Net ecosystem CO_2 exchanges between a dwarf *A.marina* mangrove and the atmosphere

-

Application of the eddy-covariance flux tower to « Le C♥ur de Voh » mangrove (New Caledonia)

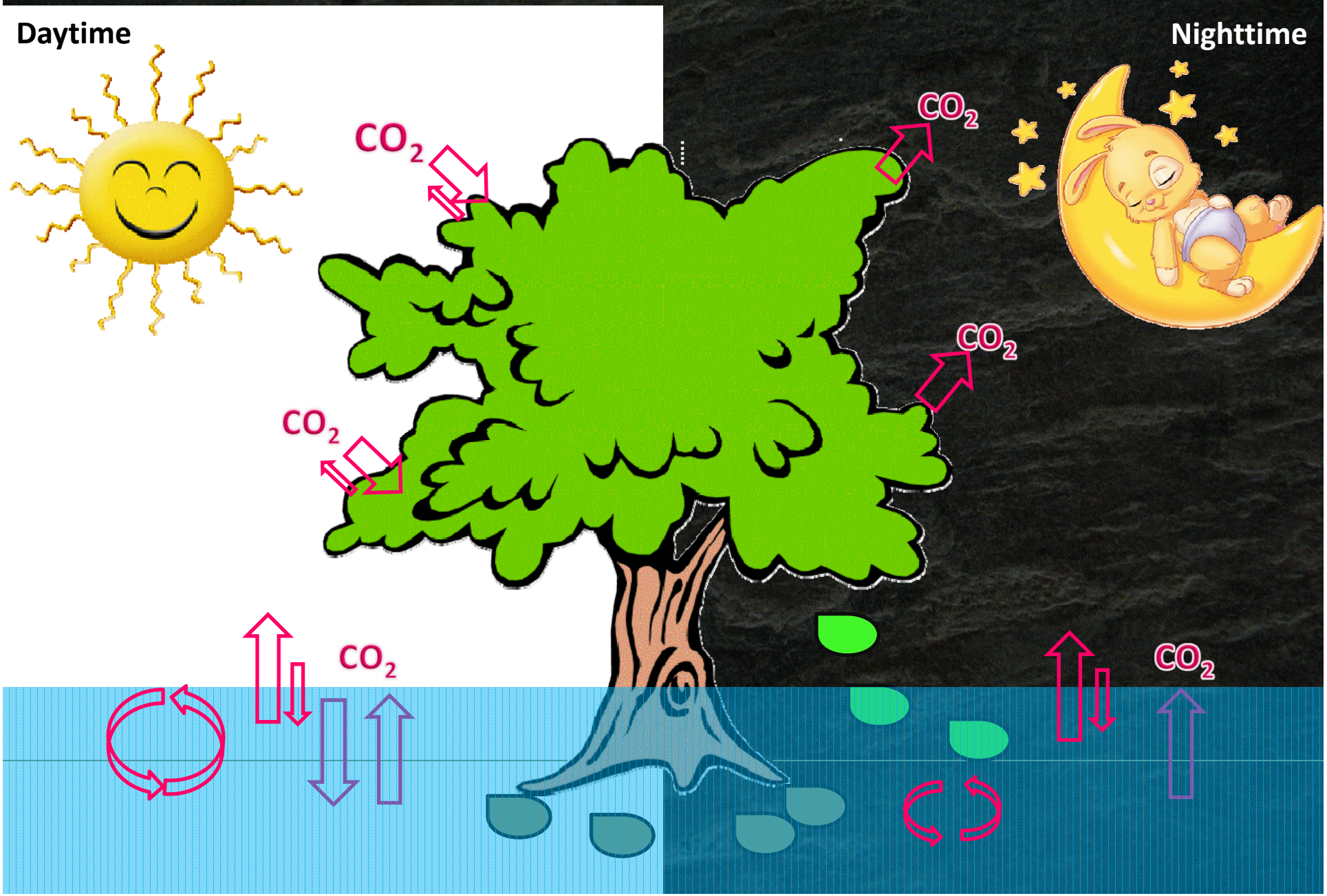
Leopold, A., Marchand, C., Renchon, A., Deborde, J., Quiniou, T., Allenbach, M.

2016. Agricultural Forest Meteorology 223, 217-232

UNIVERSITÉ de la NOUVELLE-CALÉDONIE

IRD institut de recherche pour le développement

Mangroves: Net sink or source for CO_2?



Eddy-covariance,

A powerful tool,
to measure atmosphere-ecosystem exchanges

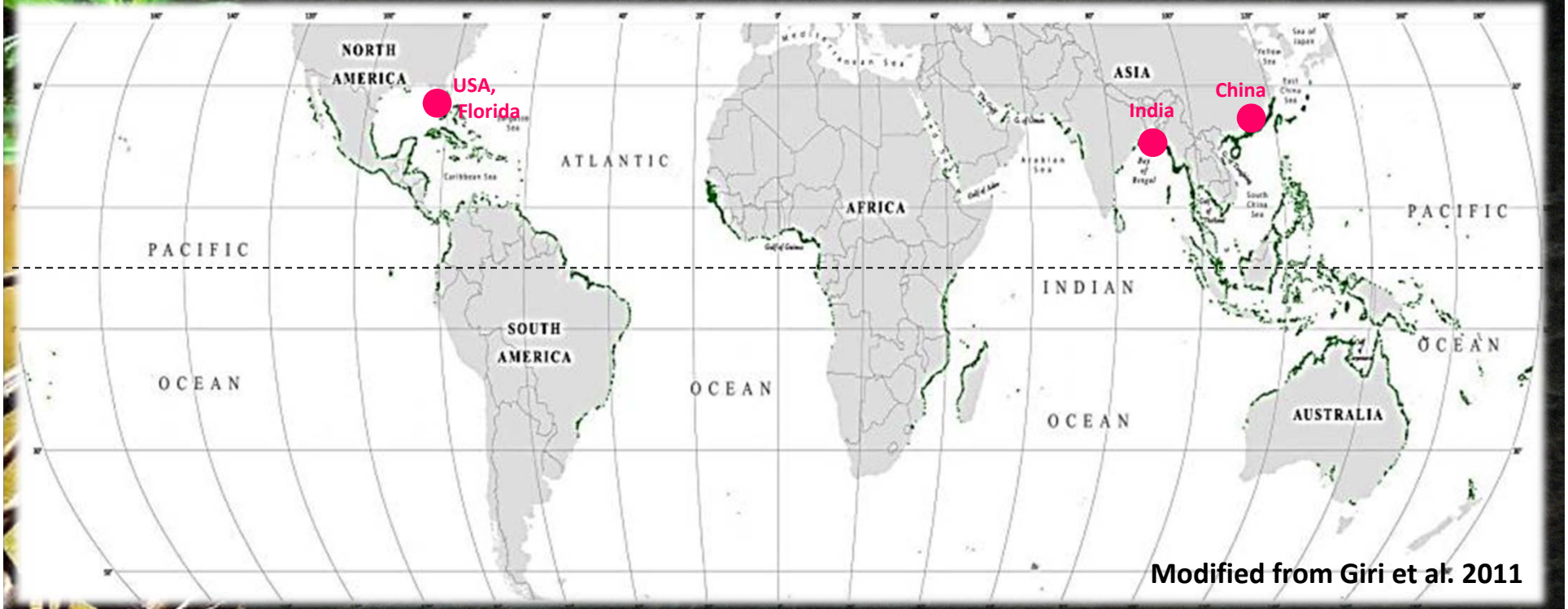
From Burba, 2005

Vertical flux (F)

As a result of covariance between gaz concentration (CO_2, ρ_C) and vertical wind component (w)

$$F(CO_2) = \overline{w.\rho_C}$$

Mangroves and Eddy-Covariance…
A rare love story…



Northern hemisphere
Humid tropical and sub-tropical climates

The story of the New Caledonian flux tower

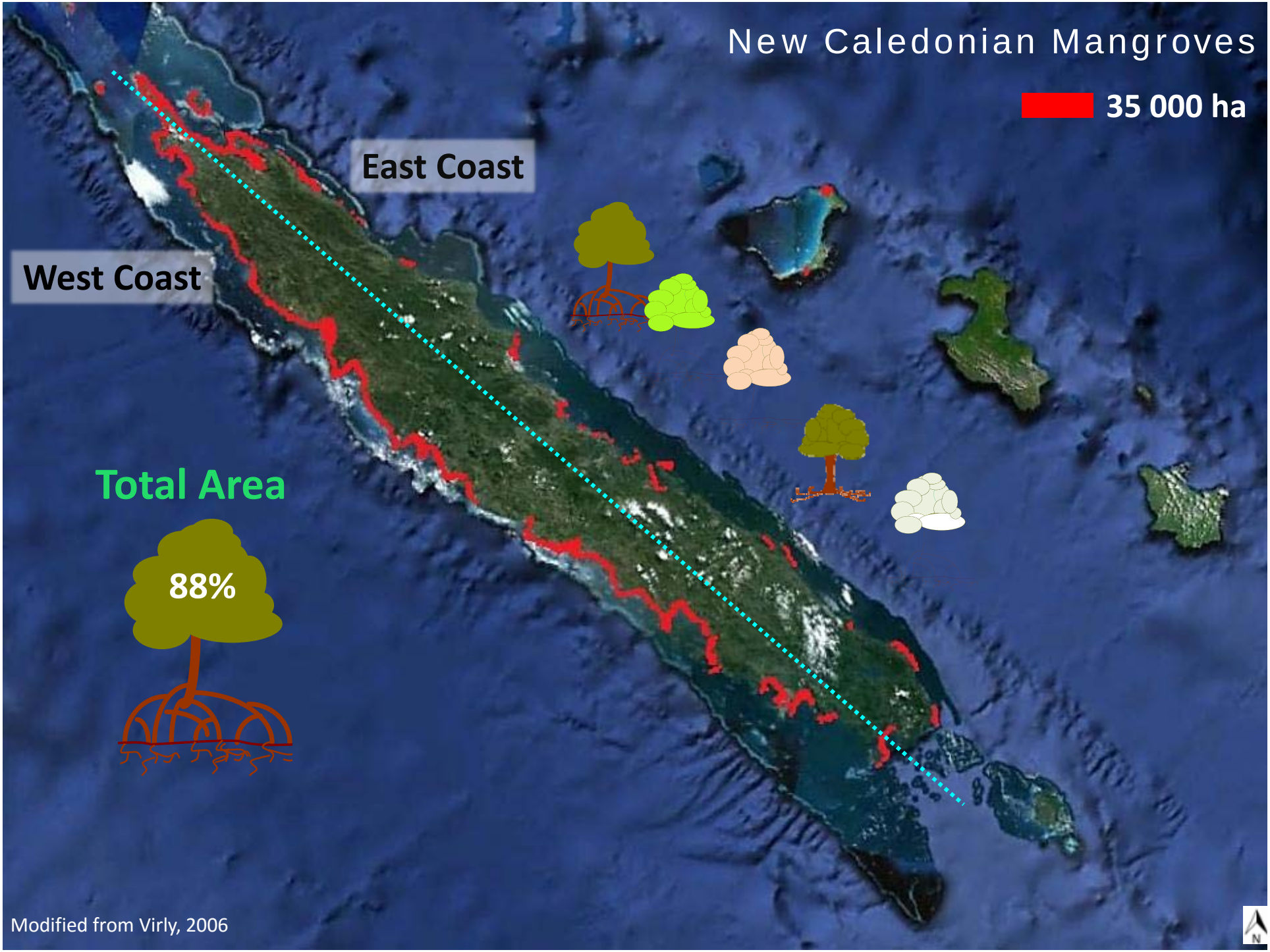
Measurements: Net Ecosystem CO_2 Exchange (NEE)

Determination: Net Ecosystem Productivity (NEP), -NEE
Ecosystem Respiration (Reco)
Gross Ecosystem Productivity (GEP)

GEP = –NEE + Reco

Modified from Giri et al. 2011

Sourthern hemisphere
Sub-tropical but semi-arid climate


New Caledonian Mangroves
35 000 ha
East Coast
West Coast
Total Area
88%
Modified from Virly, 2006

A famous mangrove grows on the New Caledonia's West Coast

« Le Cœur de Voh »

Avicennia marina var. *australasica*

- Dwarf
- H_{max} < 2m
- H_{mean}= 57.2±30.3cm
- 3.3±0.2 trees m^{-2}

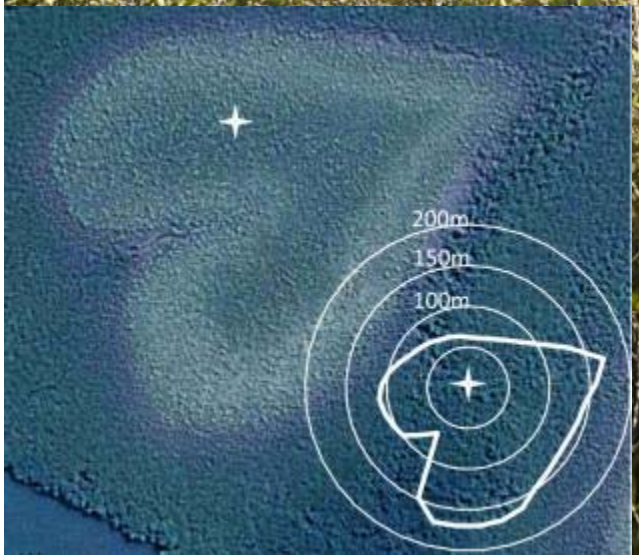
©1990, Y. Arthus-Bertrand

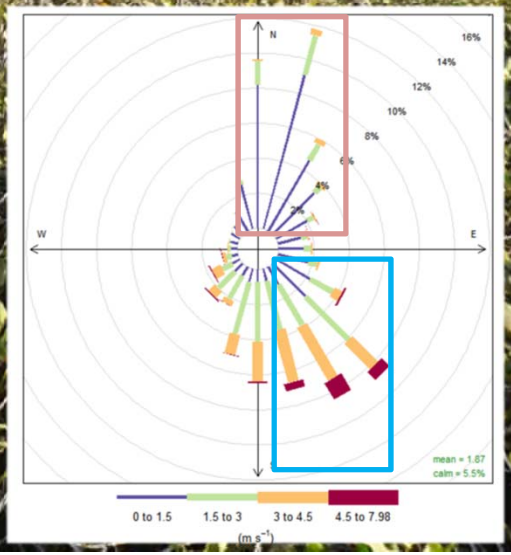
©2012, CNES/ASTRIUM

-IRGA- closed path, LI-7200
-Sonic anemometer- Windmaster

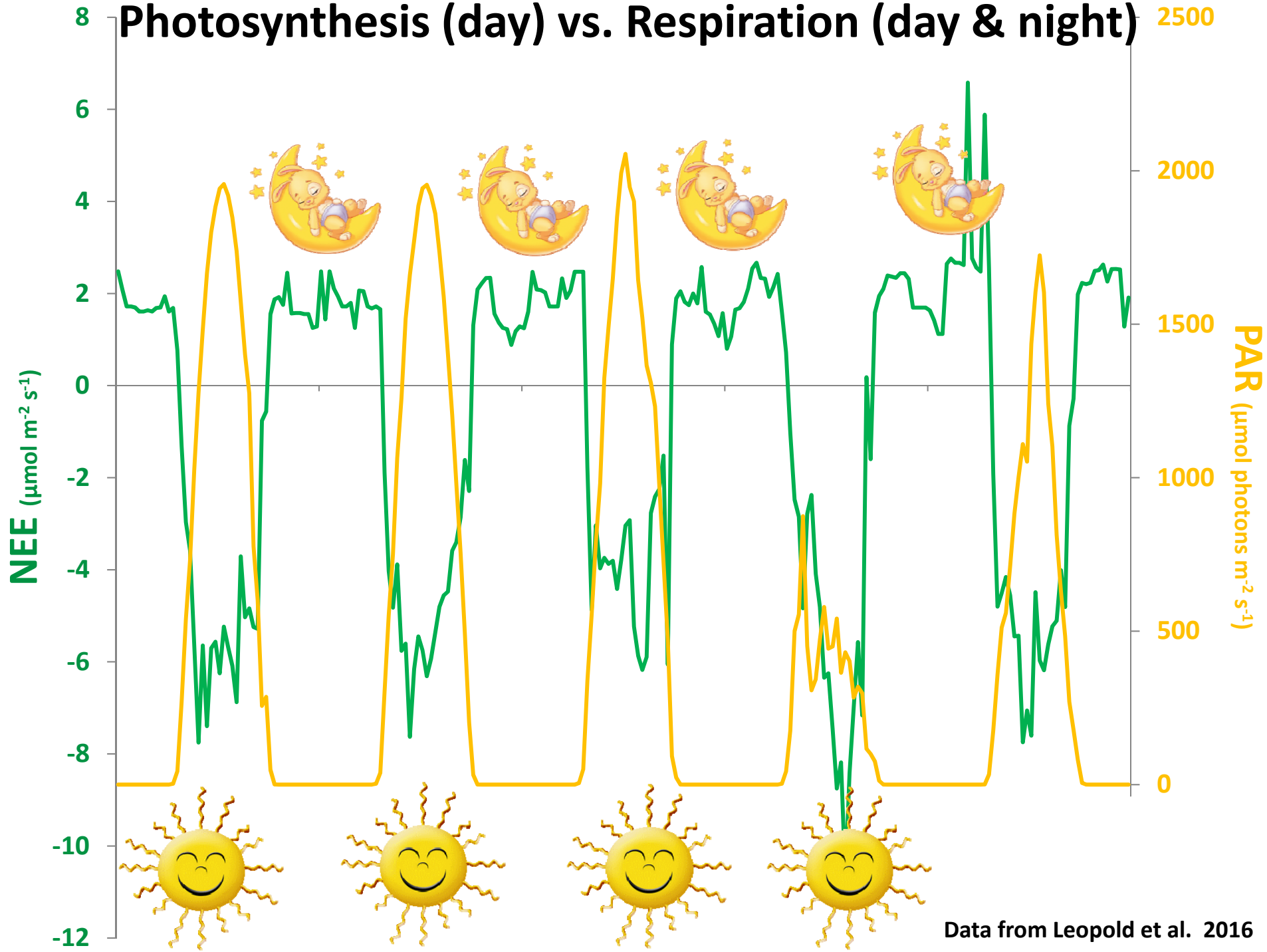
-Data logger CR1000 + meteorological sensors
- air temperature and humidity
- PAR / solar radiation
- soil heat flux plates
- sediment temperature
- rain gauge

-Tide gauges custom built





H= 3.10m

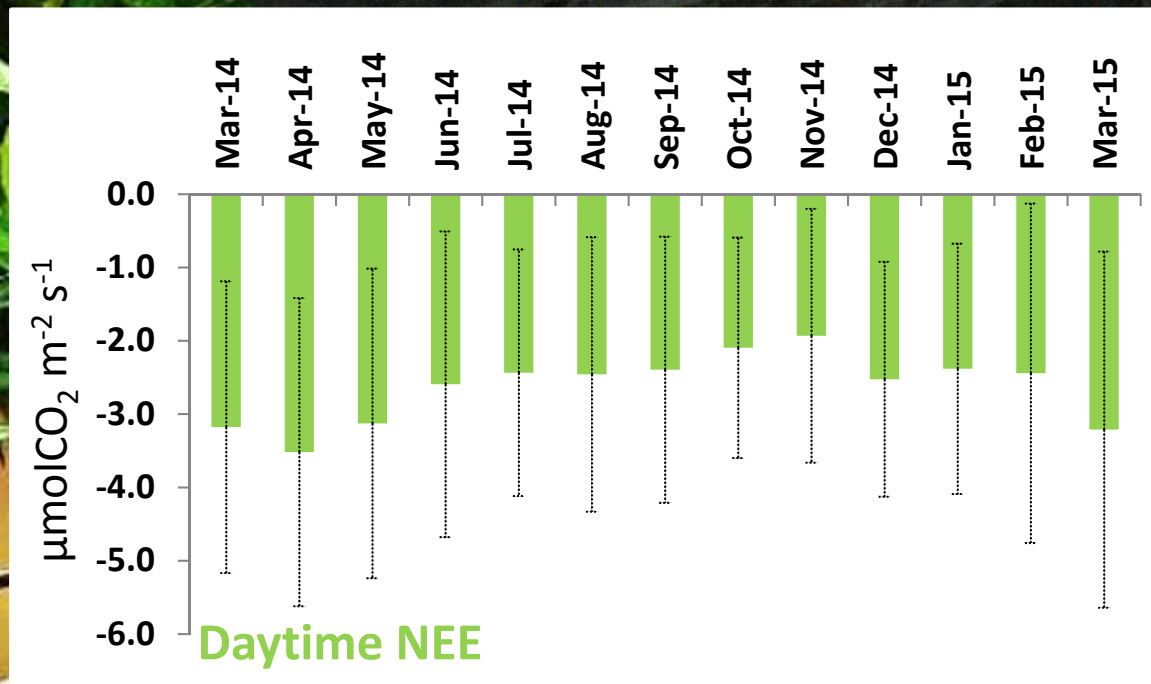

Photosynthesis (day) vs. Respiration (day & night)
NEE (µmol m-2 s-1)
PAR (µmol photons m-2 s-1)
8
6
4
2
0
-2
-4
-6
-8
-10
-12
2500
2000
1500
1000
500
0
Data from Leopold et al. 2016

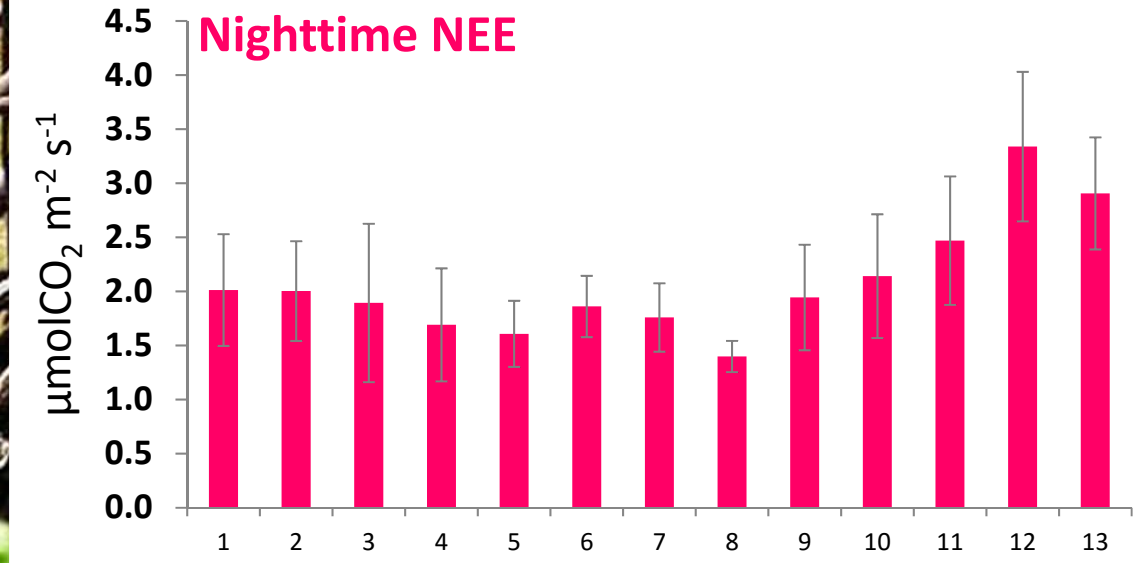
Mangroves,

As a unique forested ecosystem…

Seasonal variations of NEE

Seasonal variations of NEE





Florida mangrove*
Min: -10 to -25 µmol m^{-2} s^{-1}

90% values :
-5 to +2 µmol m^{-2} s^{-1}
Min: -10.7 µmol m^{-2} s^{-1}

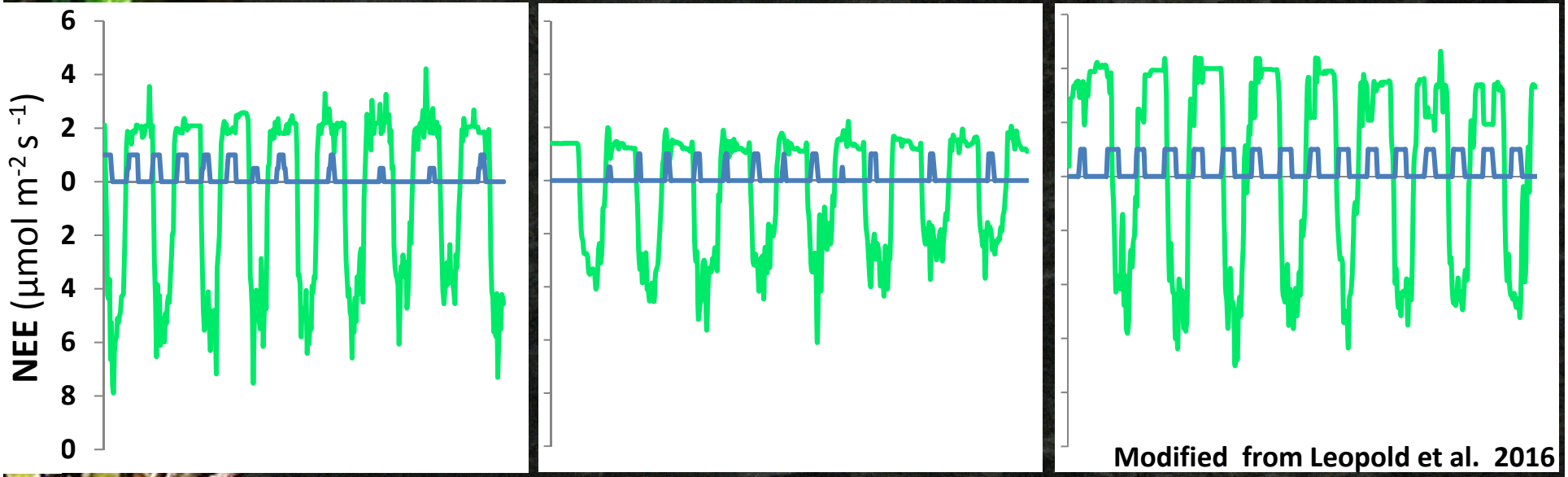
90% values :
0.38 to +3 µmol m^{-2} s^{-1}
Max: 8.80 µmol m^{-2} s^{-1}

Florida mangrove*
Max: up to 10 µmol m^{-2} s^{-1}

*Data from Barr et al. 2010

Seasonal variations of NEE

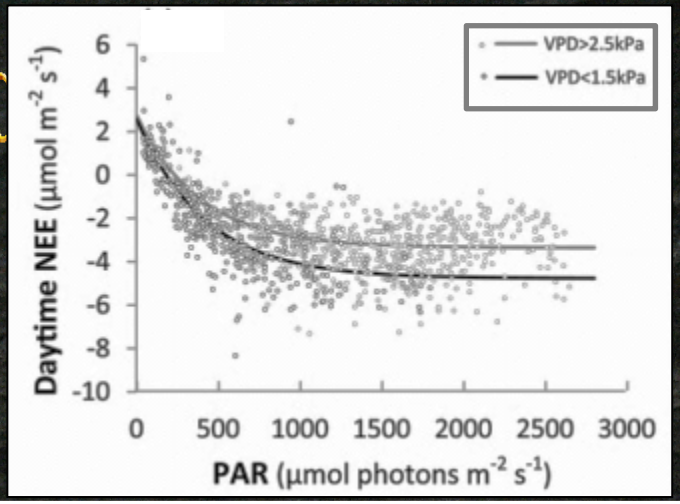
End of wet and warm season (April)	End of dry and cold season (October)	Wet and warm season (February)

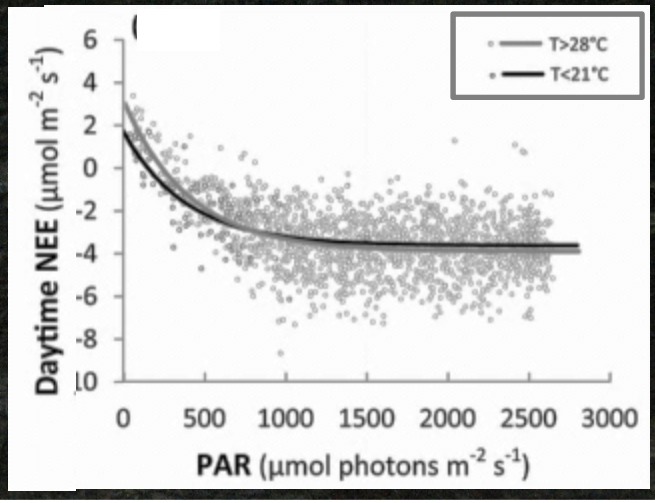


Modified from Leopold et al. 2016

Seasonal variation of both daytime and nighttime NEE minima and maxima

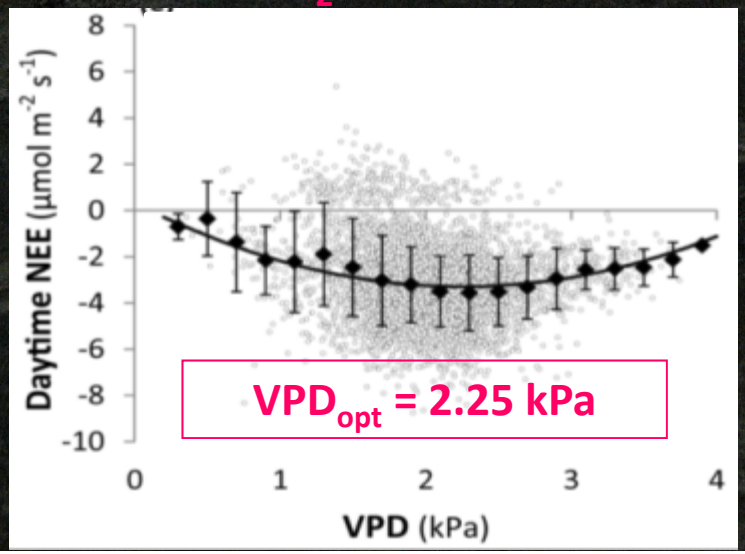
Seasonal variations of NEE, subsequent to seasonal variation of driving factors

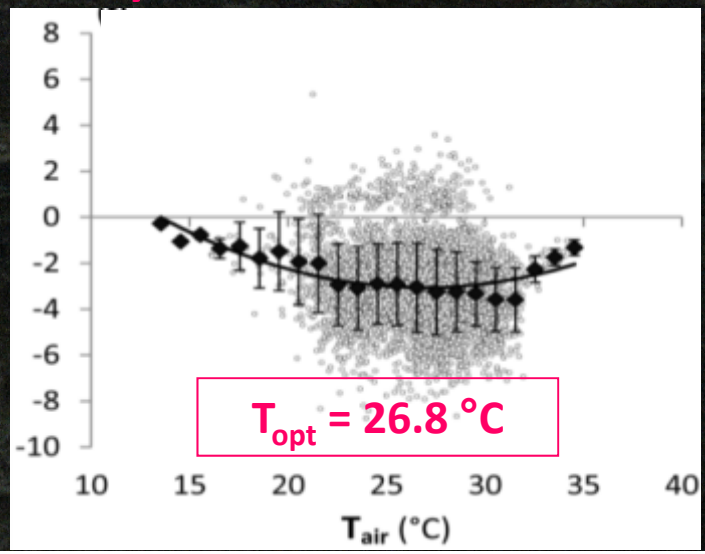




$$Nee = -(Nesat + Rd)\left(1 - exp\left\{\frac{-\alpha * PAR}{Nesat + Rd}\right\}\right) + Rd$$

Minimal NEE,
i.e. maximal CO_2 fixation rate at the ecosystem scale





Mangroves,

As a unique forested ecosystem…

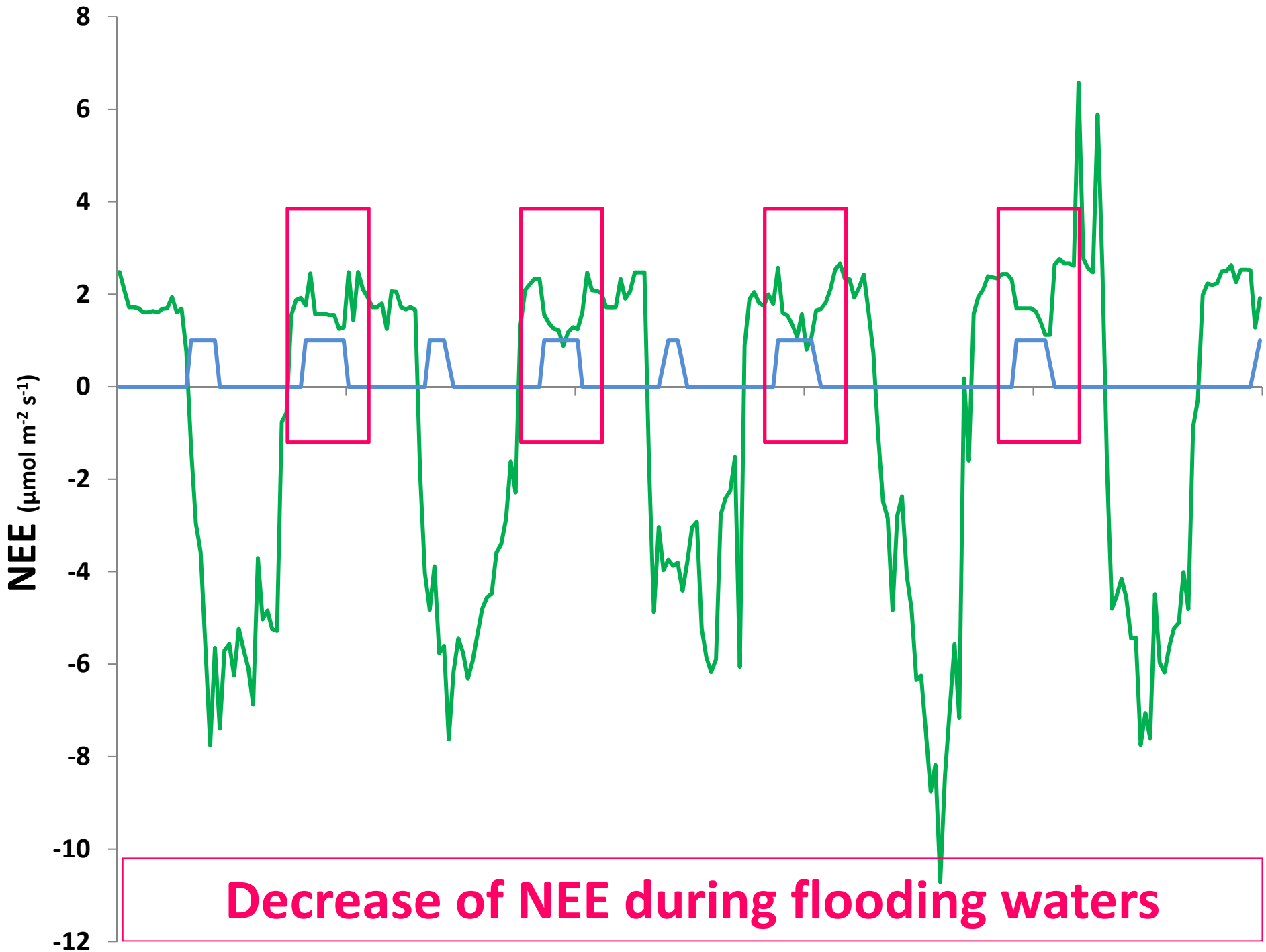
The impact of tidal cycle on NEE

Mangroves, As a unique forested ecosystem…

The impact of tidal cycle

Decrease of NEE during flooding waters

(a) As a consequence of lower CO_2 released by respiration


8
6
4
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NEE (µmol m-2 s-1)
Decrease of NEE during flooding waters

(a) As a consequence of lower CO_2 released by respiration

Mangroves, As a unique forested ecosystem…

The impact of tidal cycle

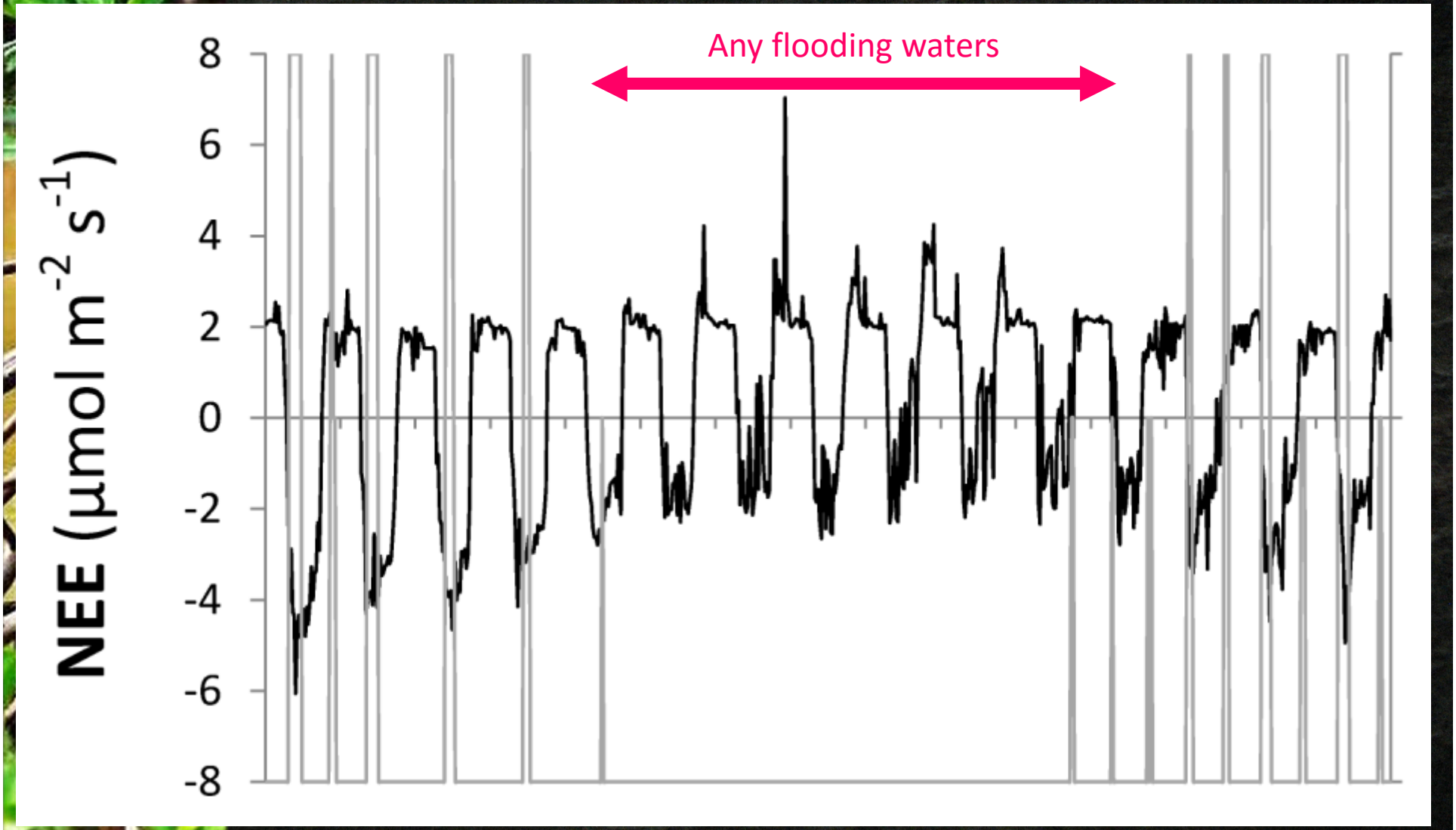
Decrease of NEE during flooding waters

(a) As a consequence of lower CO_2 released by respiration

(b) As a consequence of higher CO_2 absorbed by photosynthesis because of water availability

Decrease of NEE during flooding waters

(b) As a consequence of higher CO_2 absorbed by photosynthesis because of water availability

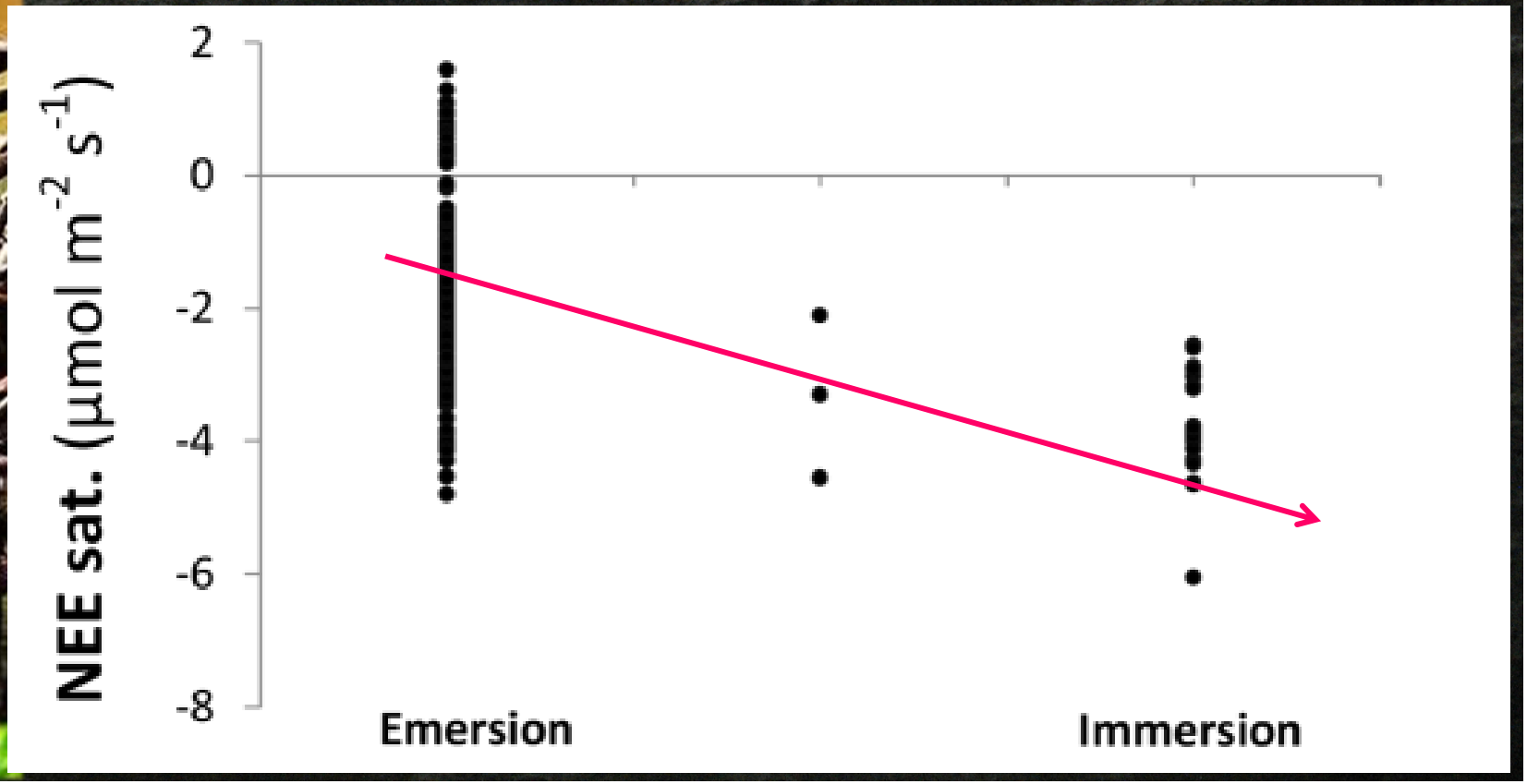


Decrease of NEE during flooding waters

(b) As a consequence of higher CO_2 absorbed by photosynthesis because of water availability

At saturing PAR, NEE minimum decreases with flooding waters.

Trees seem stressed by missing water



Mangroves,

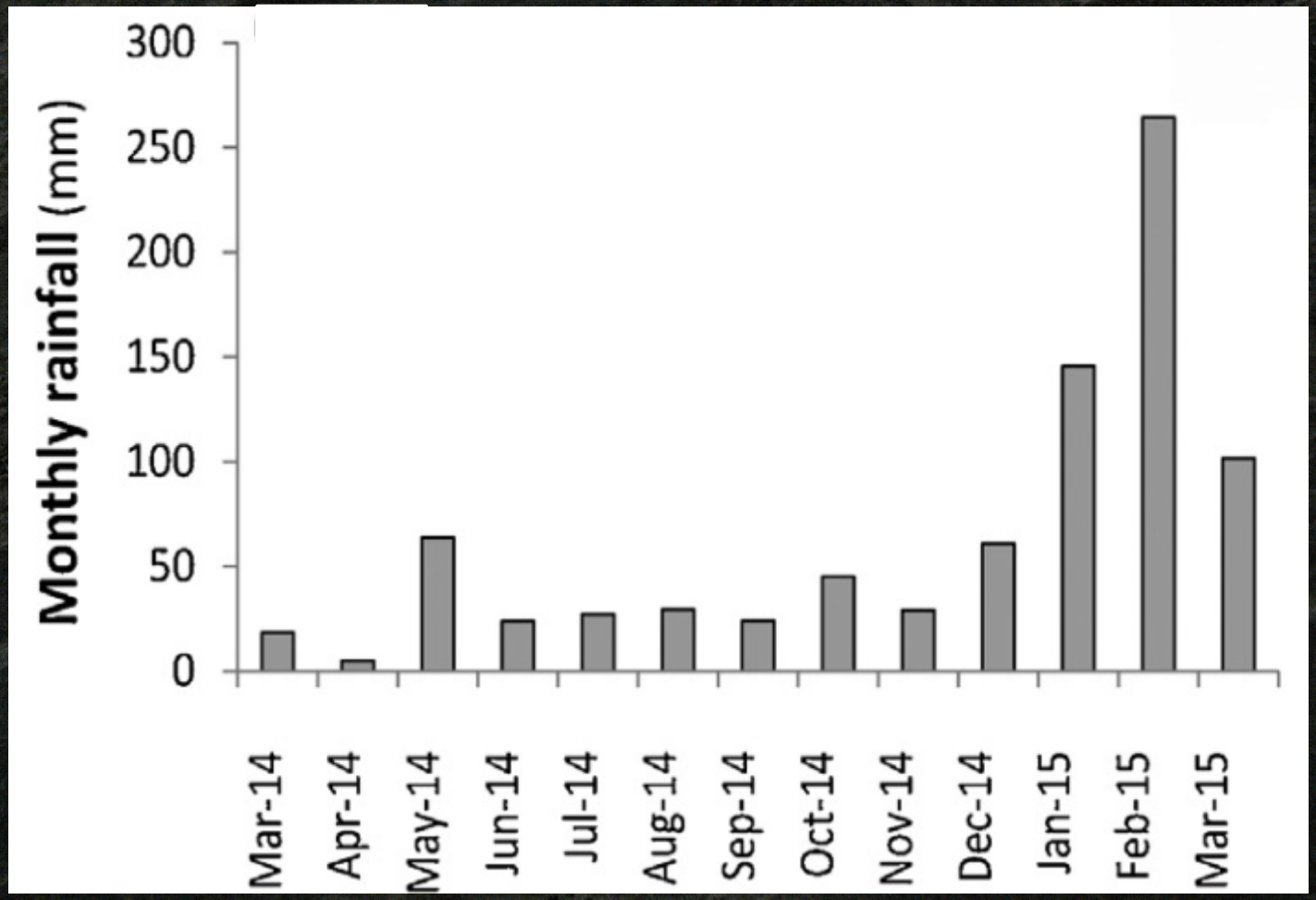
As a unique forested ecosystem…

The impact of a semi-arid climate on NEP

The impact of semi arid climate on mangrove productivity

NC West Coast:

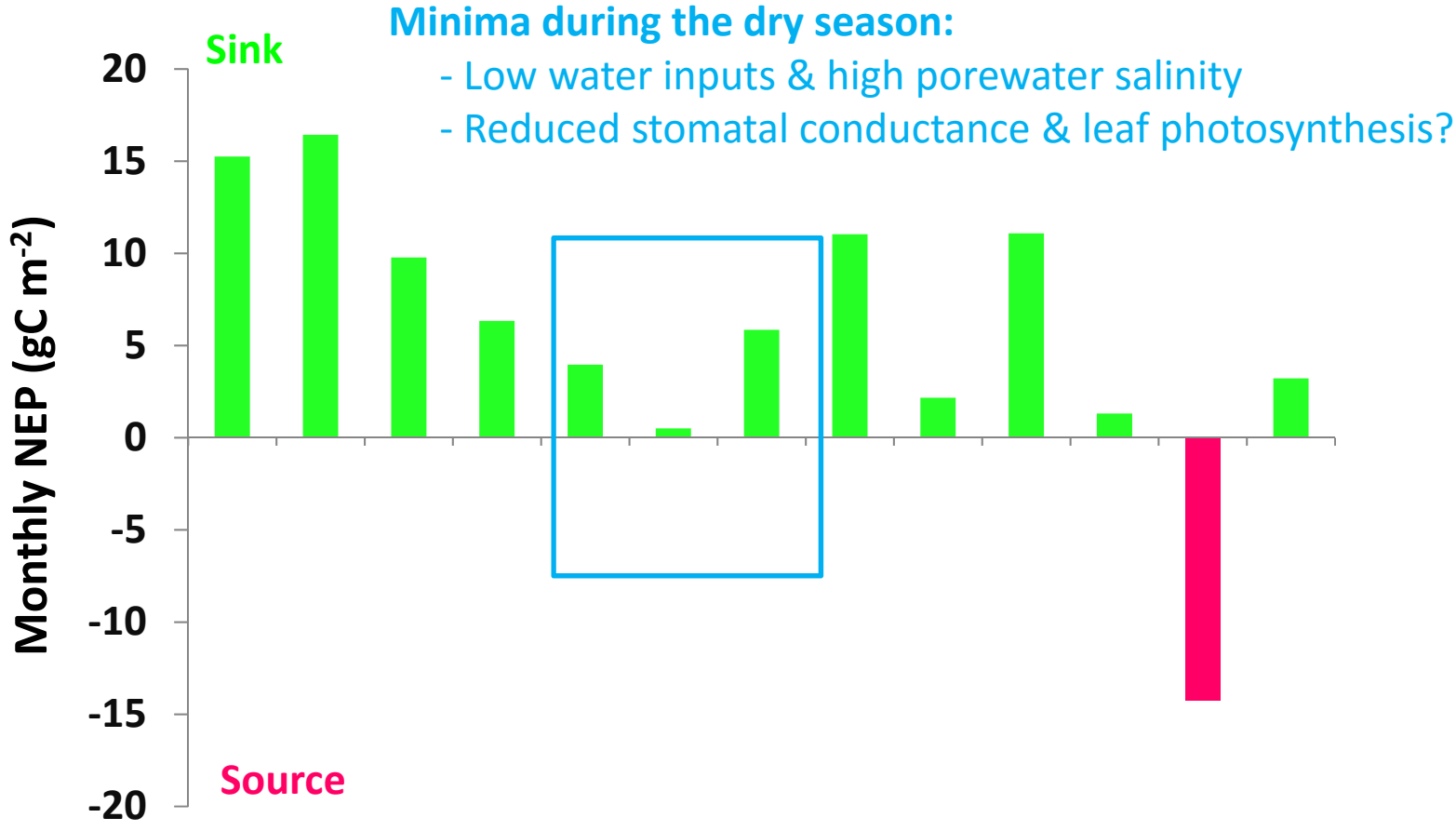
Annual rainfall < 1,000 mm, with a high seasonality



NEP of a dwarf A.marina mangrove growing under semi arid climate

Mar.14-Mar.15

Relative low annual NEP= 72.9 gC m^{-2}



Low water inputs = High porewater salinity

Decrease of gas exchanges by stomatal closure?

See Carine Bourgeois 's poster (N° 78)

(PhD candidate, AUT Auckland, IRD New Caledonia
Supervisors: Dr. A. Alfaro and Dr. C. Marchand)

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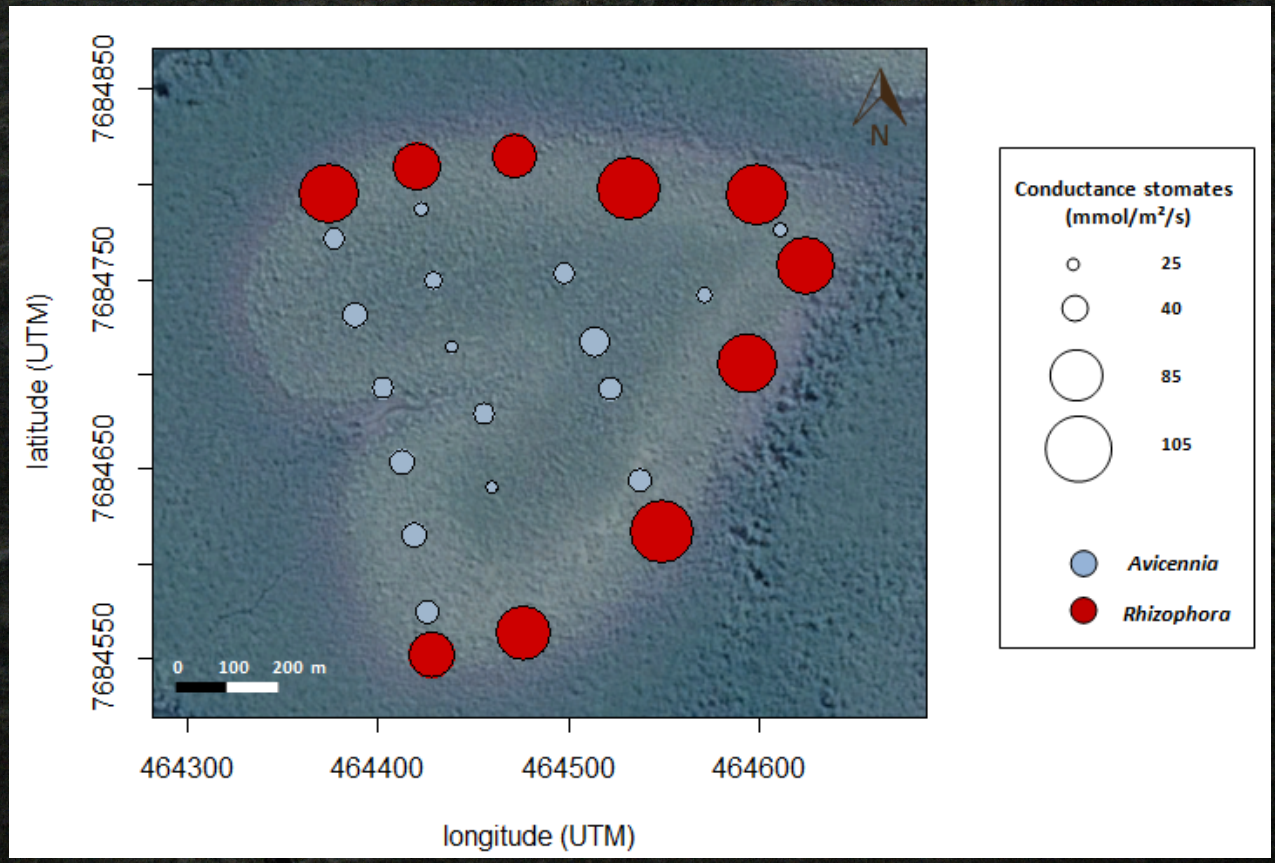

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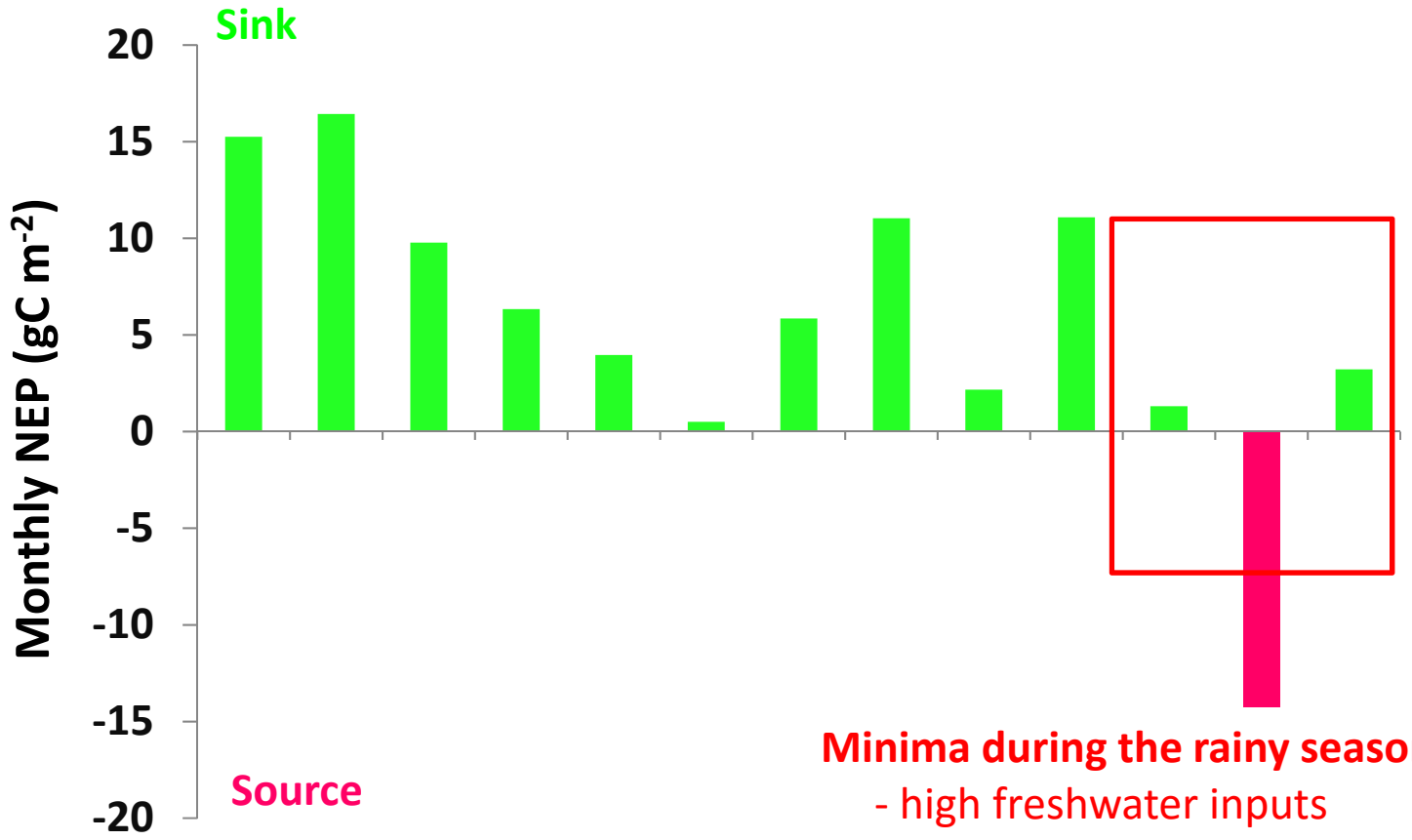
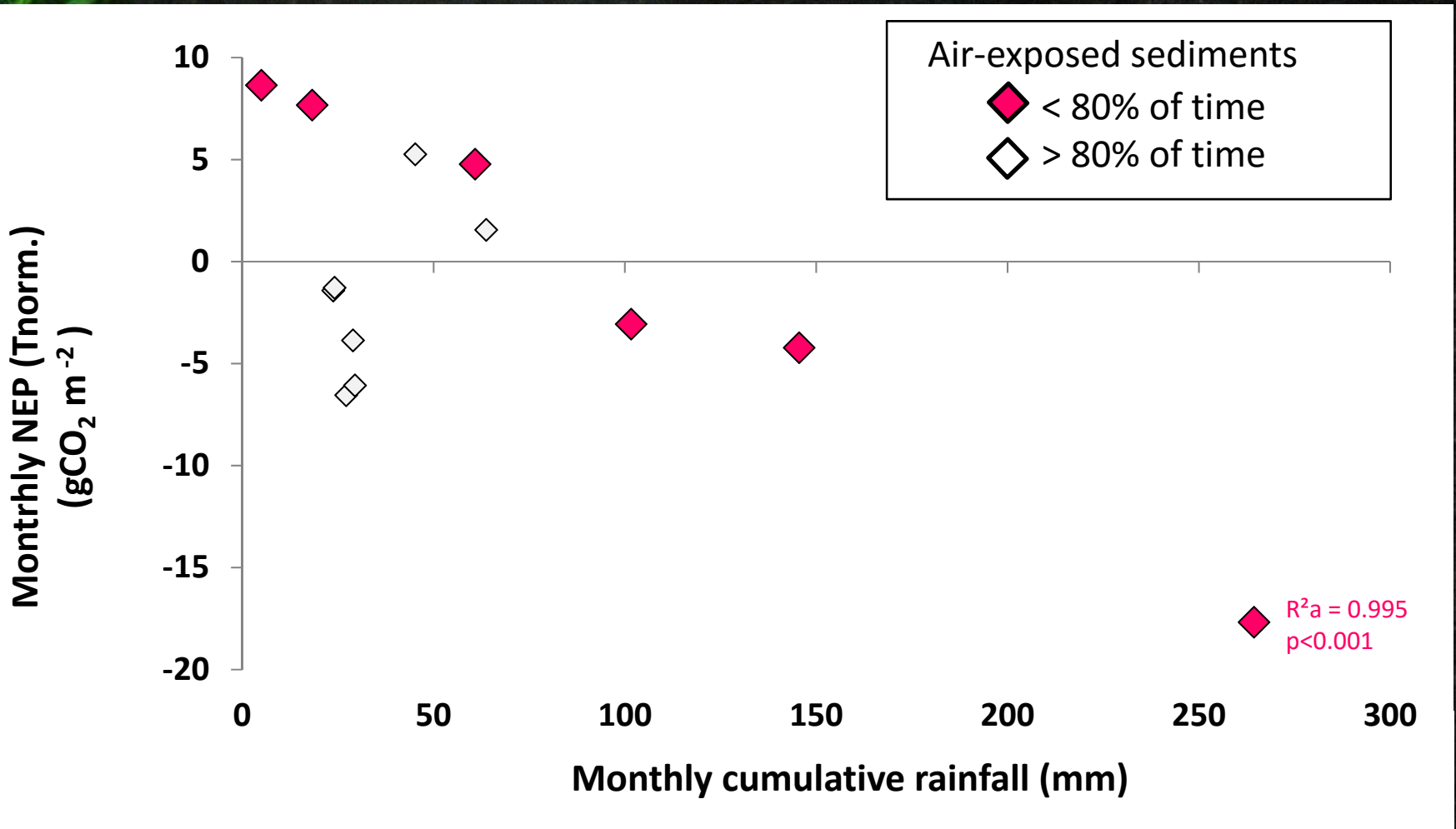


Minima during the rainy season

- high freshwater inputs
- high photosynthesis
- high respiration: resumption growth?

NEP decreases with rainfall, When seawater is not a limiting factor



Do frehswater inputs promote the growth resumption and subsequent respiratory metabolism??

(see Robert et al., 2014 and Santini et al., 2015)

Perspectives

Mar.14-Mar.15

Relative low annual NEP= 72.9 gC m^{-2}

(a) Inter-annual variation of NEP?

(b) May the NEP be lower?

Carbon exports: DOC, DIC, POC?

(e.g., 25% to 70% of NEP (Barr et al. 2010))

(c) NEE Partitioning: what is the contribution of carbon cycling components on the NEE measured?

- Soil
- Vegetation (root, leaves, pneumatophores, trunks)
- Water column

Eddy-covariance network in the Indo-Pacific area

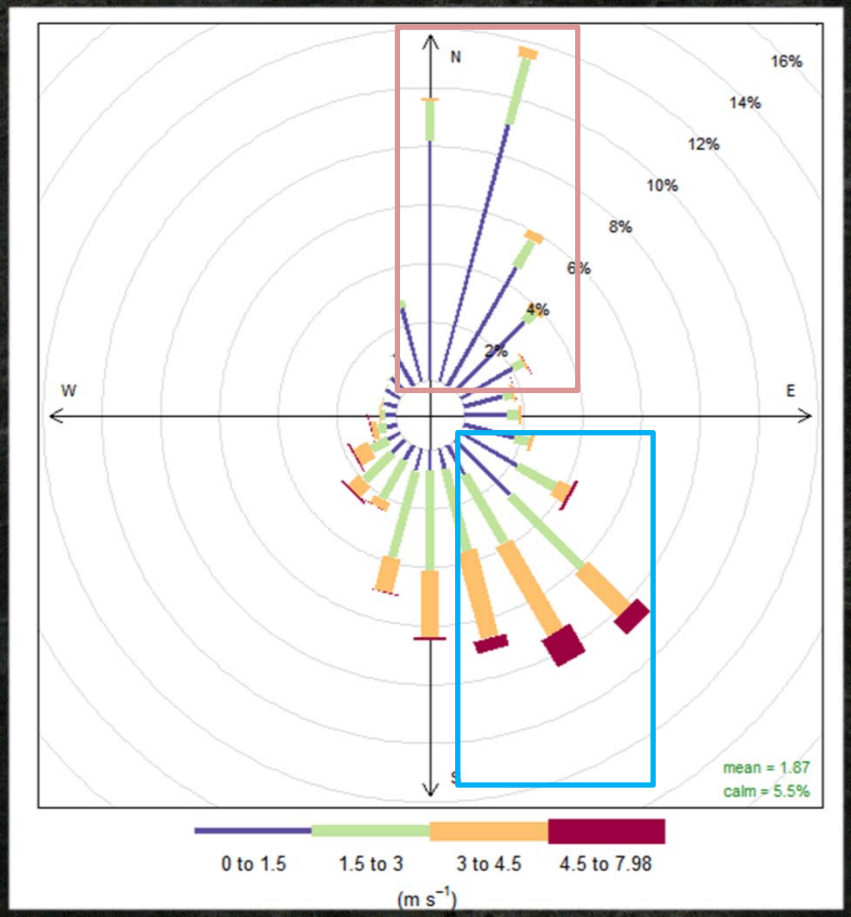
Latitudinal, climatic and biodiversity gradients:

- New Zealand (36°S), temperate climate, 1 mangrove species
- New Caledonia (21°S), semi-aride climate, 25 mangrove species
- Vietnam (10°N), tropicale climate, 60 mangrove species

THANK YOU

In situ installation of flux tower:

- Wind rose and available distances
  - Daytime: Trade winds (« Alizees »): SE
  - Nighttime: Land breeze: NE



Data acquisition and processing

Sampling rate 10Hz

30-min mean CO_2 fluxes (Eddy-pro software©) : NEE

Quality control:

- **Qc =2 according to Goulden et al. 1996**
- **U* threshold**
- **Footprint**

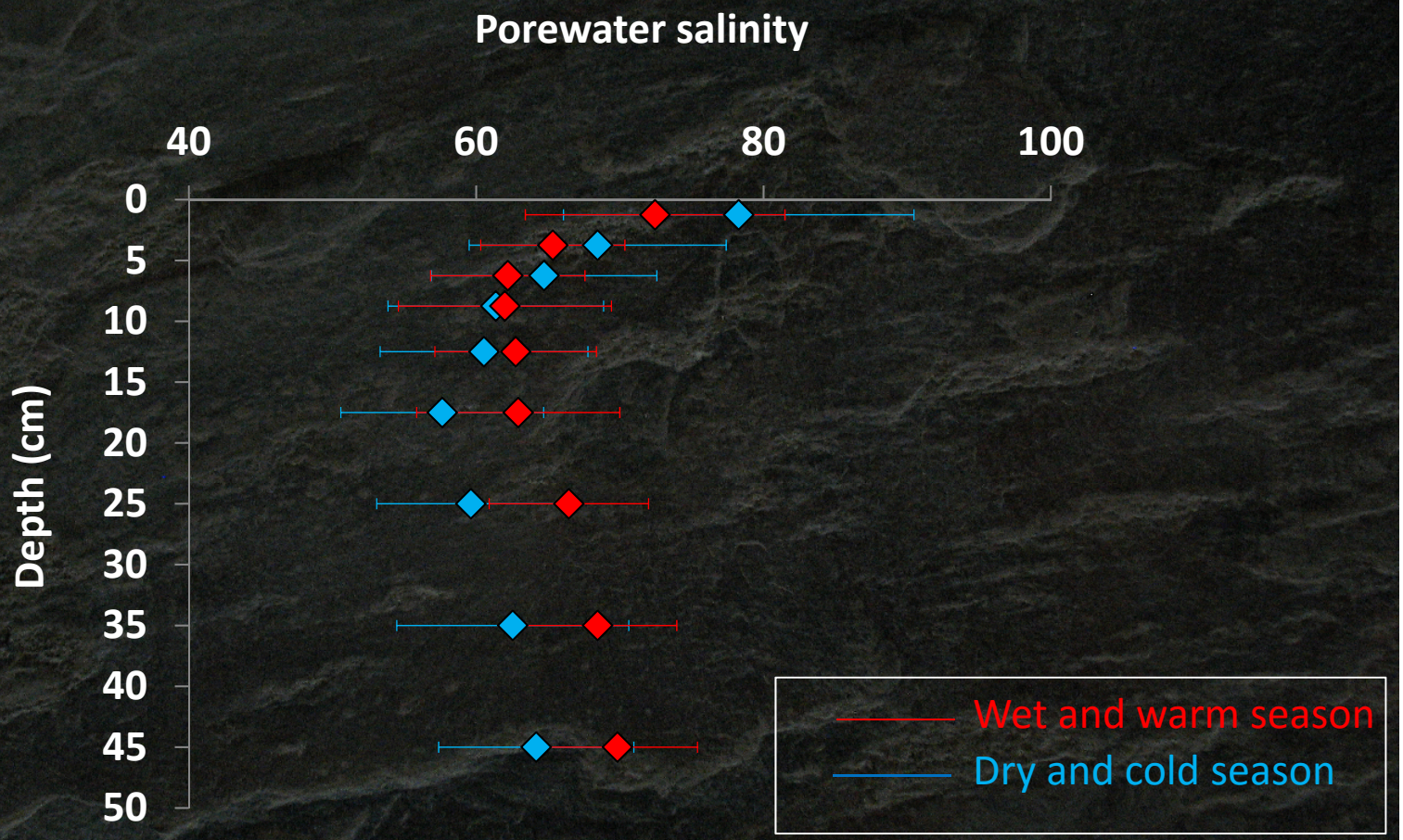
Daytime / nighttime datasets
Low tide/ high tide datasets

Relationships with environmental data (30-min interval)
(solar radiation, PAR, Air temperature, VPD)

« Gap-filling »
(Online tool from Max Planck Institut)

Partitionning: GEP and Reco
Annual Budgeting: NEP

Low water inputs = high porewater salinity



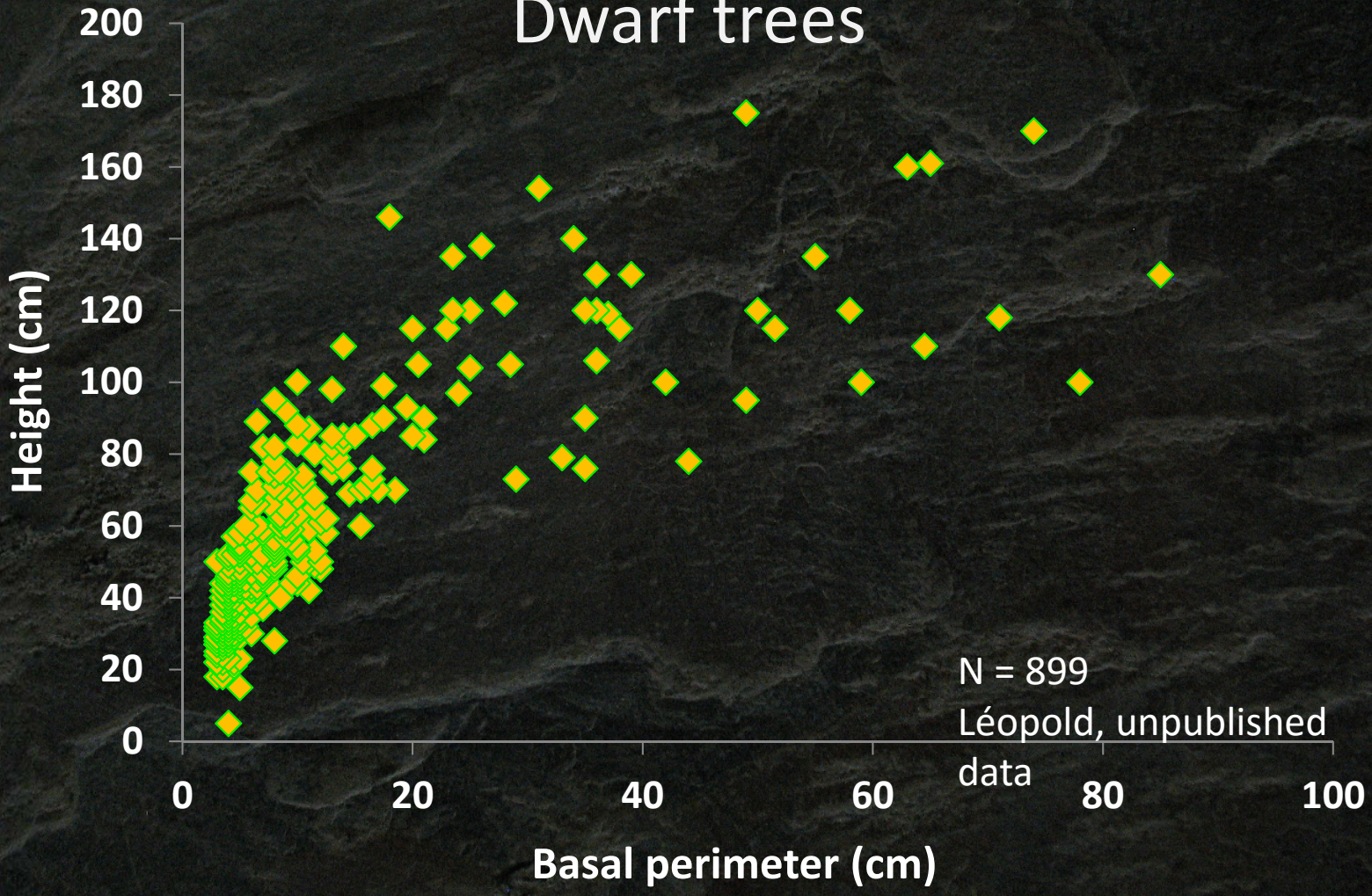
Range from 40 to 100

i.e., 1.4 à 2.8 fold the seawater salinity

High salnity of porewater along the year

=

Dwarf trees



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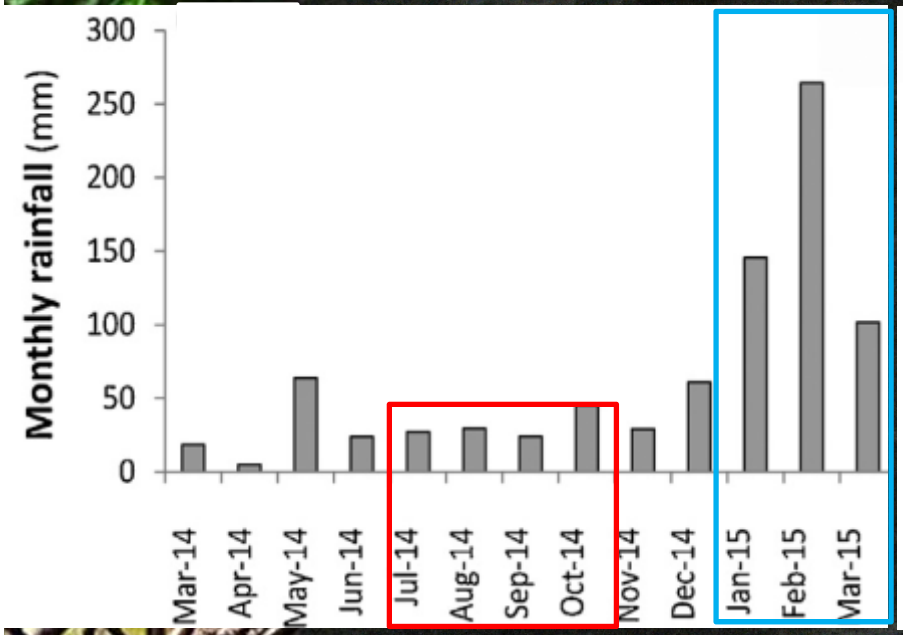
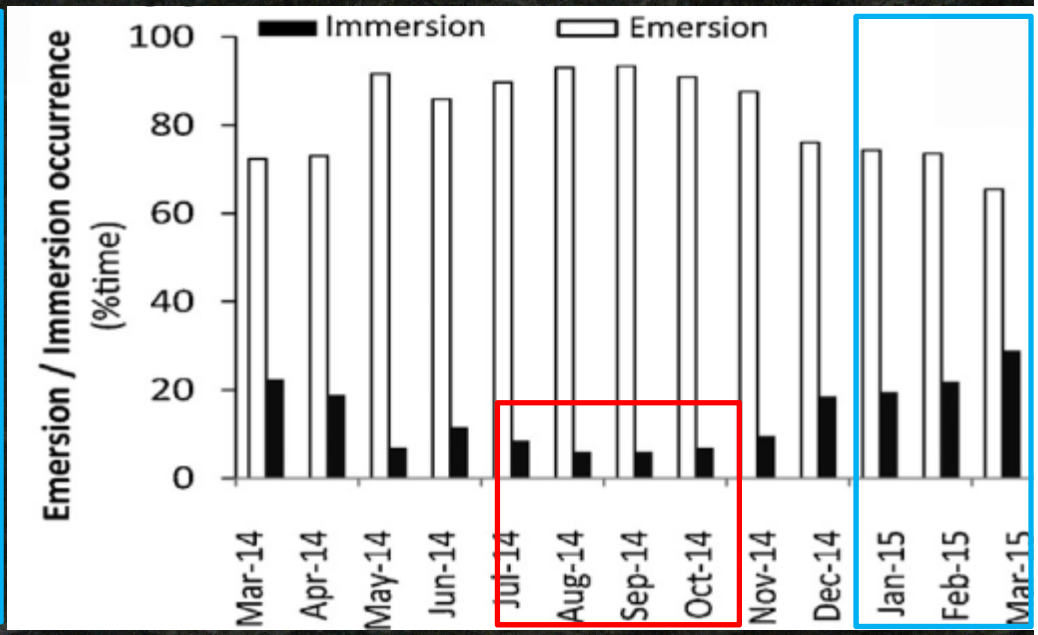
The impact of semi arid climate on mangrove productivity

Rainfall seasonality controls mangrove immersion rate by seawater at high intertidal locations



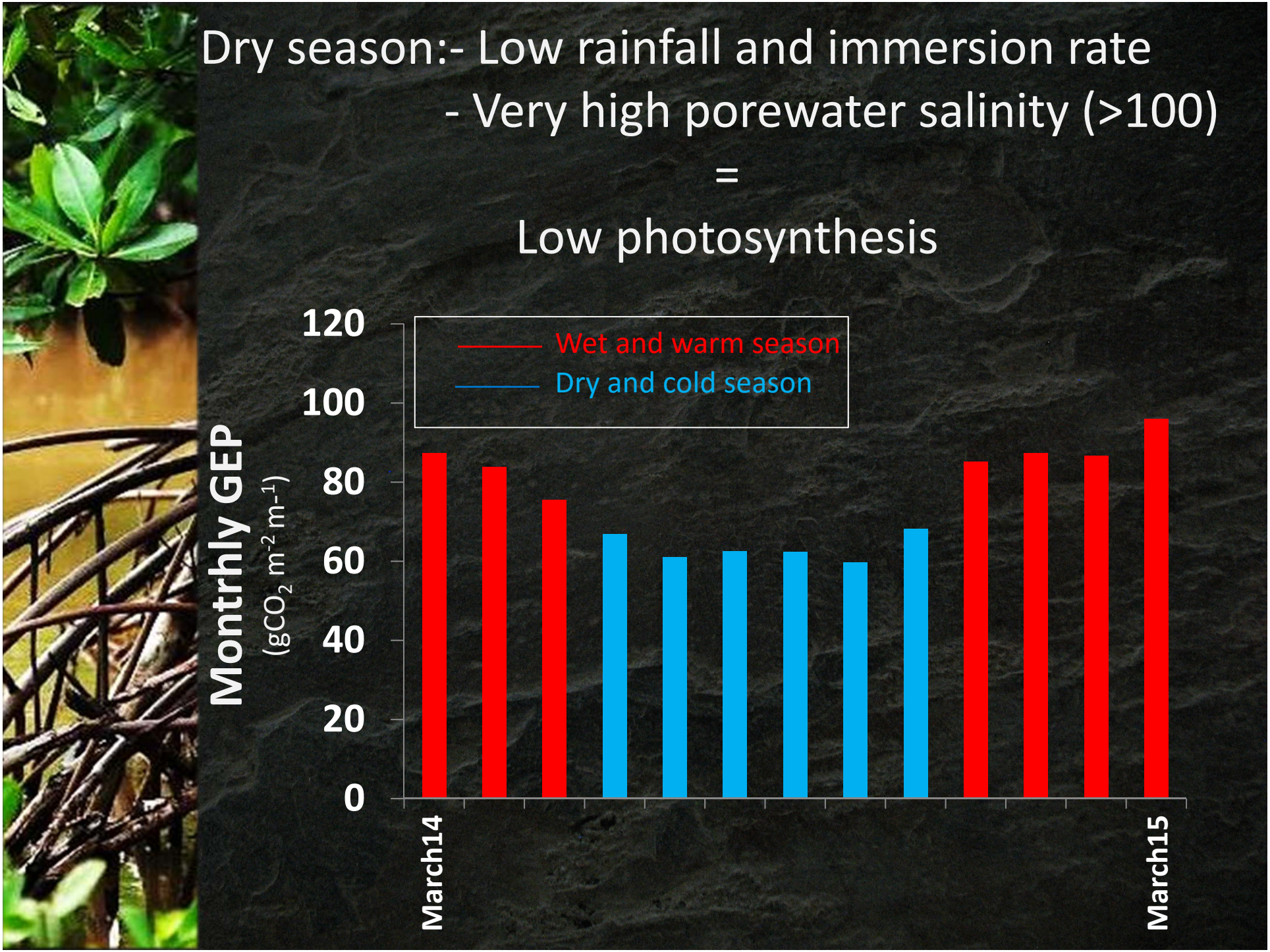


Rainy season:

- high rainfall & immersion rates

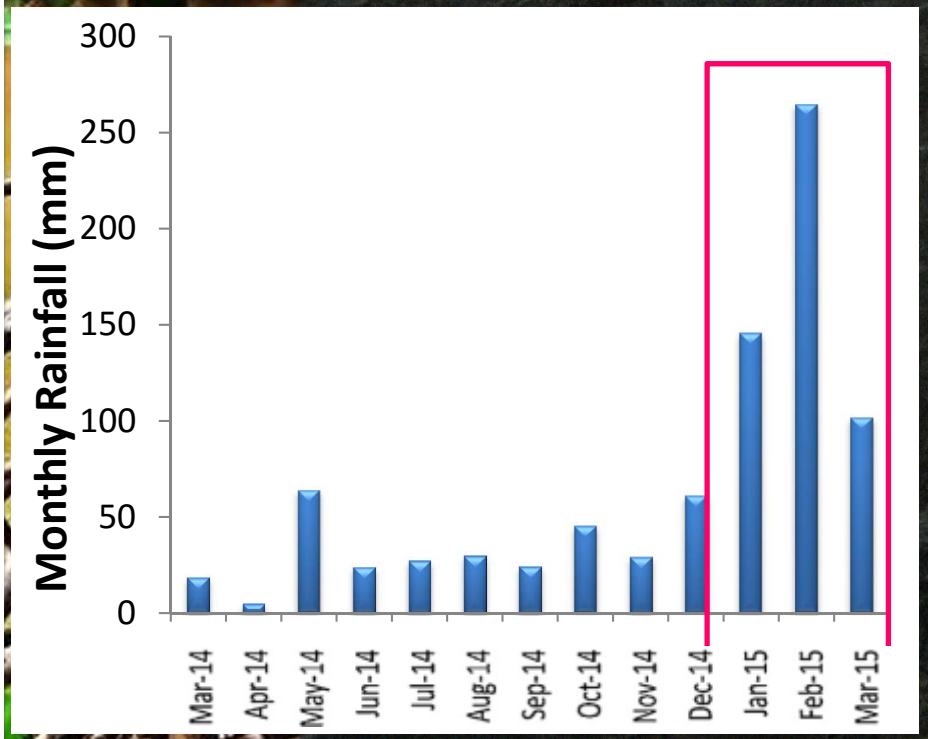
Dry season:

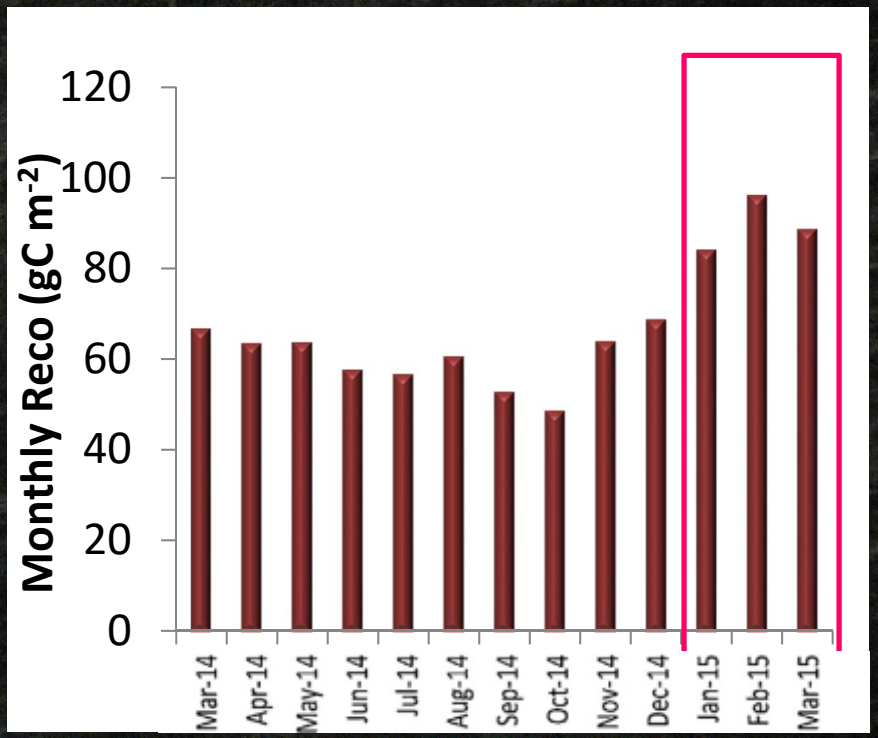
- low rainfall & immersion rates


Dry season:- Low rainfall and immersion rate
- Very high porewater salinity (>100)
=
Low photosynthesis
Wet and warm season
Dry and cold season
Monthly GEP
(gCO2 m-2 m-1)
120
100
80
60
40
20
0
March14
March15

Rainfall seems to have benefit effects on mangrove photosynthesis…

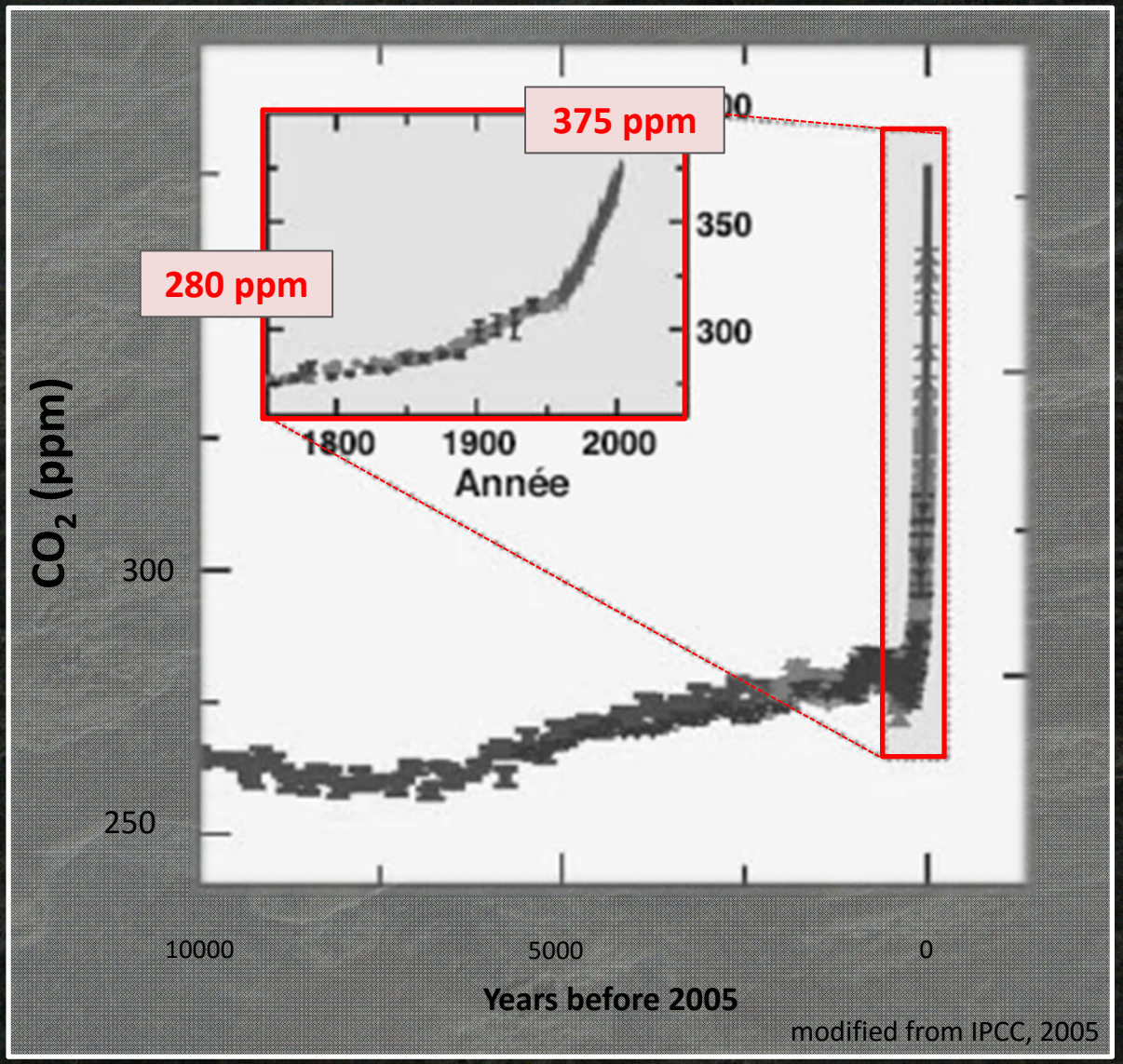
But also on ecosystem respiration…

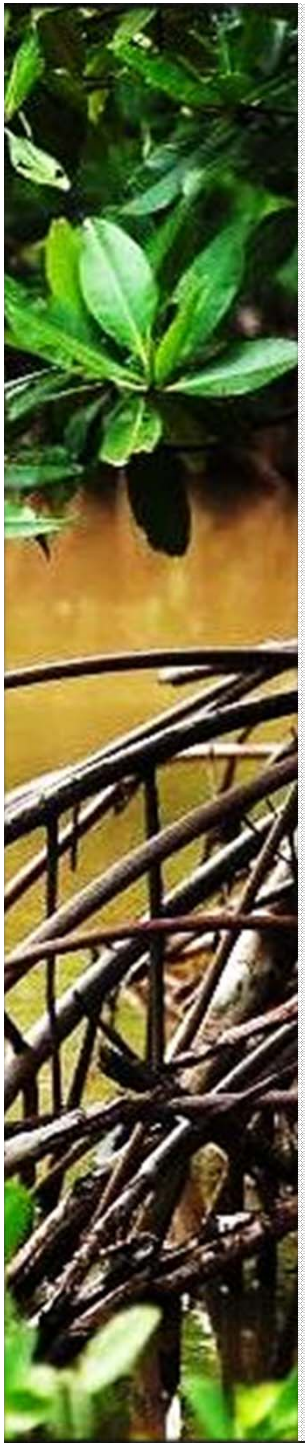




Global climate changes...

As a consequence of anthropogenic GHG increase.





Rainfall rate, as a driver of subtropical mangrove NEP