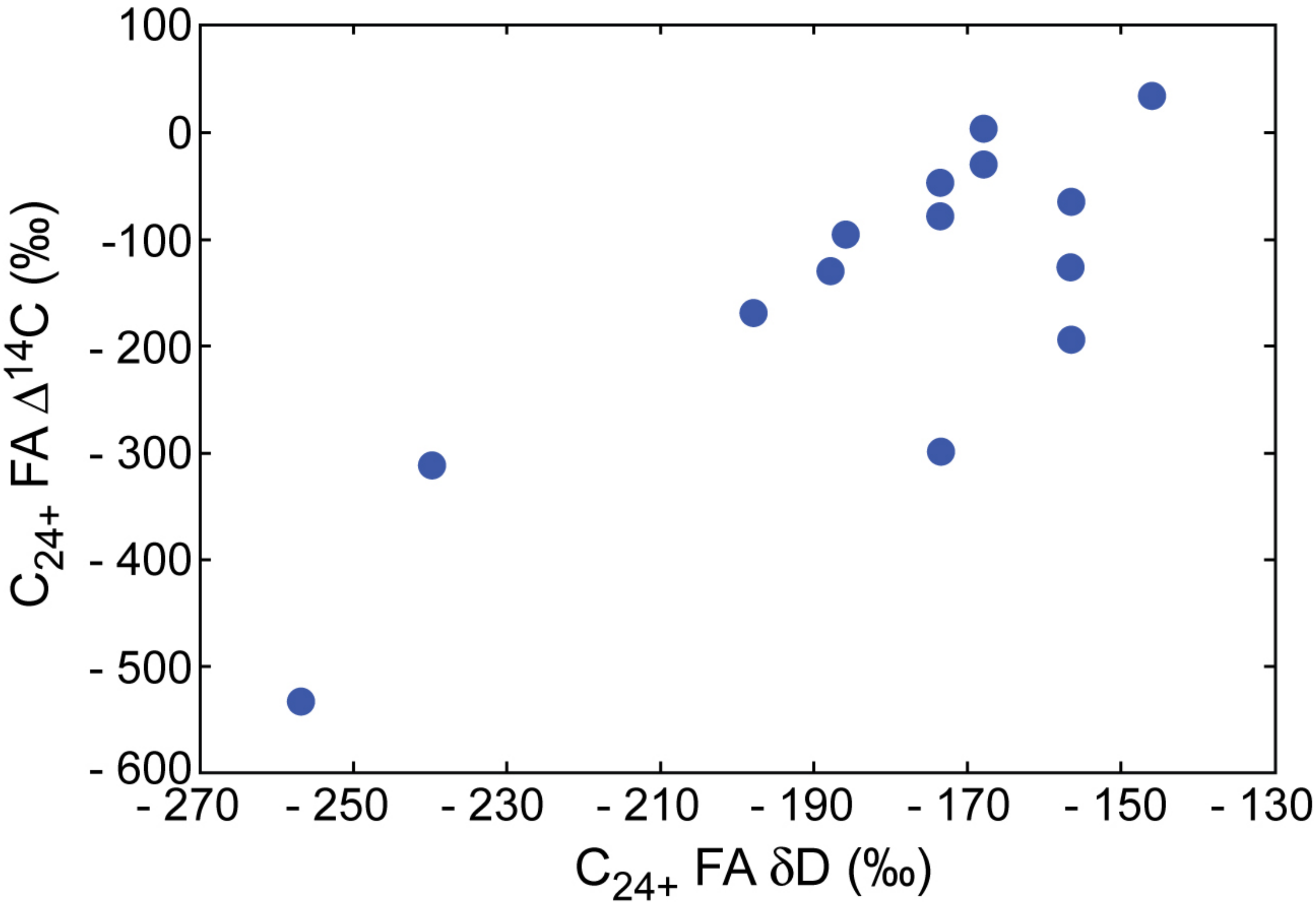


Latitudinal variation of terrestrial OC residence time

Eglinton & al., in prep



Residence time and environmental proxies: a climatic control



Eglinton & al., in prep

Take home messages:

1)POC delivered by rivers to the ocean is a mixture of components characterized by contrasted age and reactivity. These components play contrasted role in the C cycle.

2)Isotopic methods allow disentangling this complex mixture (i.e. quantify and characterize each components)

3)Climate exerts a first order control on the dynamics of POC export to the ocean, both in large tropical rivers and in SMRI

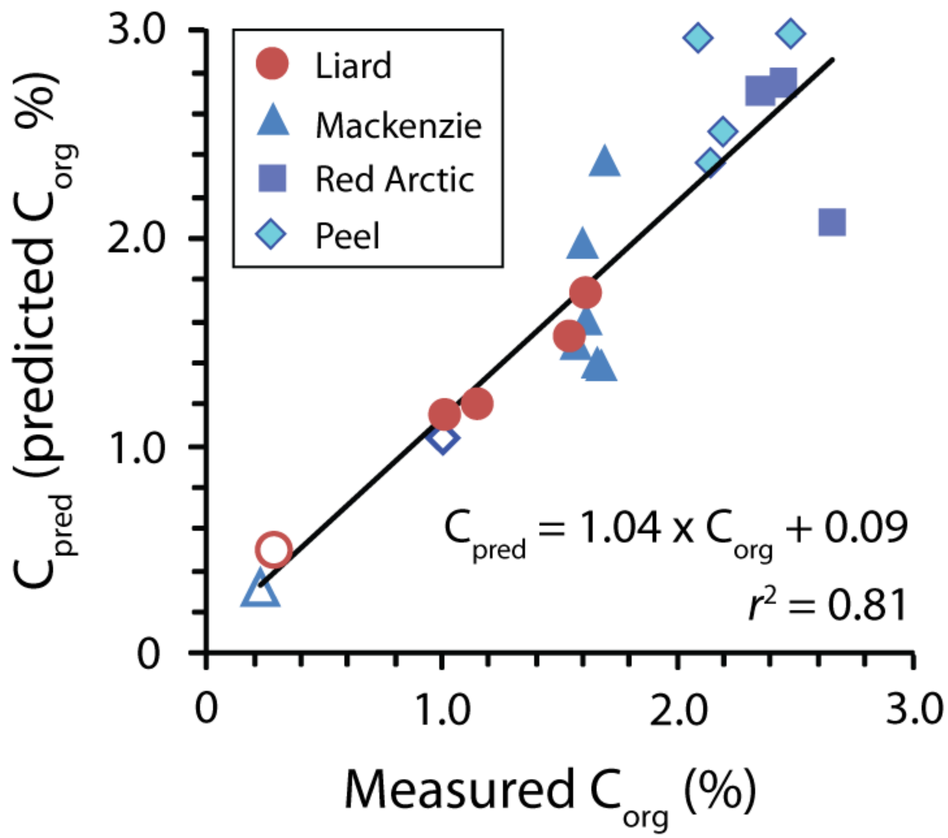
Acknowledgments

T. Eglinton, B. Peucker-Ehrenbrink, B. Rosenheim, C. France-Lanord, J. Gaillardet, R. Hilton, A. Galy, O. Beyssac, T. Bianchi, C. Rabouille, M. Goni, R. M. Holmes, J. Zhang, Y. Wu, NOSAMS staff, C. Johnson, S. Sylva, D. Montlucon and many others!!

OCE - Chemical Oceanography
Emerging Topics in Biogeochemical Cycles

and thank you for your attention!

Testing the end member mixing model

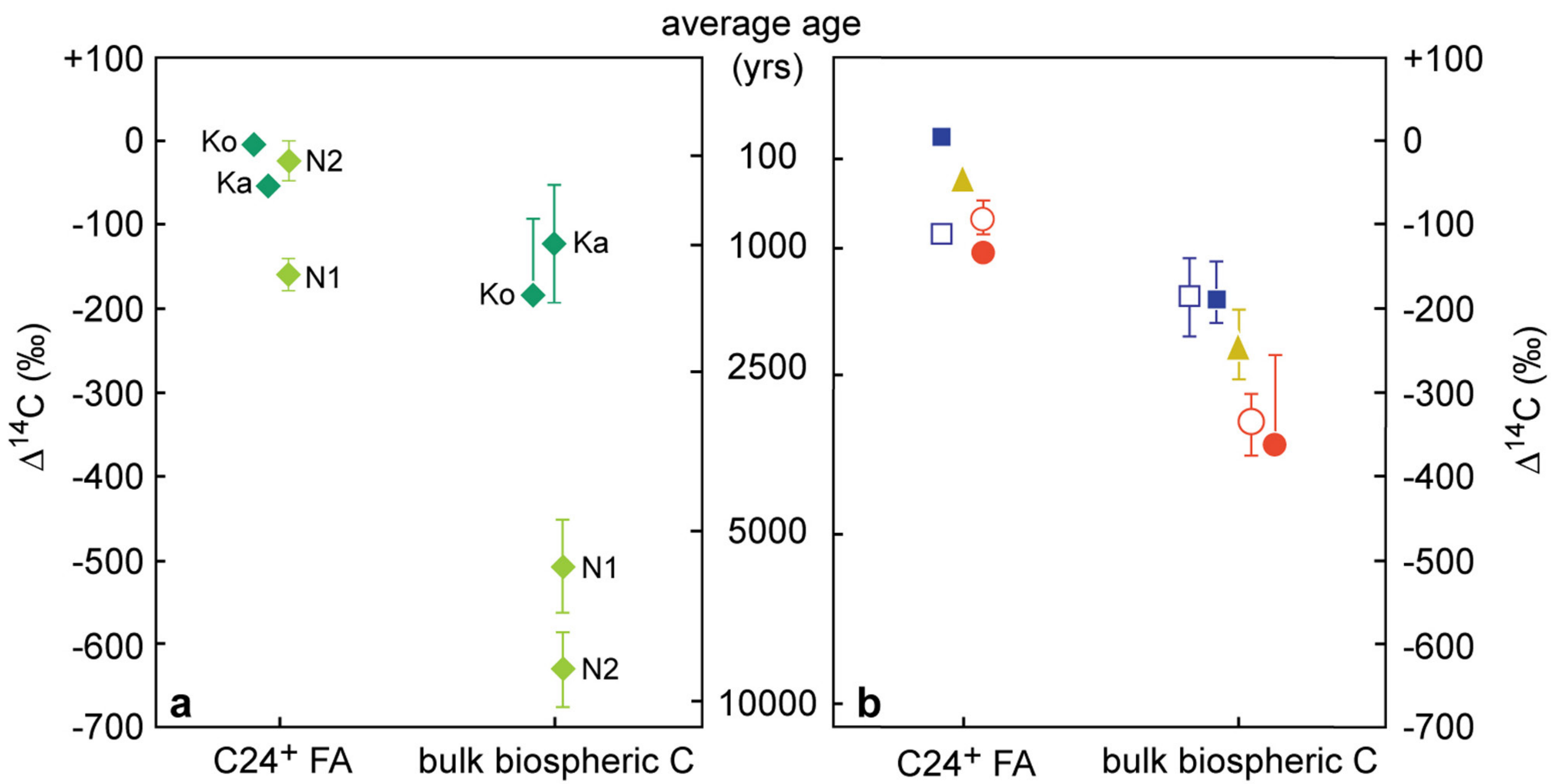


End member	$\delta^{13}C_{org}$ ‰	F_{mod}	C_{org} %
Modern POC	-26.7	1.0	**30**
Aged POC	-25.7	0.2	**10**
Fossil POC (Mac & Liard)	-27.2	0	**0.4**
Fossil POC (Peel & Red)	-27.2	0	**0.9**

Hilton et al., in prep

^{14}C composition of vegetation biomarkers

Galy & Eglinton
Nature Geoscience, 2011



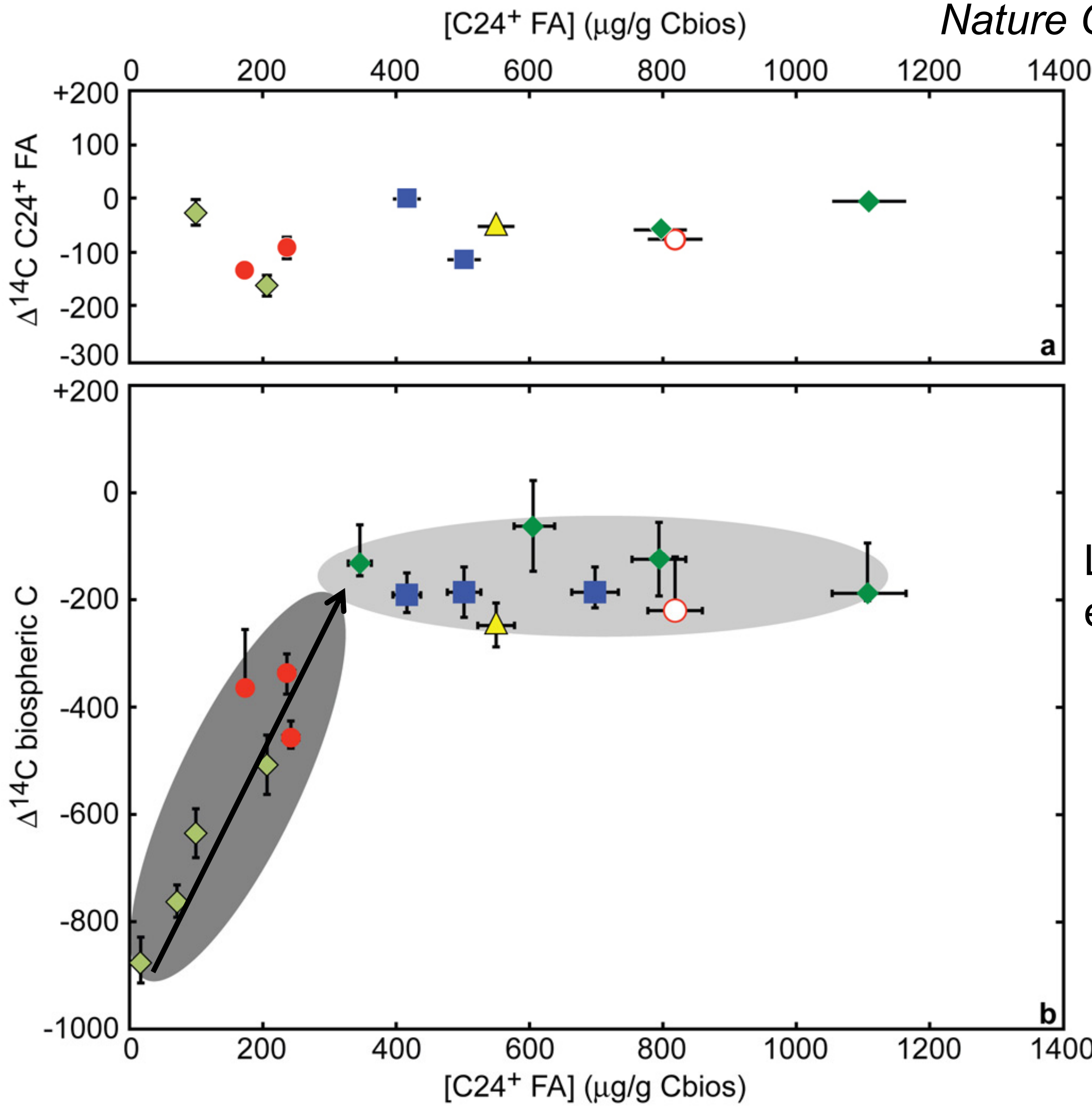
Vascular plants biomarkers are much younger than bulk biospheric C

Residence time of the vegetation component is not homogenous at the basin scale

Presence of a refractory component with longer residence time than bulk biospheric C

Residence time of the refractory component

Galy & Eglinton
Nature Geoscience, 2011

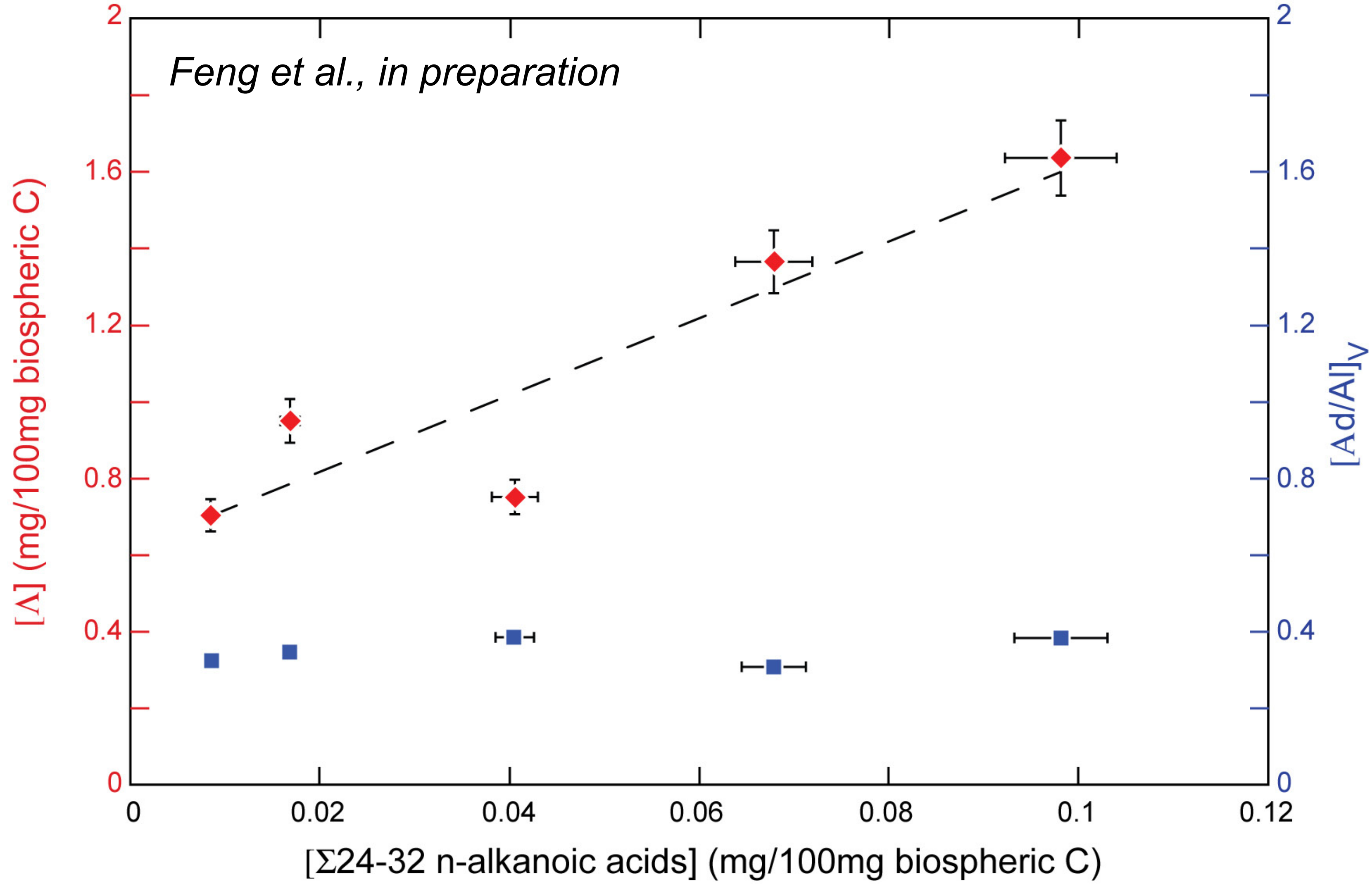


Labile vegetation endmember

Refractory old endmember

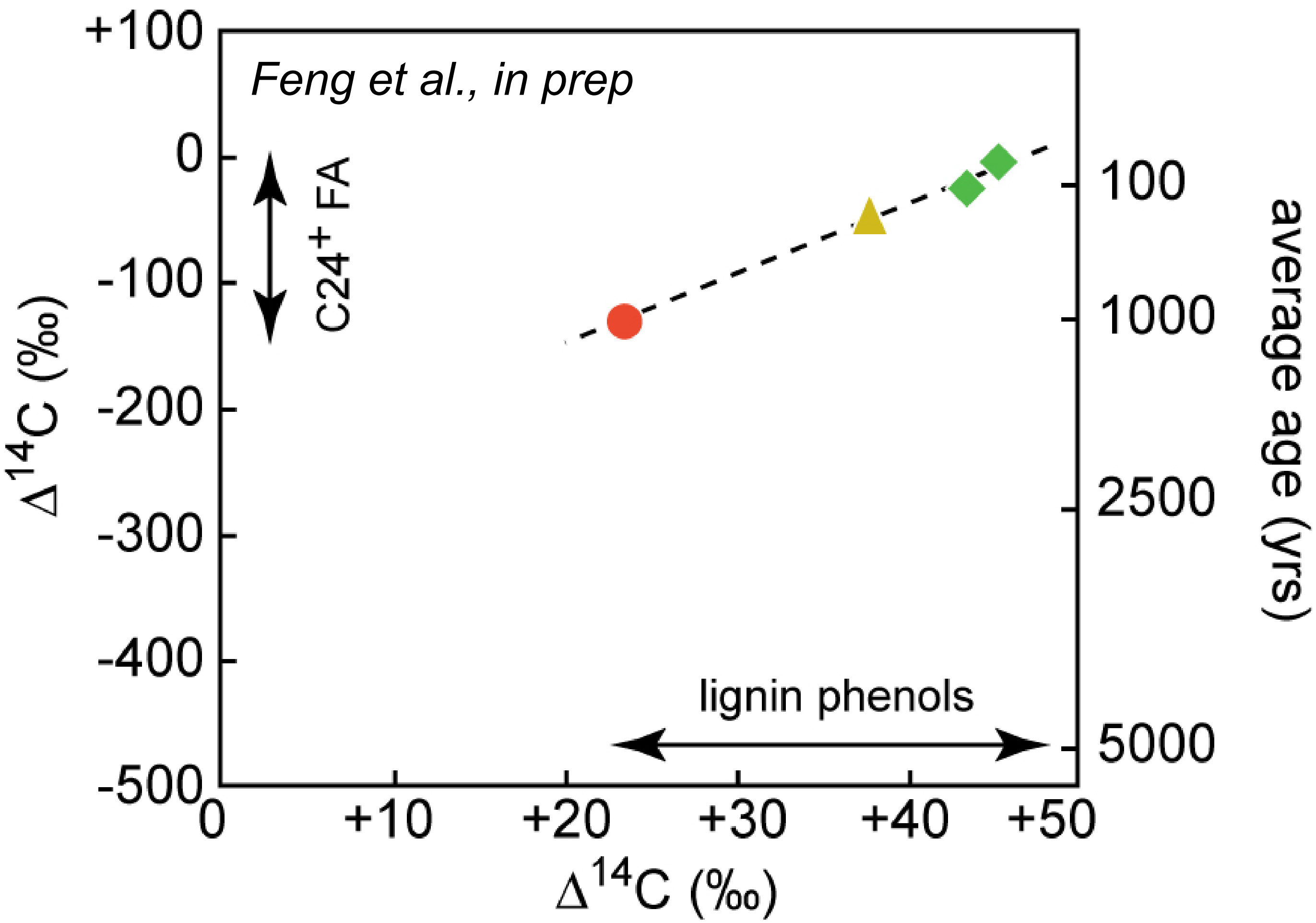
Binary mixing: relatively young labile C + old refractory C
Old component residence time ≈ 15 ka

Composition of the refractory component: lignin?



"fresh" vegetal matter – good correlation between lignin and FA

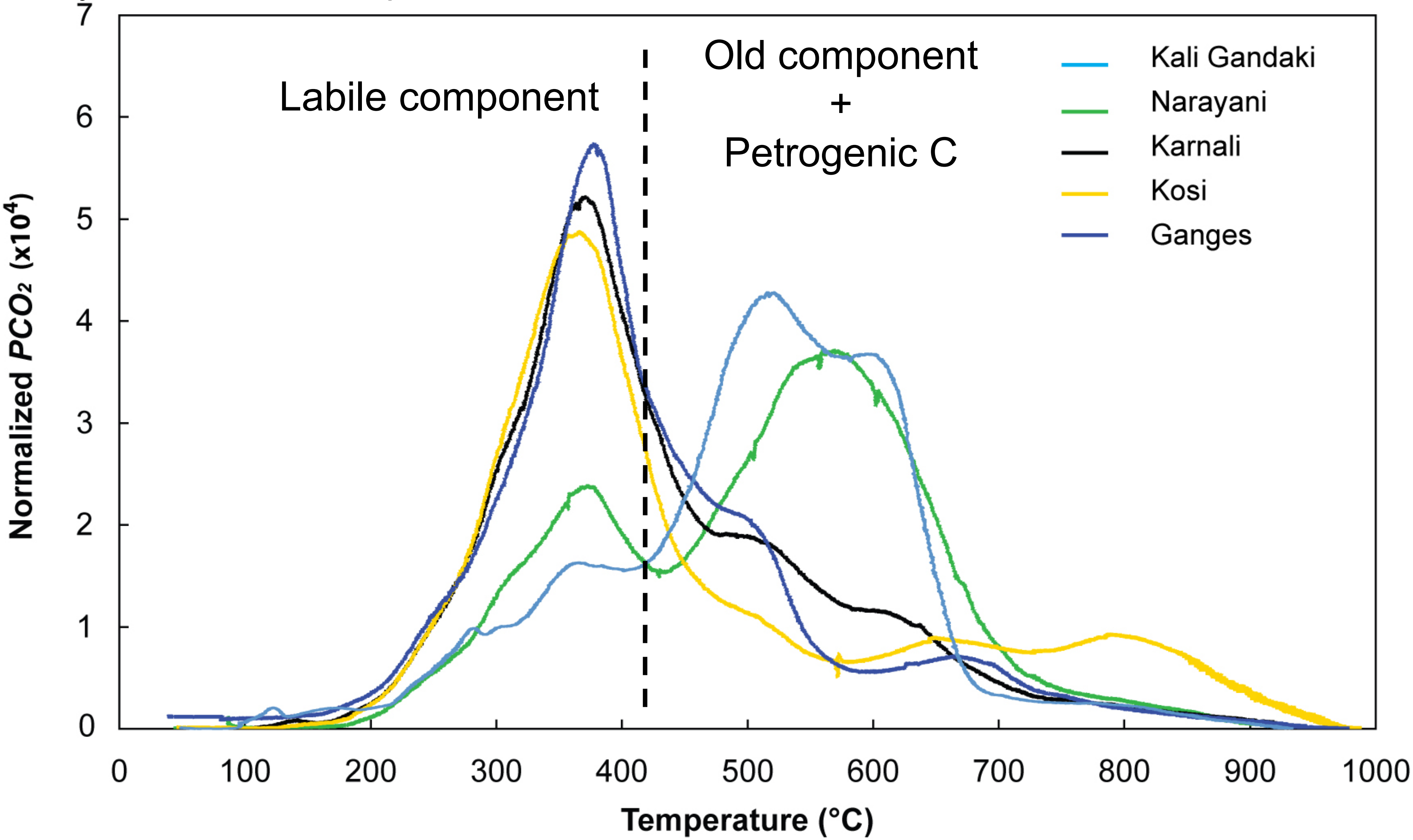
^{14}C composition of lignin phenols



Decadal residence time – good correlation between lignin and FA

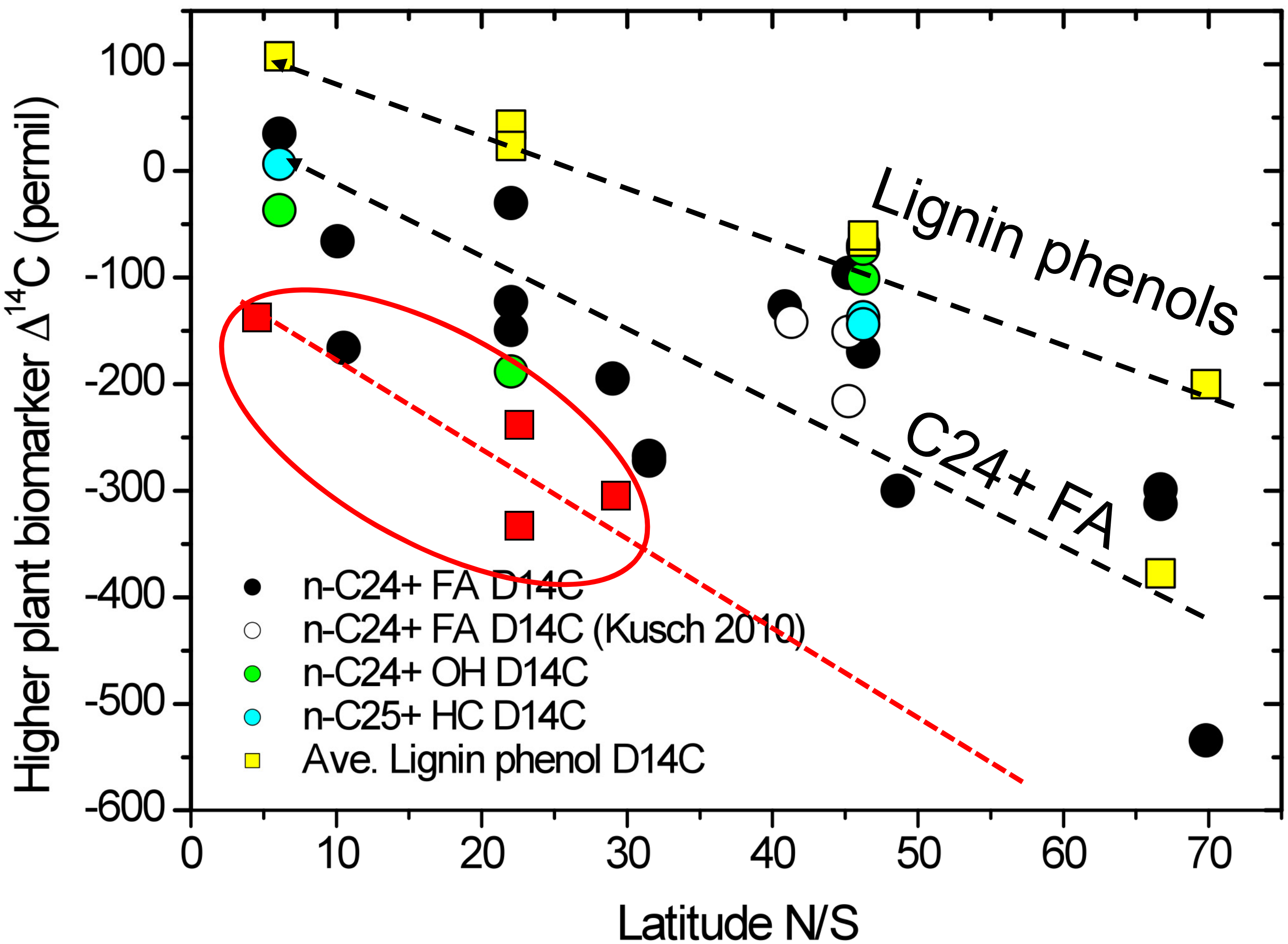
Thermal selectivity

Galy & Rosenheim, unpublished

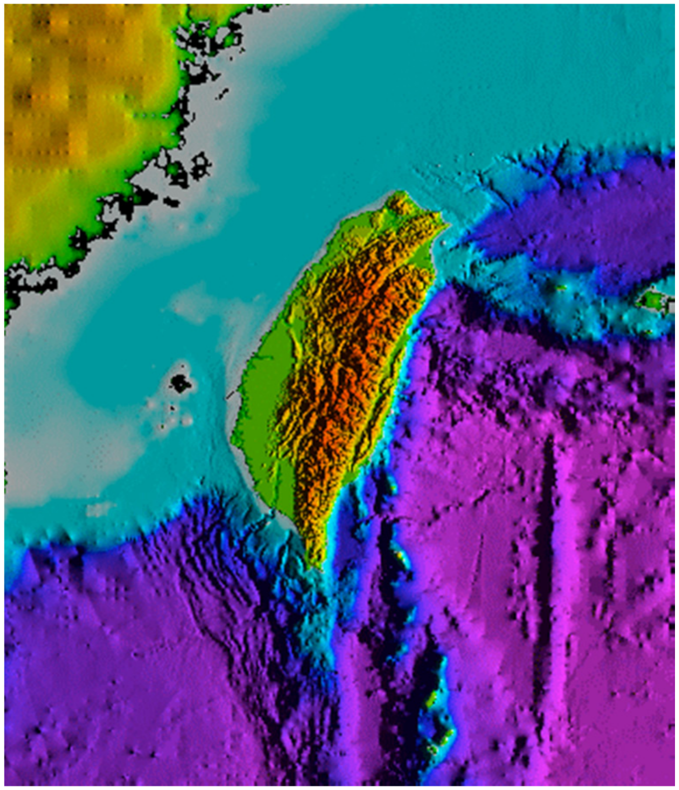


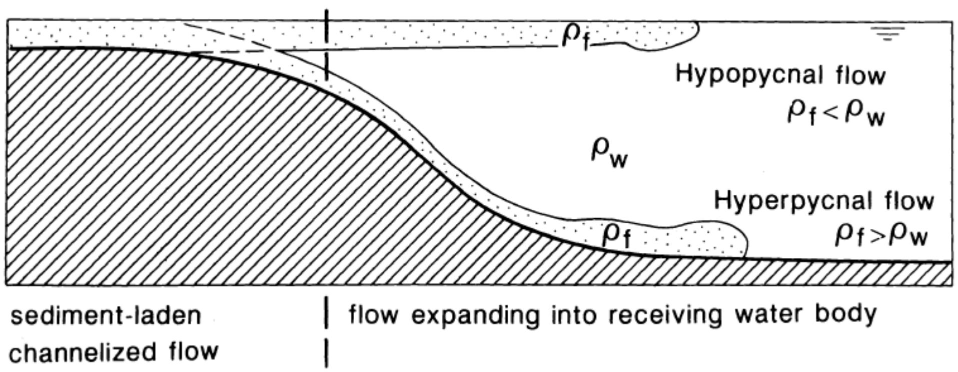
Transition between labile and refractory components at ca. 400° C?

Is old refractory biospheric C ubiquitous?



Fate of OC delivered during typhoons to the ocean





- Lack of well developed floodplain and shelf
- Hyperpycnal flow
- Direct transfer of OC to the deep sea
- High burial efficiency

A climatic control