Global Sensitivity Analysis of STICS Soil Inputs on CO_2 and H_2O fluxes in Burgundy Vineyards

Julien Giraudo[1] *, Julien Crétat[1], Mathieu Thevenot[1], Olivier Mathieu[1], Cassandre Gaudnik[2], Thomas Montagnac[3]

[1]Université Bourgogne Europe, CNRS, Biogéosciences UMR 6282, 21000 Dijon, France
[2]Comité Champagne, 51200 Epernay, France
[3]Comité Bourgogne, 21200 Beaune, France

julien.giraudo@ube.fr

XIVth STICS seminar, 17-19 March 2026. organized by Uliege-GxABT & INRAE

- **Viticulture vs climate change: a double challenge**

Mitigation

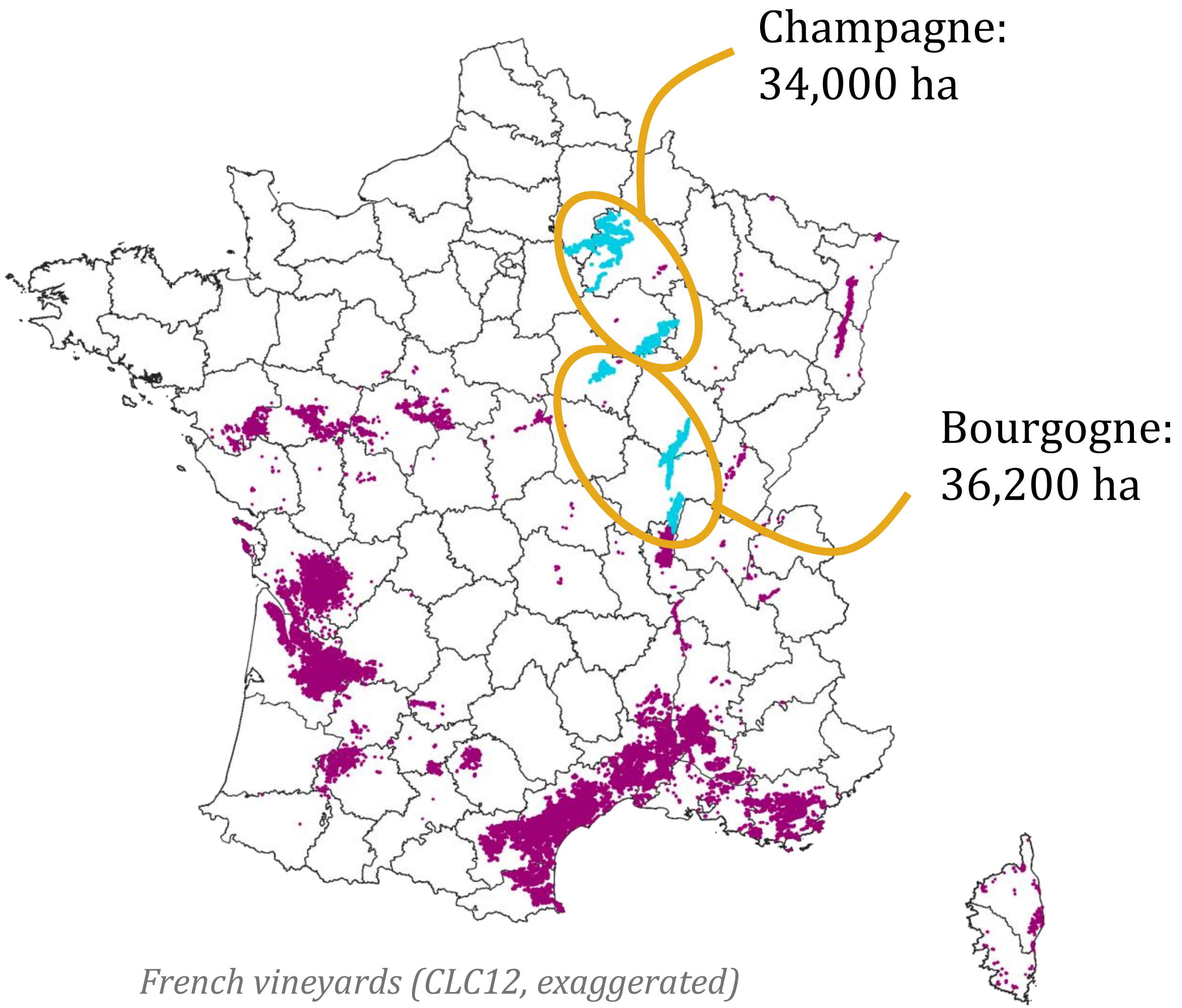
Adaptation

(Scandellari et al., 2016; van Leeuwen et al., 2019)

- **The Burgundy and Champagne comitees set carbon neutrality objectives**

VINS DE BOURGOGNE

COMITÉ CHAMPAGNE



French vineyards (CLC12, exaggerated)

- **Viticulture vs climate change: a double challenge**

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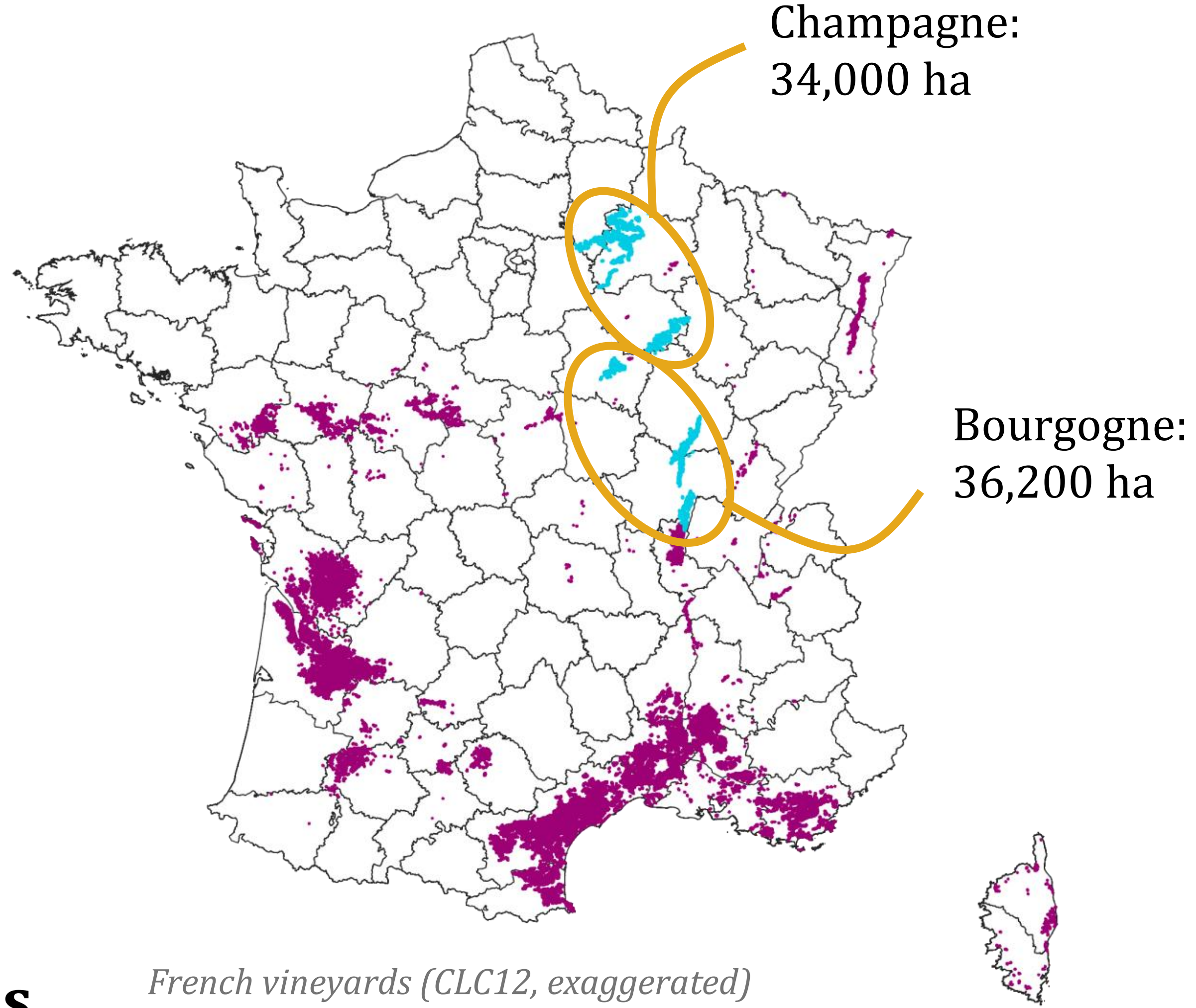
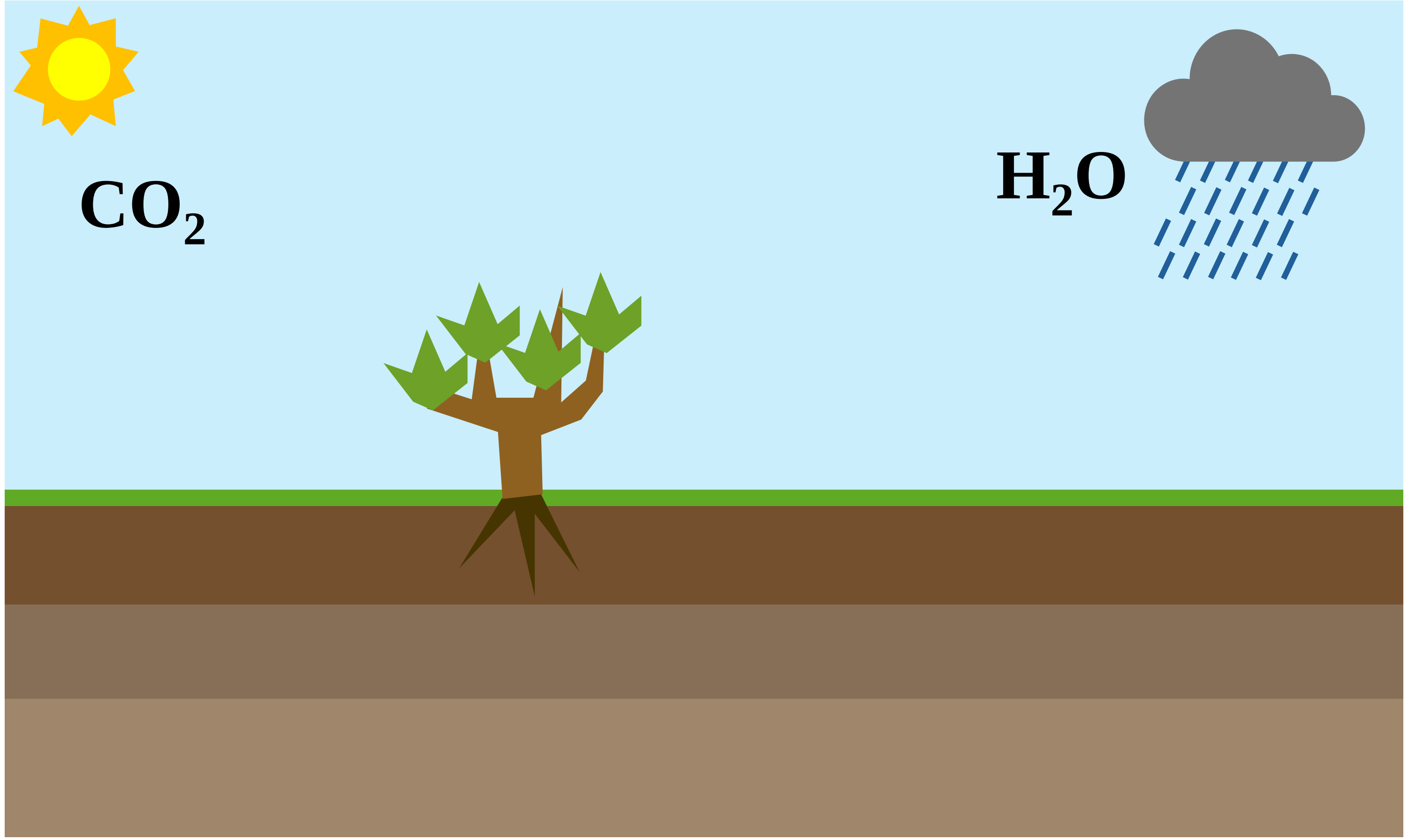


French vineyards (CLC12, exaggerated)

→ Need to study carbon and water fluxes

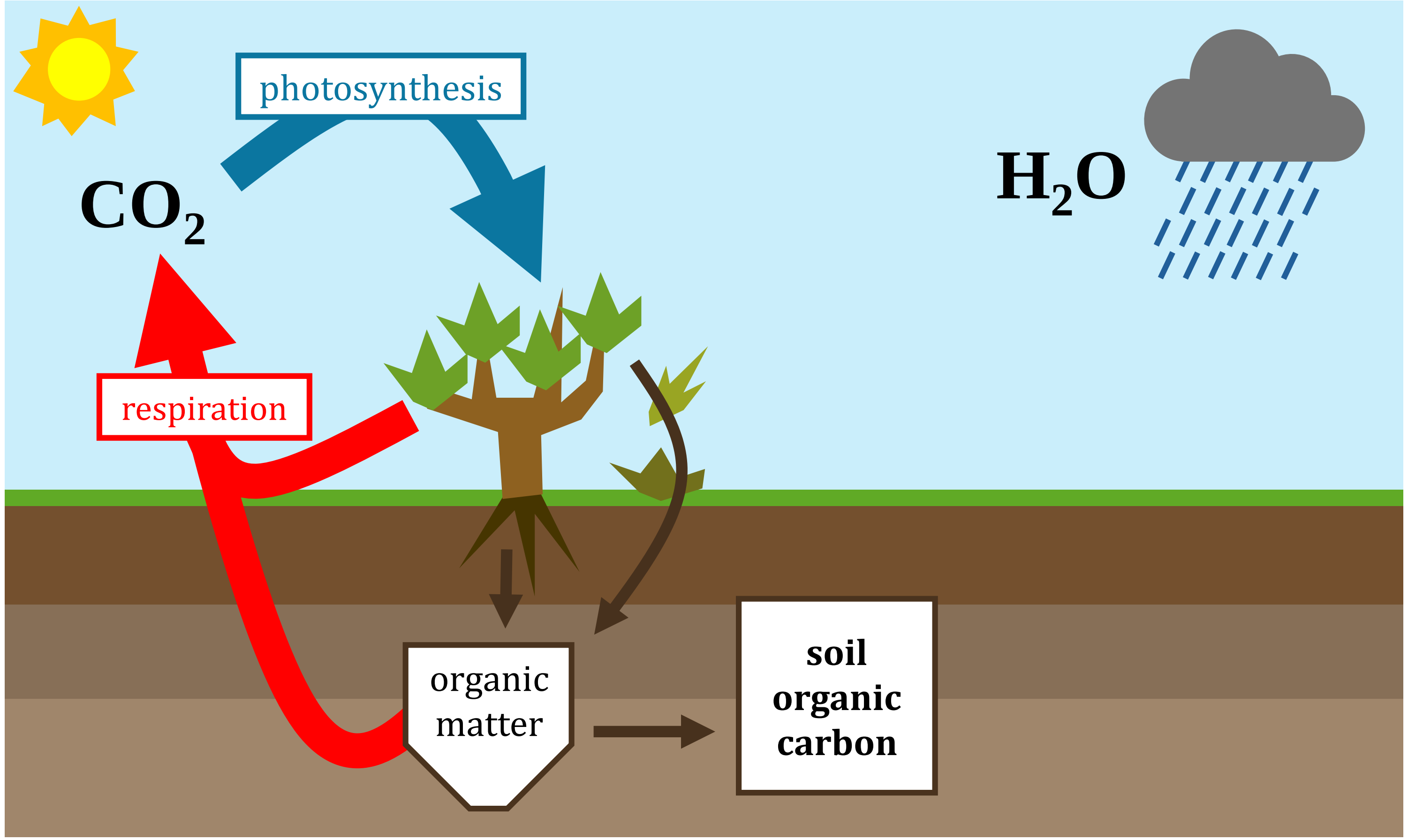
Carbon and water fluxes in the vineyard ecosystem



(Calvet et al., 2021)

Carbon and water fluxes in the vineyard ecosystem

NEE=
respiration - photosynthesis



(Calvet et al., 2021)

Carbon and water fluxes in the vineyard ecosystem

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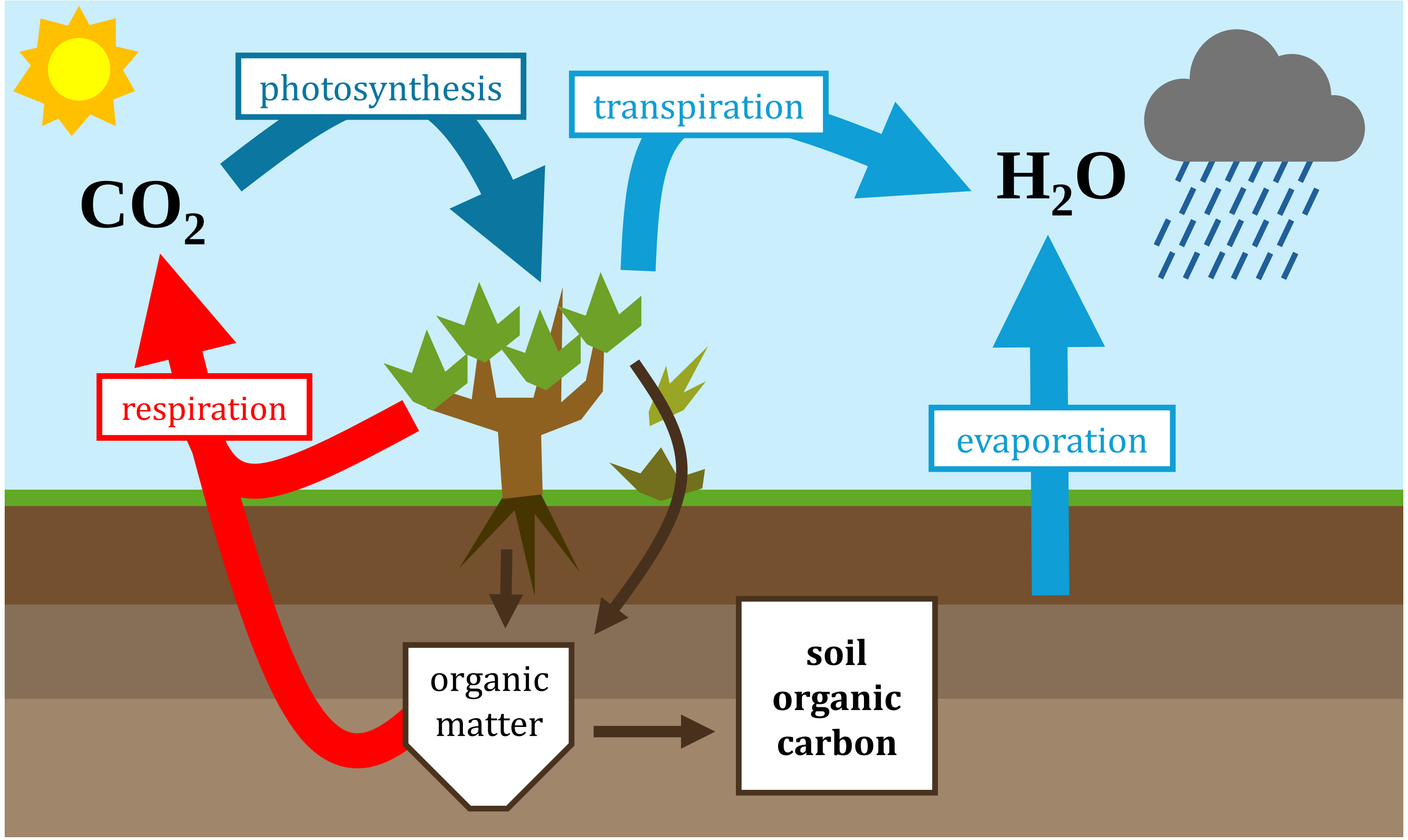
respiration - photosynthesis

ET=
transpiration + evaporation



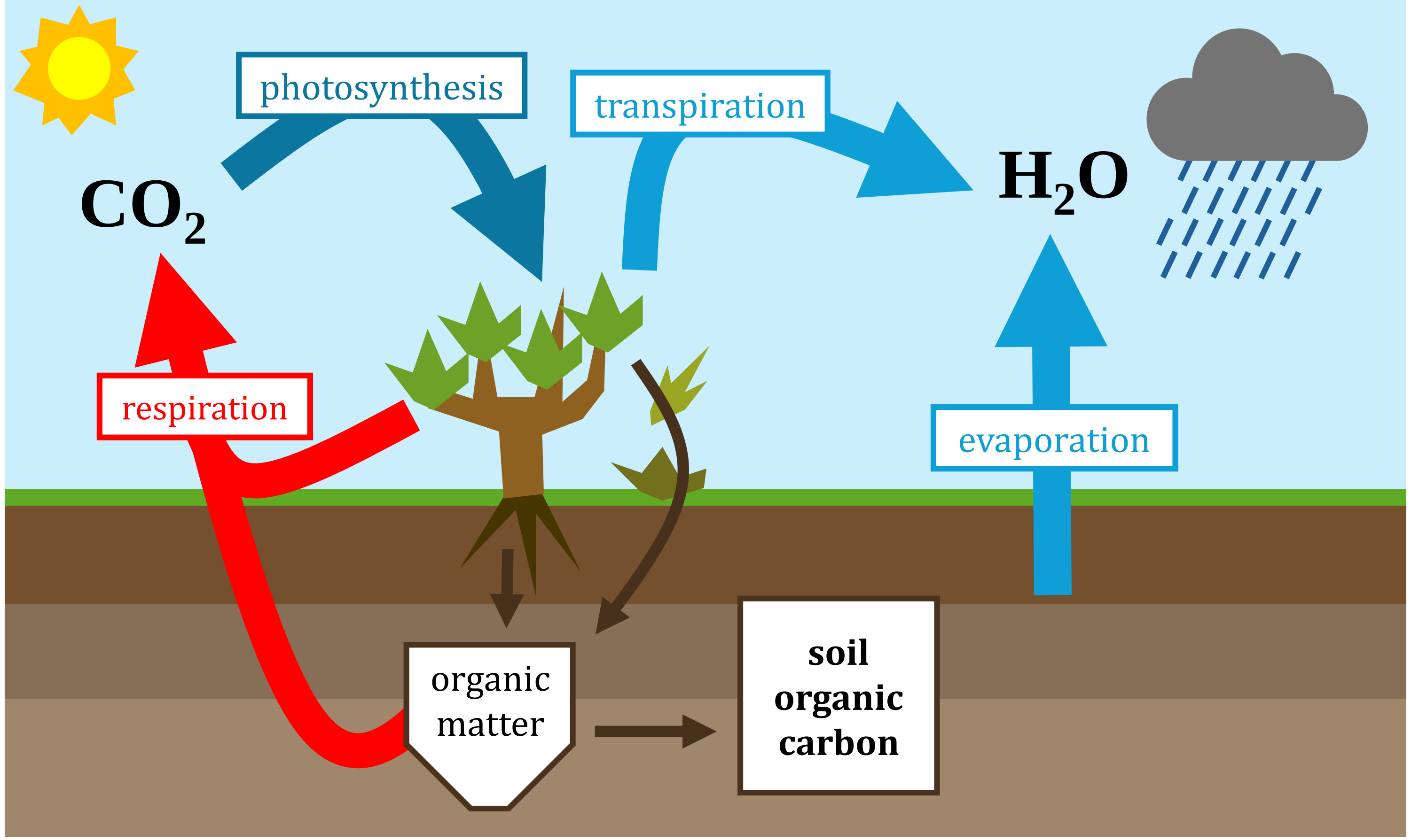
(Calvet et al., 2021)

Carbon and water fluxes in the vineyard ecosystem

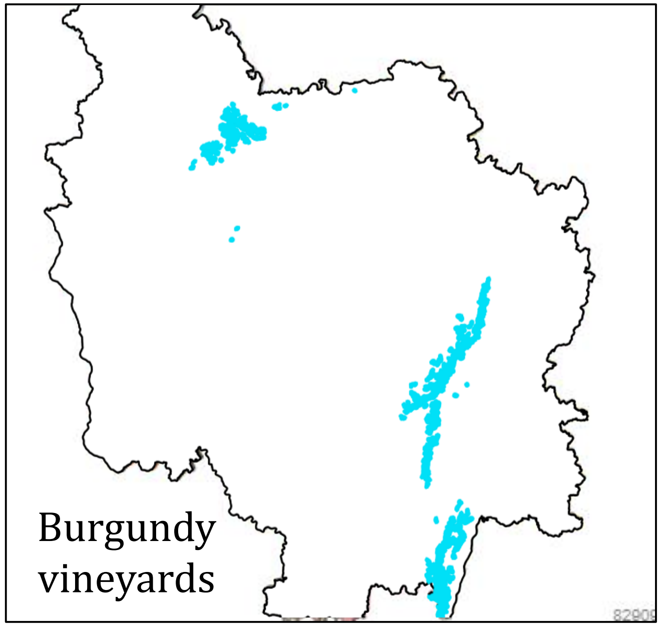
NEE=
respiration - photosynthesis

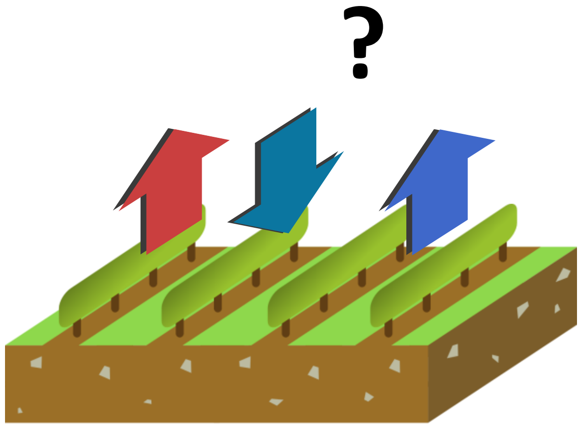
ET=
transpiration + evaporation

many drivers !

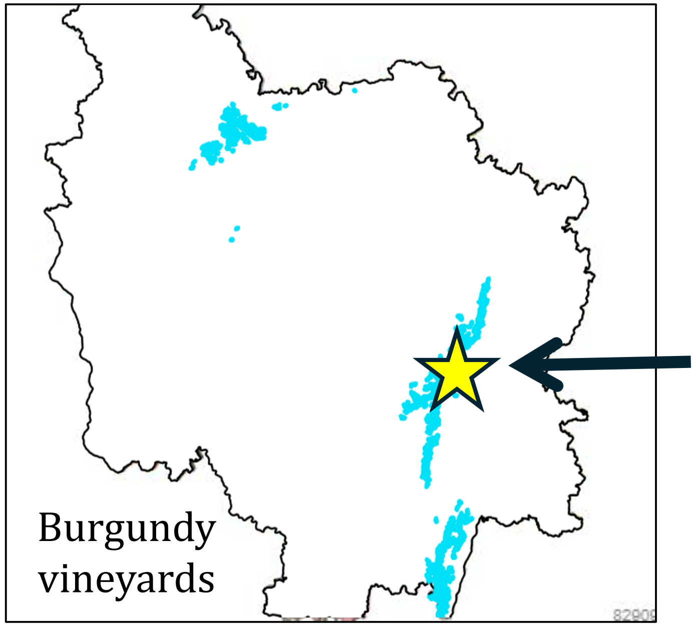


(Calvet et al., 2021)

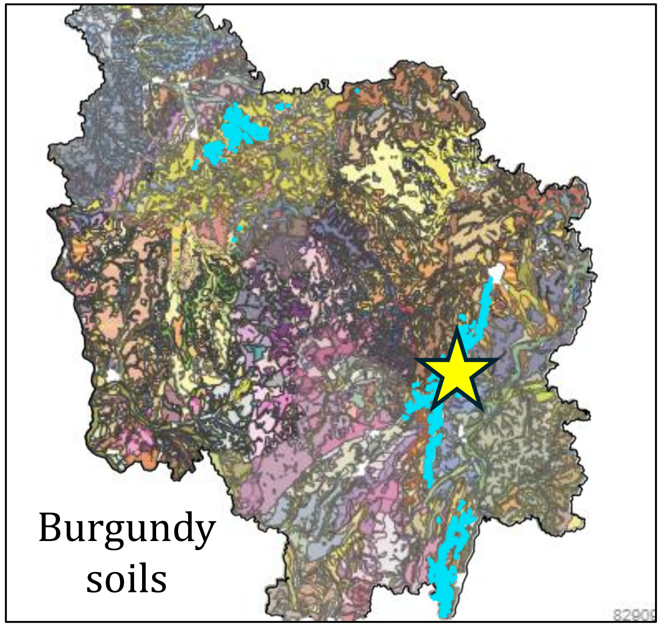

Burgundy
vineyards


?

Observation



Rully flux station
(june 2024~now)



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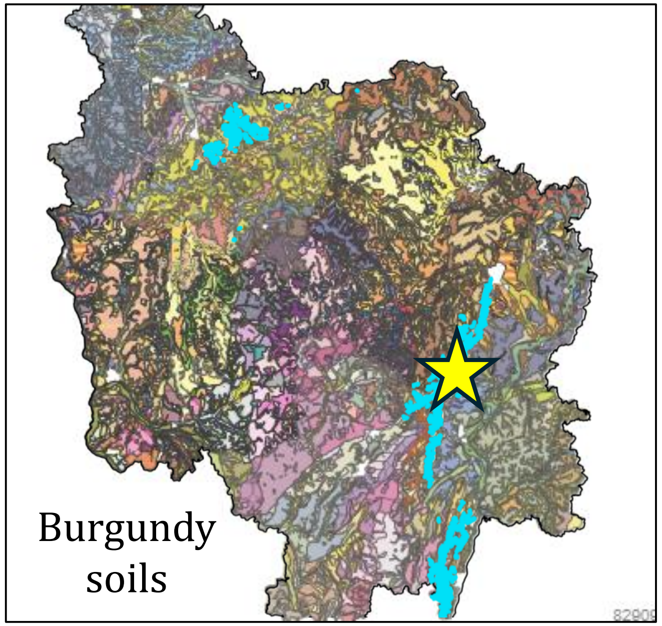

Observation

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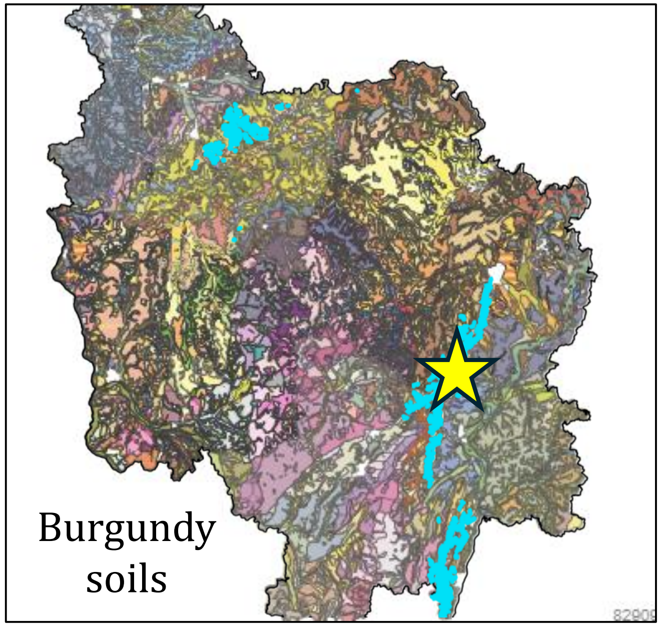
Modelling



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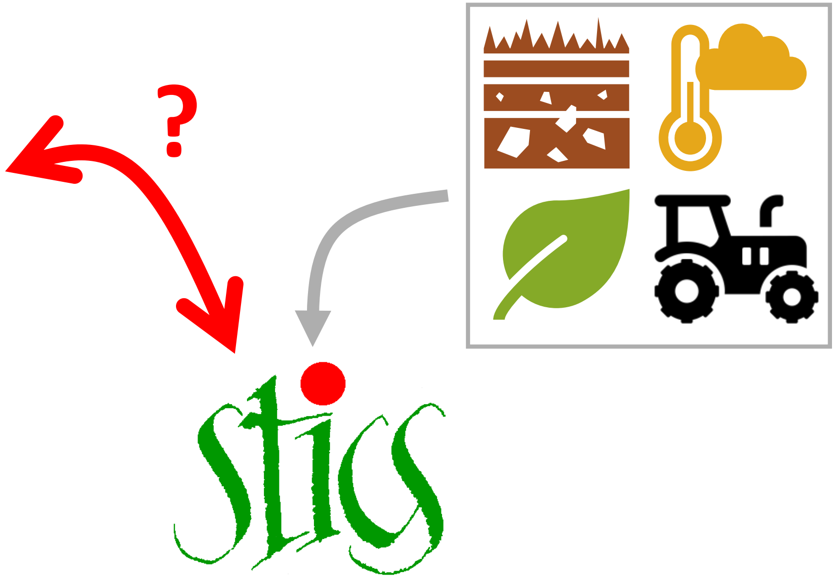
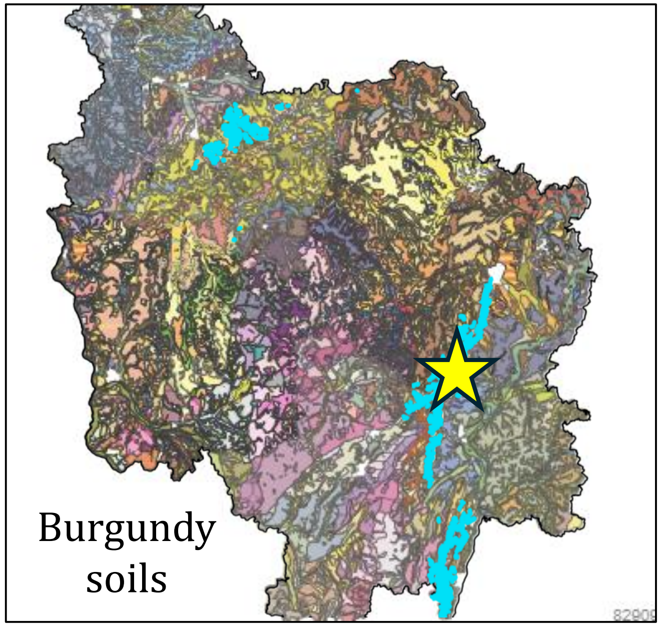


(i) Evaluating STICS capability to model NEE and ET in a temperate vineyard



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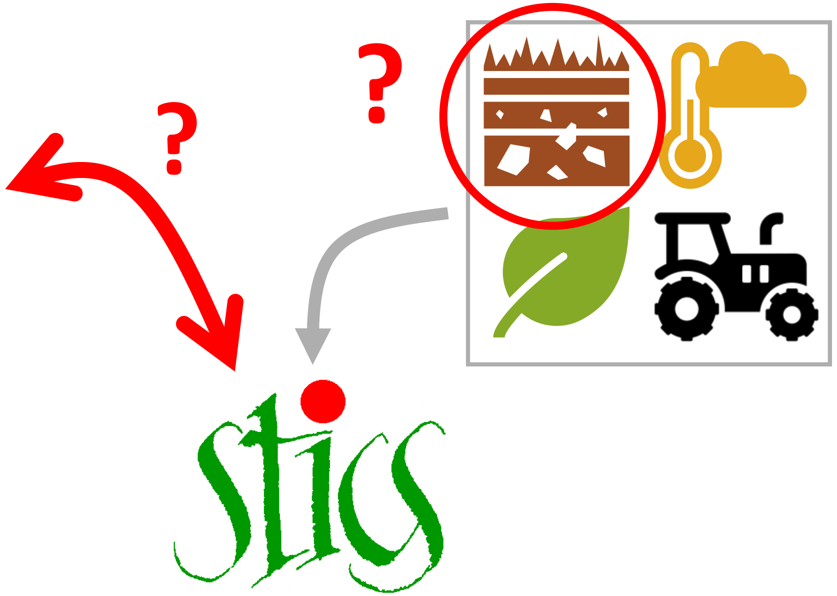


(i) Evaluating STICS capability to model NEE and ET in a temperate vineyard

(ii) Identifying and ranking the main soil drivers of NEE and ET in STICS

STICS version :

« vigne »
(10.2.0)

Vine parameterized for carbon reserve simulations in the Champagne context

+

NEE computation:
Adapted from *Delandmeter et al., 2023*

STICS version :

« vigne »
(10.2.0)

Vine parameterized for carbon reserve simulations in the Champagne context

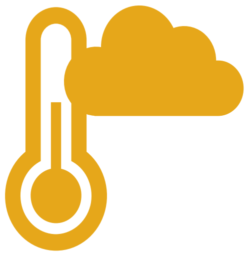
+

NEE computation:
Adapted from *Delandmeter et al., 2023*

Inputs :

Pinot Noir in Guyot-style pruning	Rully plot 2025 management	3 contrasted years +2025

Climate Inputs



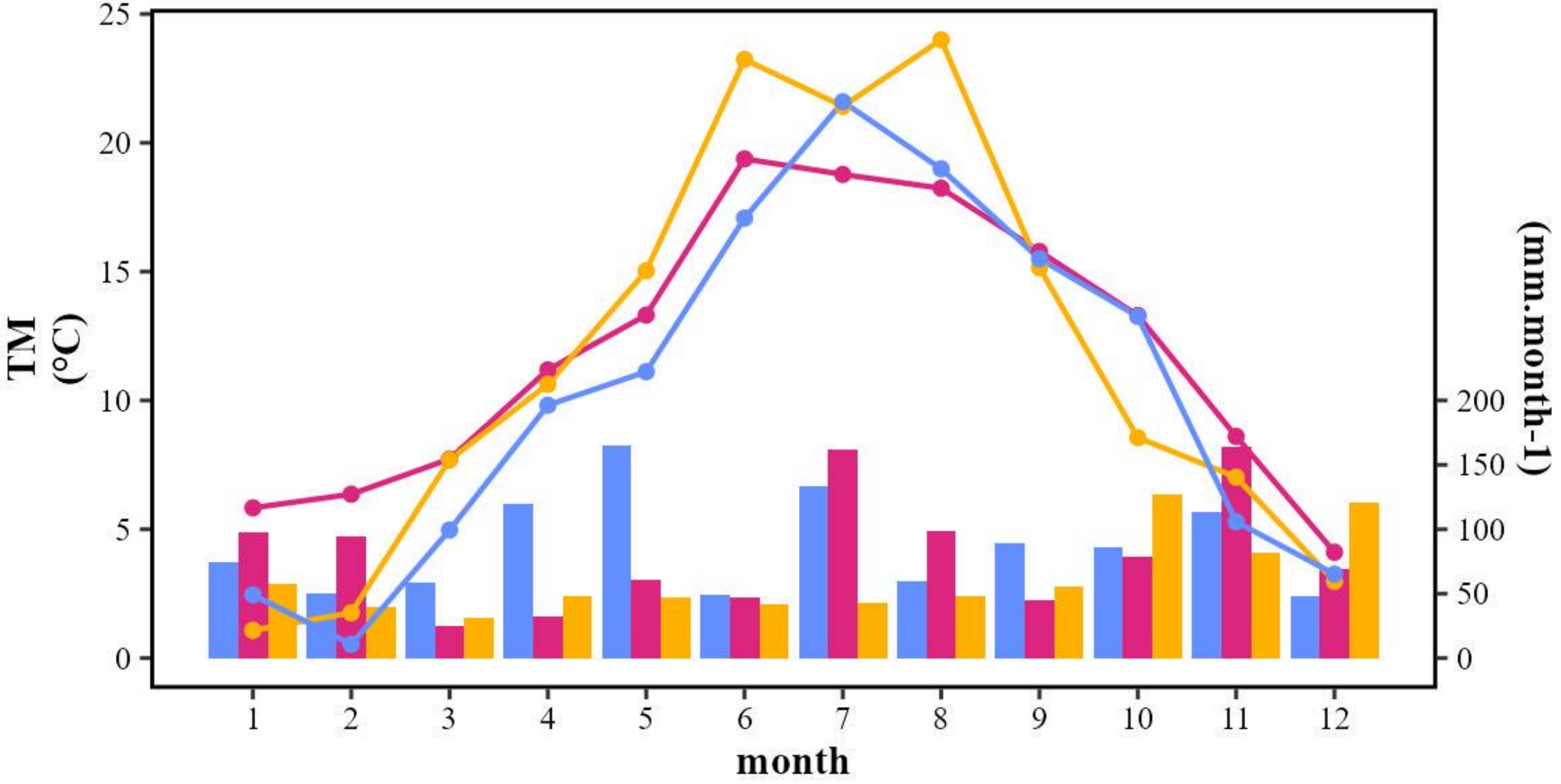
SAFRAN-SIM2 daily values

2014 : near normal

2003 : hot & dry

2013 : cold & rainy

+2025



(Soubeyroux et al., 2008, Le Moigne et al., 2020)

STICS version :

« vigne » (10.2.0)

Vine parameterized for carbon reserve simulations in the Champagne context

+

NEE computation:
Adapted from *Delandmeter et al., 2023*

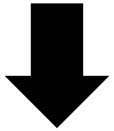
Inputs :

Pinot Noir in Guyot-style pruning	Rully plot 2025 management	3 contrasted years +2025	**110cm, 5 layers**

Global sensitivity analysis (GSA)

Soil Inputs

35 variables
(texture, pH, C & N content, bulk density, AWC...)



bounds needed!

Input
argi
norg
profhum
calc
pH
concseuil
albedo
q0
ruisolnu
obstarac
zesx
cfes
Z0solnu
CsurNsol
finert
HCCF_1
HCCF_2-5
HMINF_1
HMINF_2-5
DAF_1
DAF_2-5
cailloux_1
cailloux_2-5

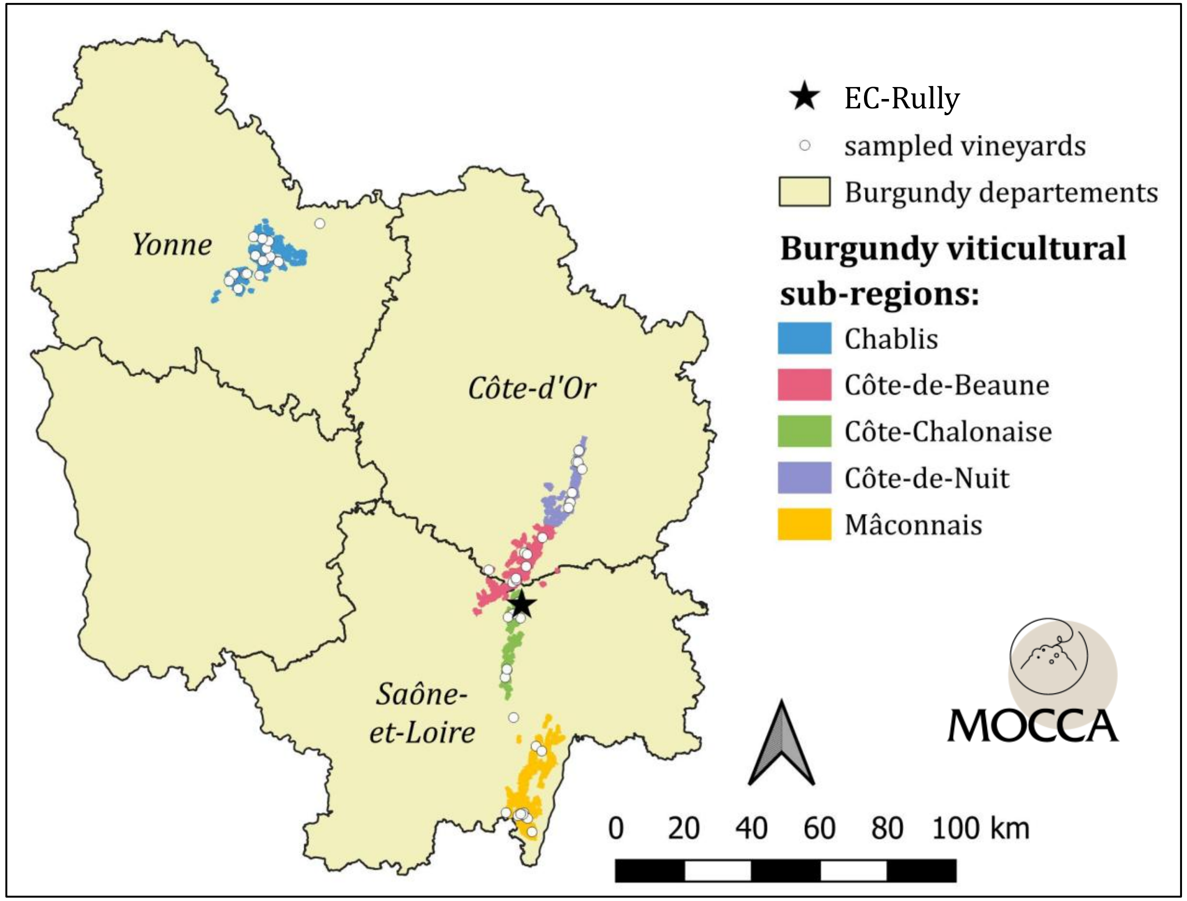
Soil Inputs

35 variables

(texture, pH, C & N content, bulk density, AWC...)

bounds needed!

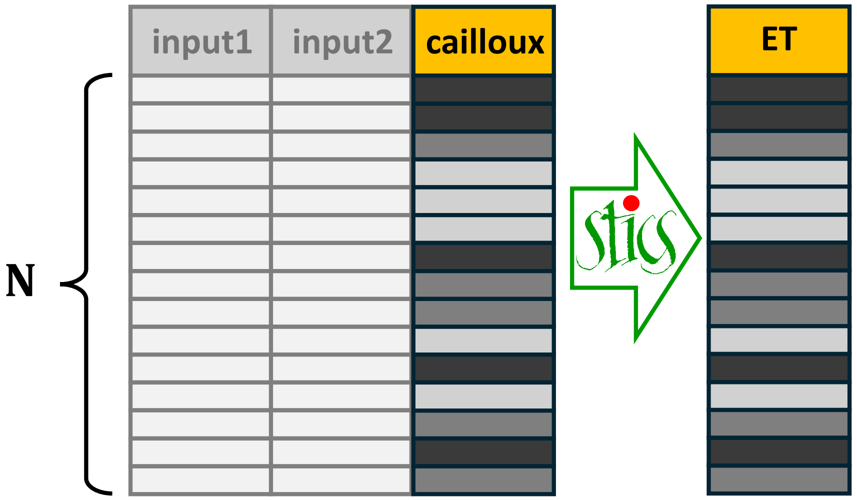
Input	Min	Max	Determination of bounds
argi	**6.3**	**49**	measured
norg	**0.05**	**0.3**	estimated
profhum	**20**	**40**	default bounds
calc	**2.6**	**62**	measured
pH	**5.3**	**8.6**	measured
concseuil	**0**	**0.5**	default bounds
albedo	**0.16**	**0.37**	estimated
q0	**7.9**	**12.0**	estimated
ruisolnu	**0.01**	**0.3**	estimated
obstarac	**50**	**110**	default bounds
zesx	**10**	**110**	default bounds
cfes	**0.5**	**4**	default bounds
Z0solnu	**0.01**	**0.02**	estimated
CsurNsol	**8**	**11**	measured
finert	**0.5**	**1**	default bounds
HCCF_1	**22**	**31**	estimated
HCCF_2-5	**19**	**27**	estimated
HMINF_1	**12**	**21**	estimated
HMINF_2-5	**10**	**20**	estimated
DAF_1	**1.4**	**2**	measured
DAF_2-5	**1.3**	**2.1**	measured
cailloux_1	**1.5**	**65**	measured
cailloux_2-5	**0.9**	**63**	measured



- measured
- estimated
- default bounds

GSA method : PAWNgen (*Pianosi et al., 2015, 2018*) → *illustration with cailloux~ET*

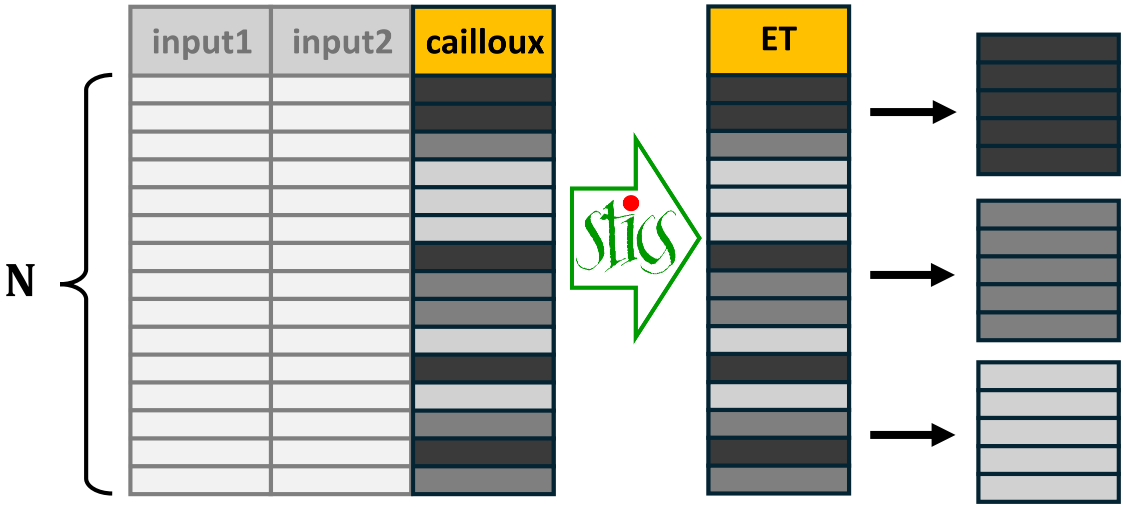
1: **N** random sampling of inputs



GSA method : PAWNgen (*Pianosi et al., 2015, 2018*) → *illustration with cailloux~ET*

1: **N** random sampling of inputs

2: Divide the outputs in **n** classes



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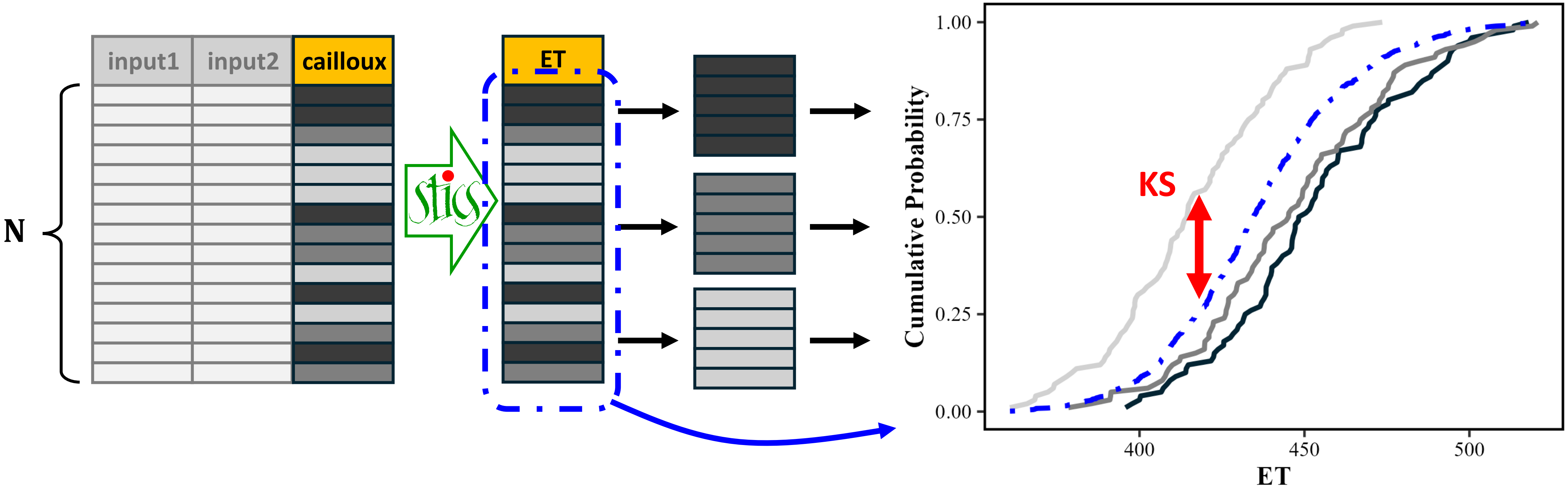
1: N random sampling of inputs

2: Divide the outputs in **n** classes

3: Compare the **n** conditioned CDF with the unconditioned



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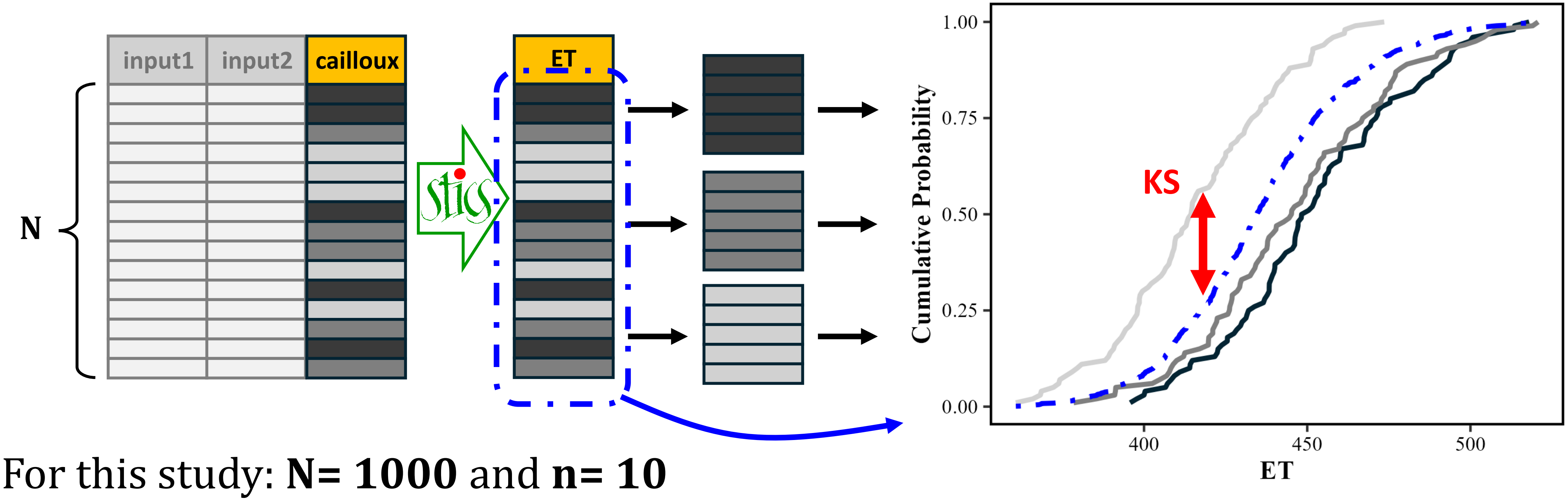
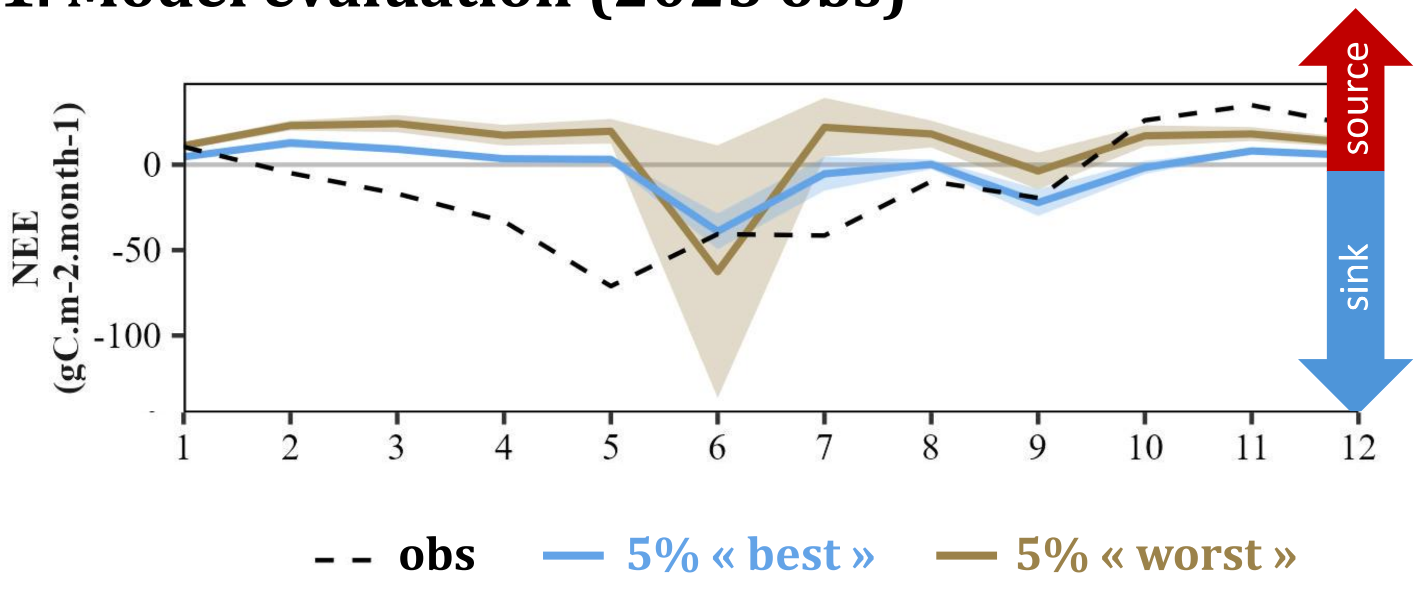


For this study: **N= 1000** and **n= 10**

1. **Model evaluation (2025 obs)**
2. **Annual cycle and budget of simulated fluxes**
3. **Results of GSA**

1. Model evaluation (2025 obs)



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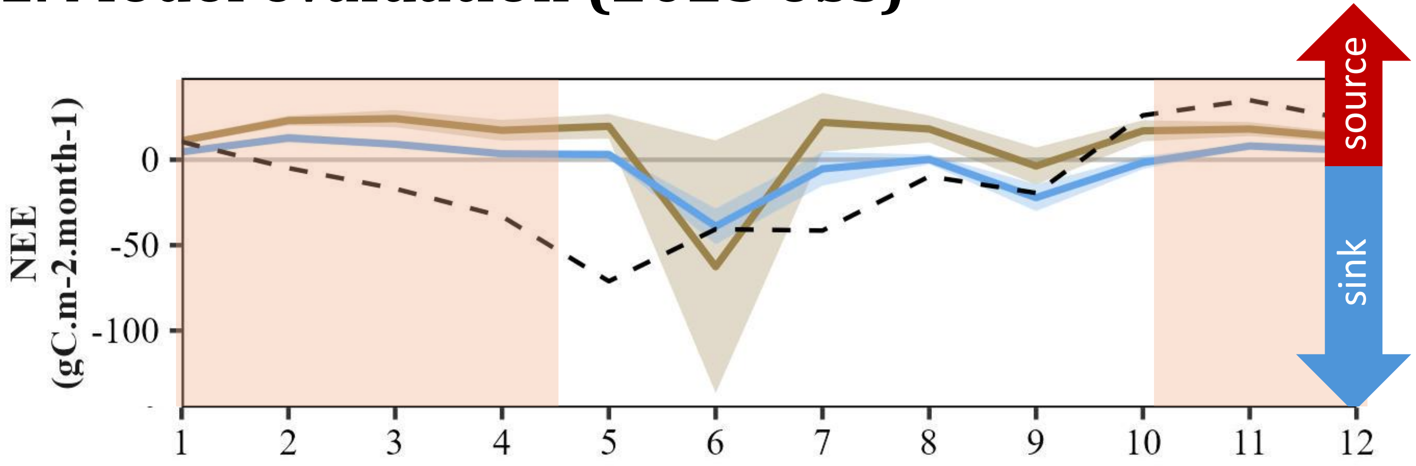


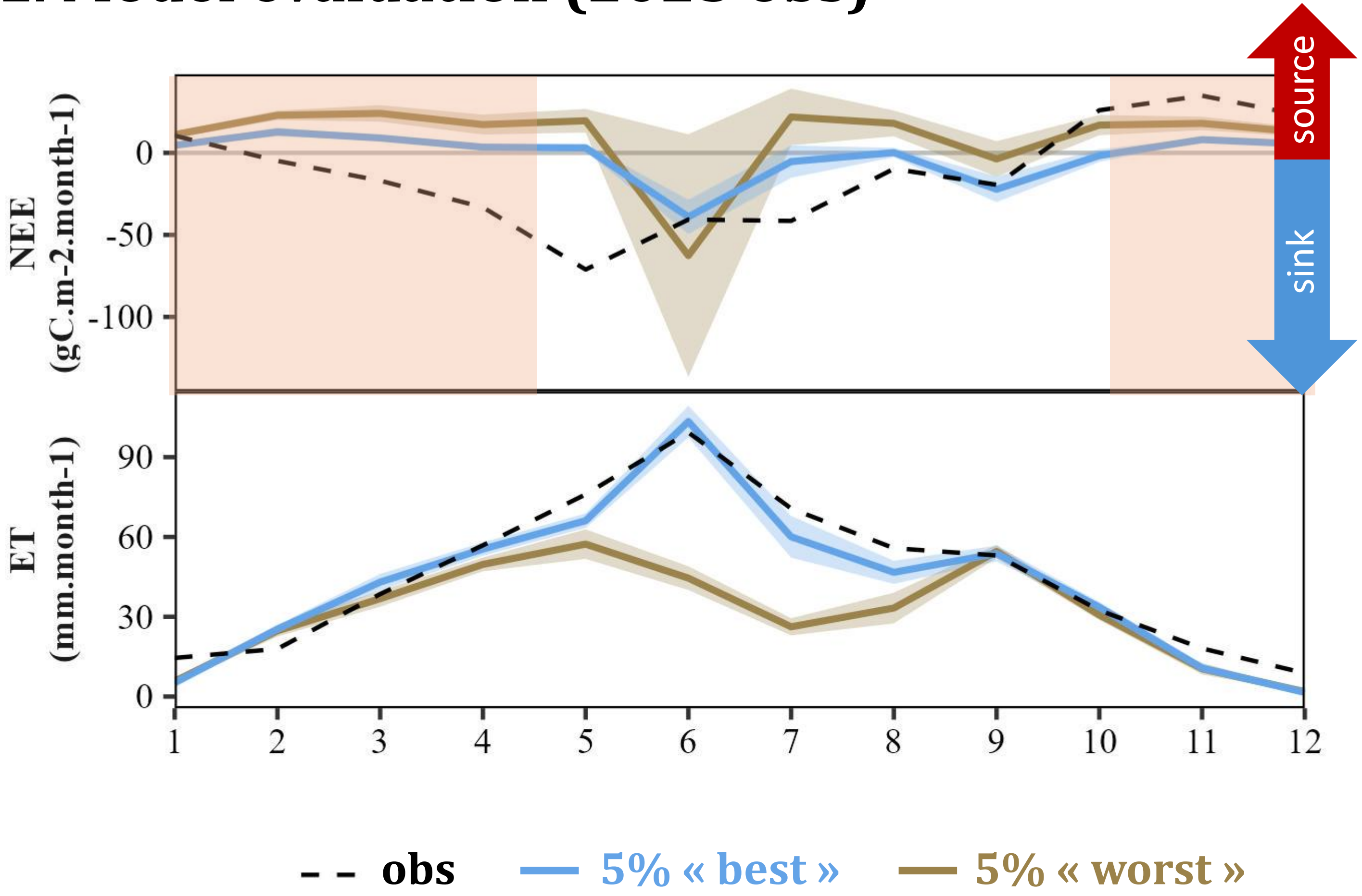
- - obs 5% « best » 5% « worst »

NEE: biases in dormant phases (cover crop?)

+ C uptake

- C uptake

1. Model evaluation (2025 obs)

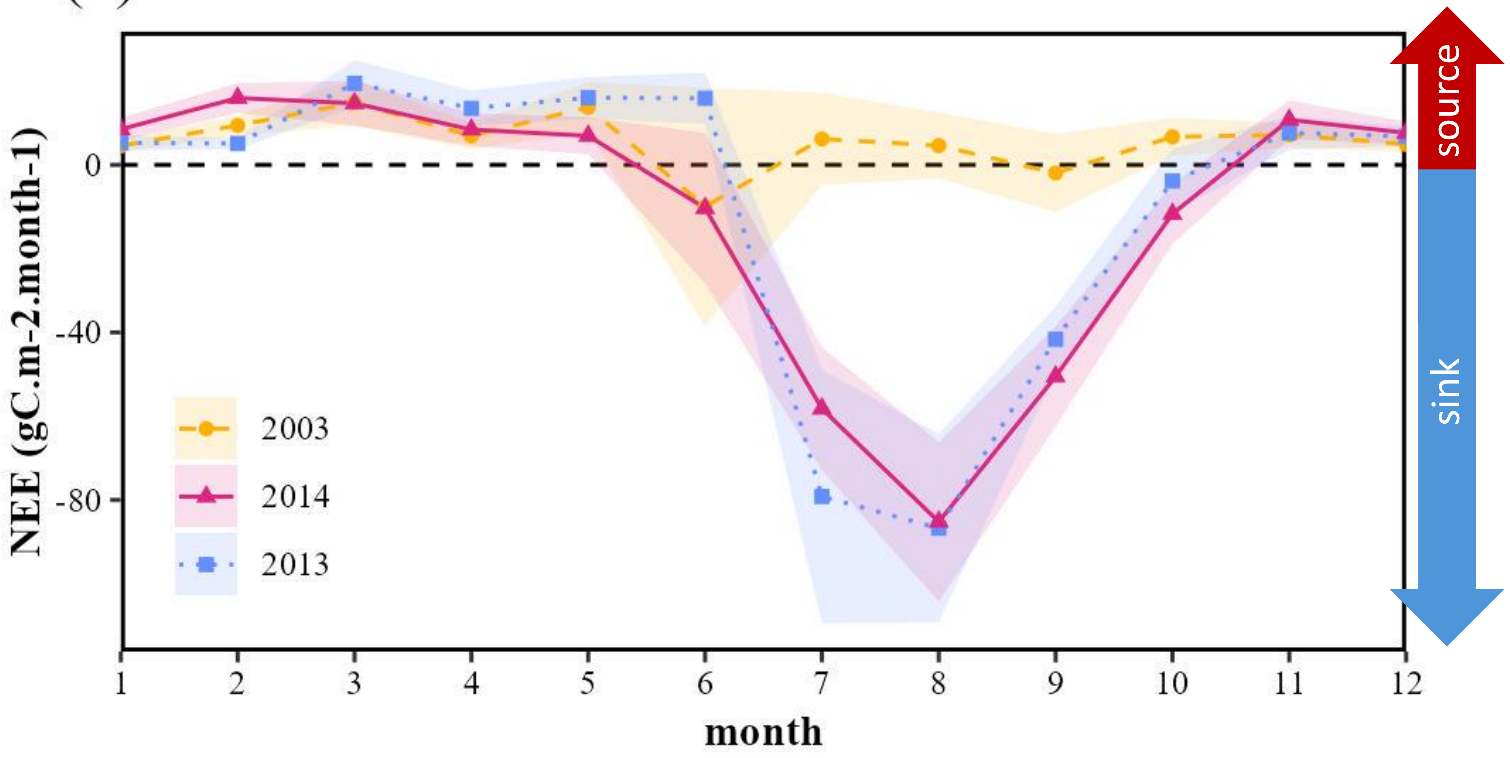


NEE: biases in dormant phases (cover crop?)

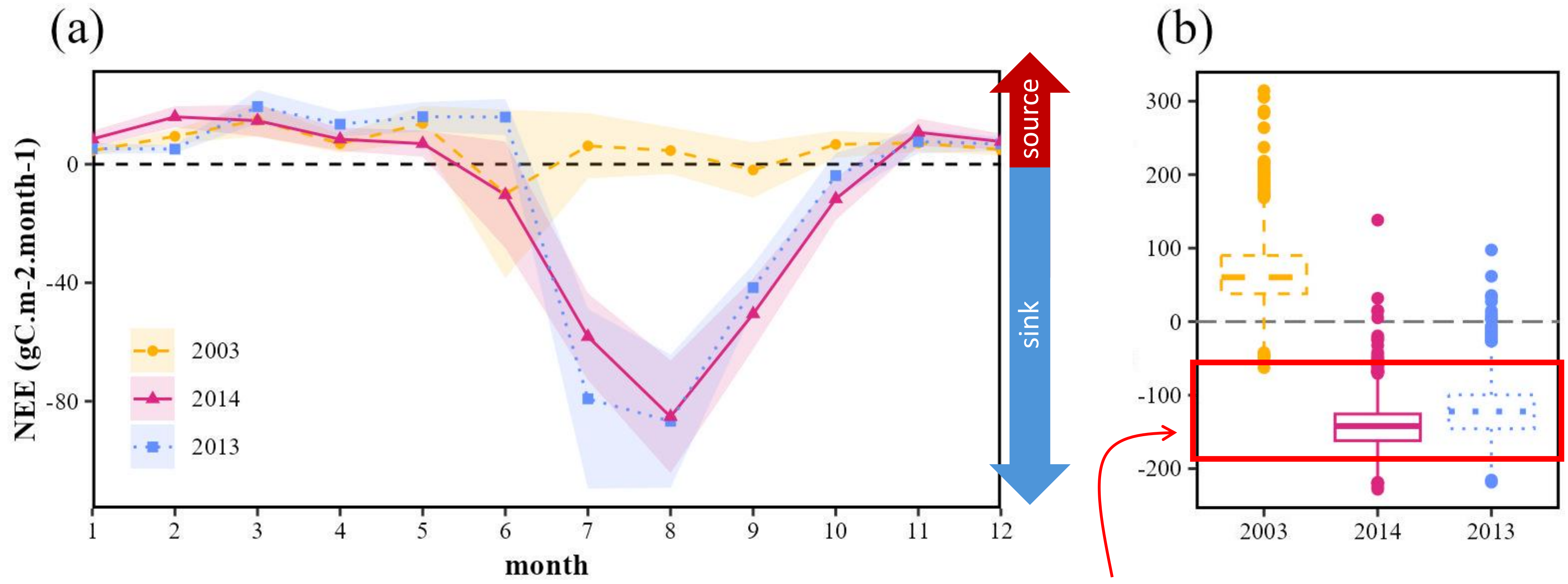
ET: accurate skill

2. Annual cycle and budget of simulated fluxes

(a)



2. Annual cycle and budget of simulated fluxes

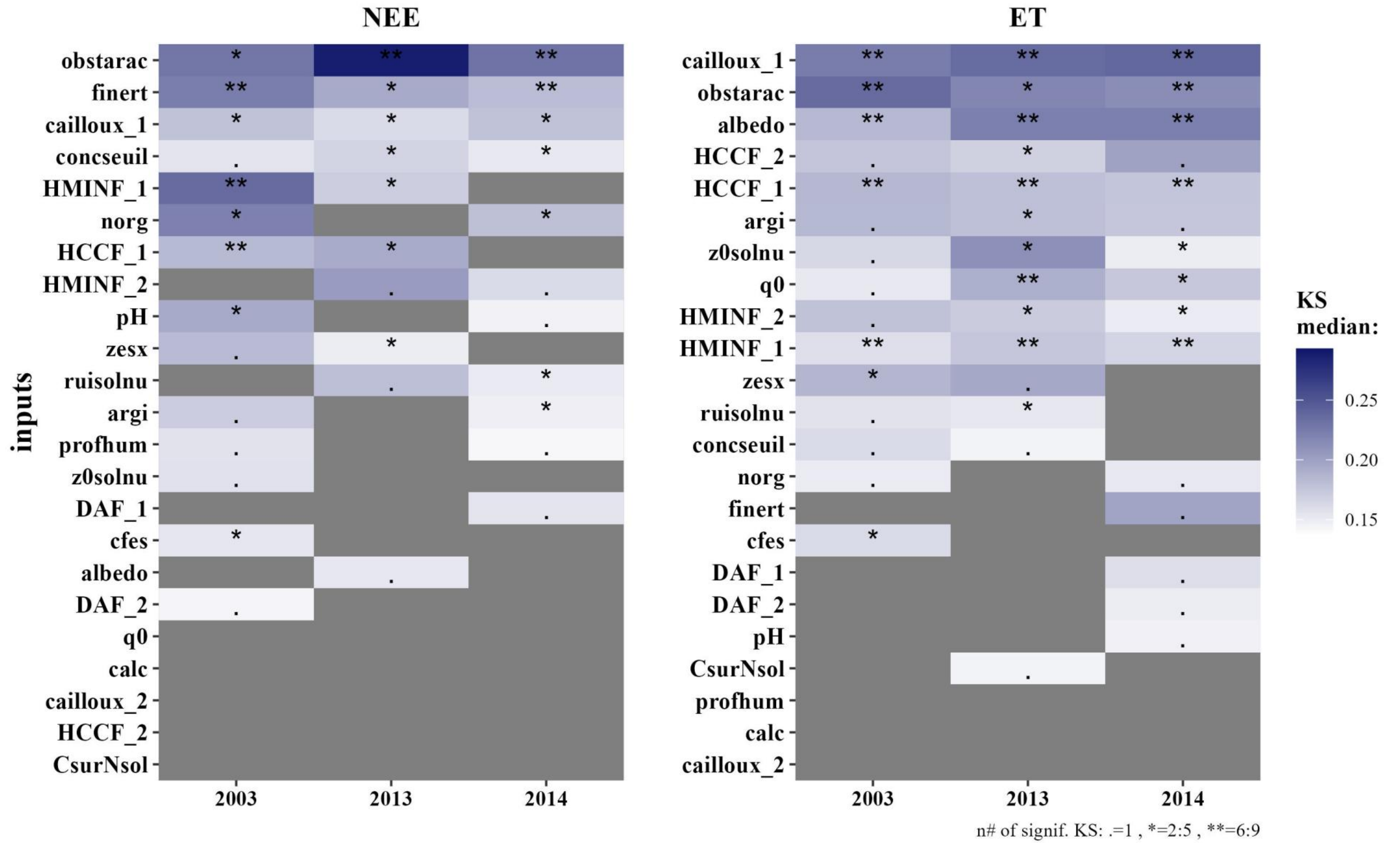


→2014 & 2013: annual budget consistent with the **litterature**

→2003: strong CO_2 release in hot & dry conditions

(Chiriacò et al. 2019 ; Marras et al. 2015 ; Pitacco et al. 2025; Tezza et al. 2019 ; Valenti et al. 2019 ; Gianelle et al. 2015)

3. Results of GSA



significance:

. = weak

* = moderate

** = strong

3. Results of GSA

Both NEE & ET:

- **root depth** (*obstarac*)
- **hydric parameters** (*HCCF, HMINF*)

(Heuer & Casper, 2011 Ruget et al., 2002)

significance:

. = weak

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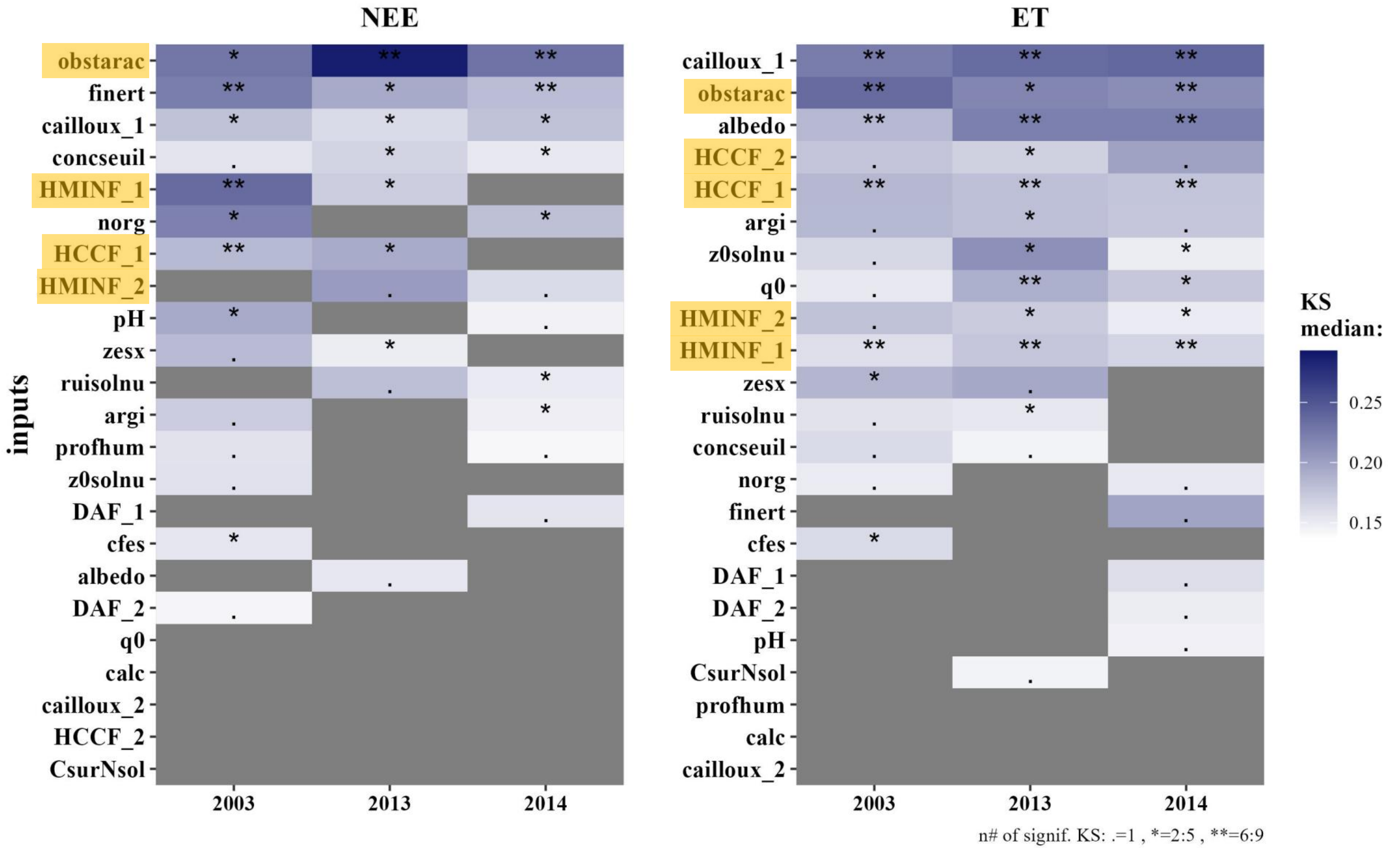


3. Results of GSA

Both NEE & ET:

- **root depth** (*obstarac*)
- **hydric parameters** (*HCCF, HMINF*)

(Heuer & Casper, 2011 Ruget et al., 2002)

NEE:

- **% stable OM** (finert*)

ET:

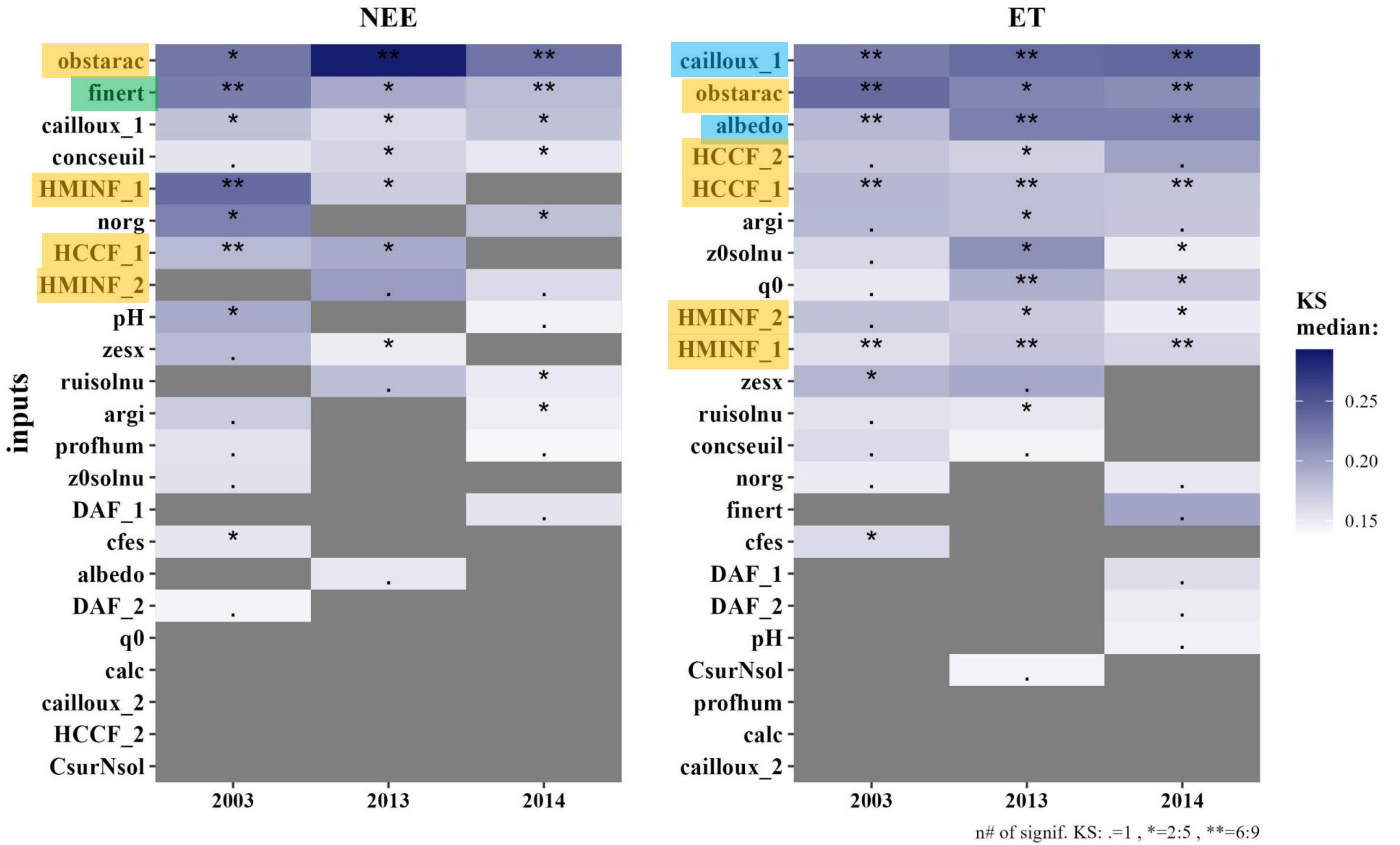
- **cailloux_1** (coarse elements)
- **albedo**

significance:

. = weak

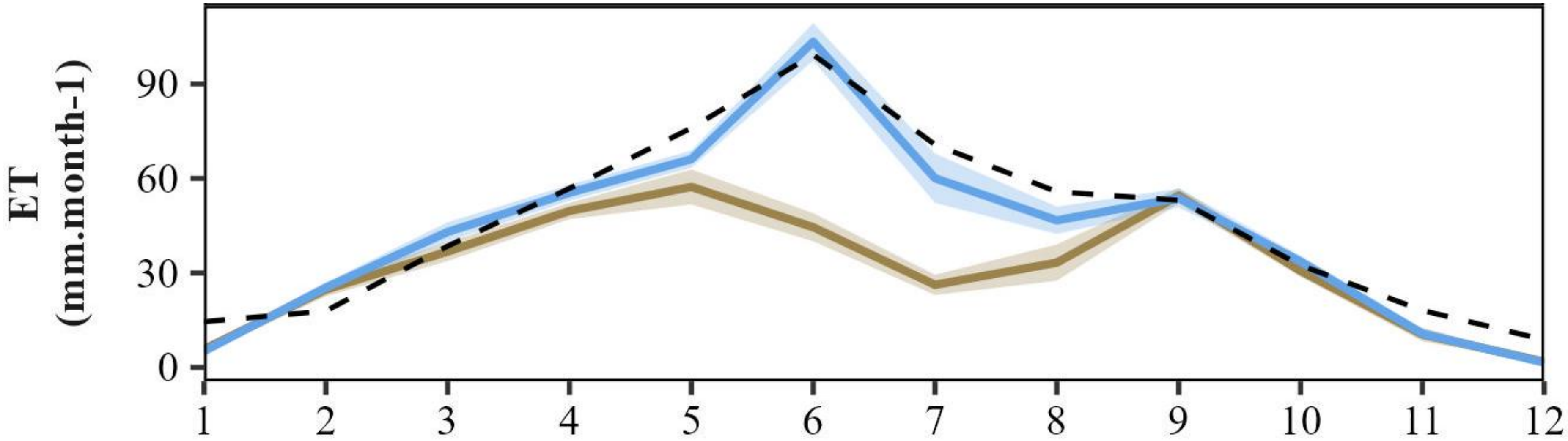
* = moderate

** = strong



*: model default bounds

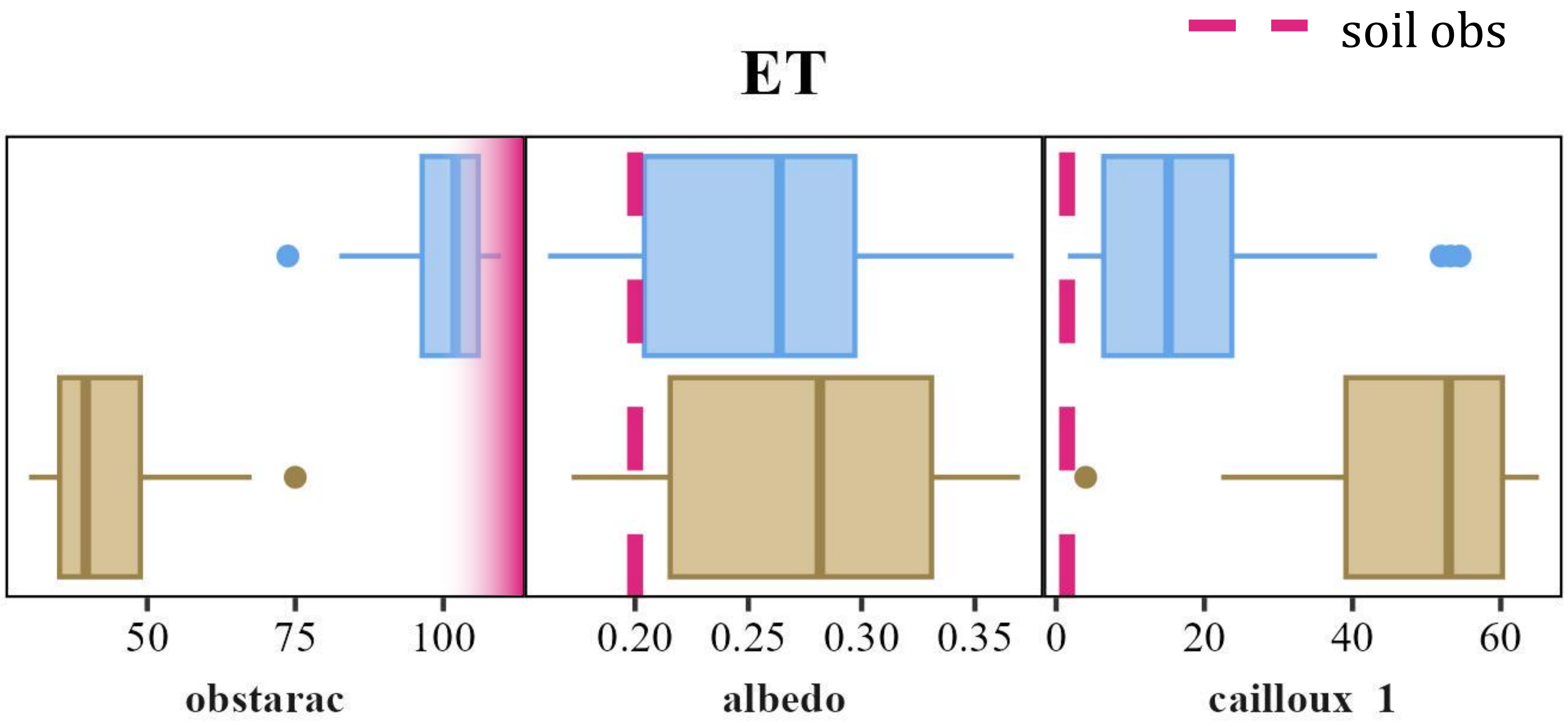
Discussion: comparison of GSA results with soil obs



5% « best » & 5% « worst »

Soil inputs of best simulation = observed soil parameters?

Discussion: comparison of GSA results with soil obs



→Inputs of the best simulations roughly correspond to the observed soil parameter values

(e.g., Varella et al., 2010)

Take home message

(i) Model evaluation

- Seasonality and annual budget in the range of literature
- 2025 obs: accurate skill for ET, unsatisfactory for NEE but a huge room for improvement (cover crop)

(ii) GSA

- Root depth and hydric parameters need to be accurately assessed in priority for correct fluxes simulations
- Stable organic matter for NEE
- Topsoil coarse elements and albedo for ET

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THANK YOU FOR YOUR ATTENTION

julien.giraudo@ube.fr

Université Bourgogne Europe

cnrs

BGS Biogéosciences

Bourgogne Bureau Interprofessionnel des Vins de Bourgogne

Comité Champagne

INRAE

Liège université Gembloux Agro-Bio Tech

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Annexe

Computation of NEE

Delandmeter et al., 2023 equation :

$$NEE = HR(>0) + NPP(<0)$$

with NPP as daily derivative of $TCC = \boldsymbol{masecvg} * 0.42 + \boldsymbol{mafruit} * 0.44 + \boldsymbol{msrac} * 0.38 + \boldsymbol{mafeuiltombe} * 0.42$

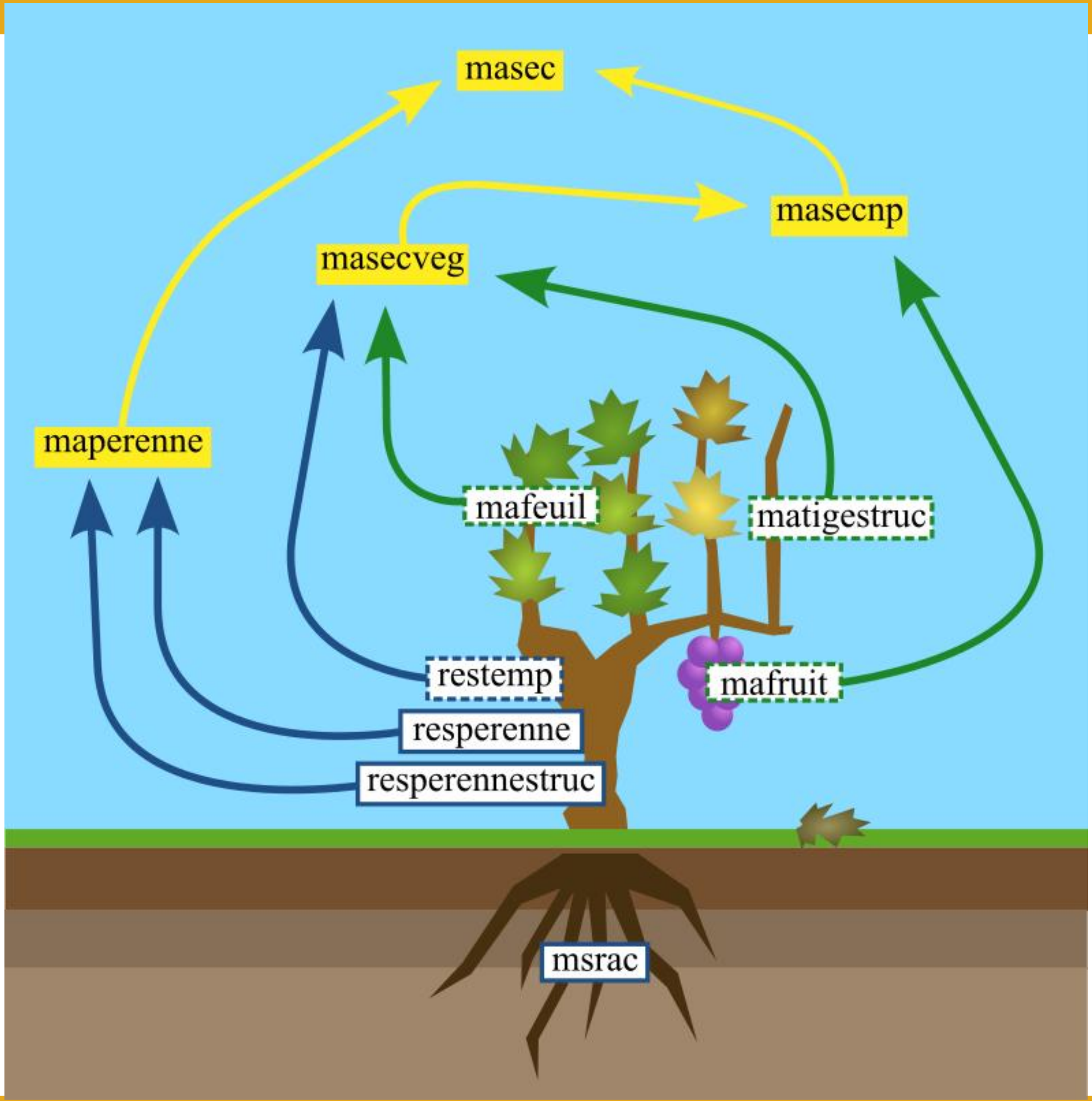
We suggest :

$$NEE = HR(>0) - CO2resperenne + NPP(<0)$$

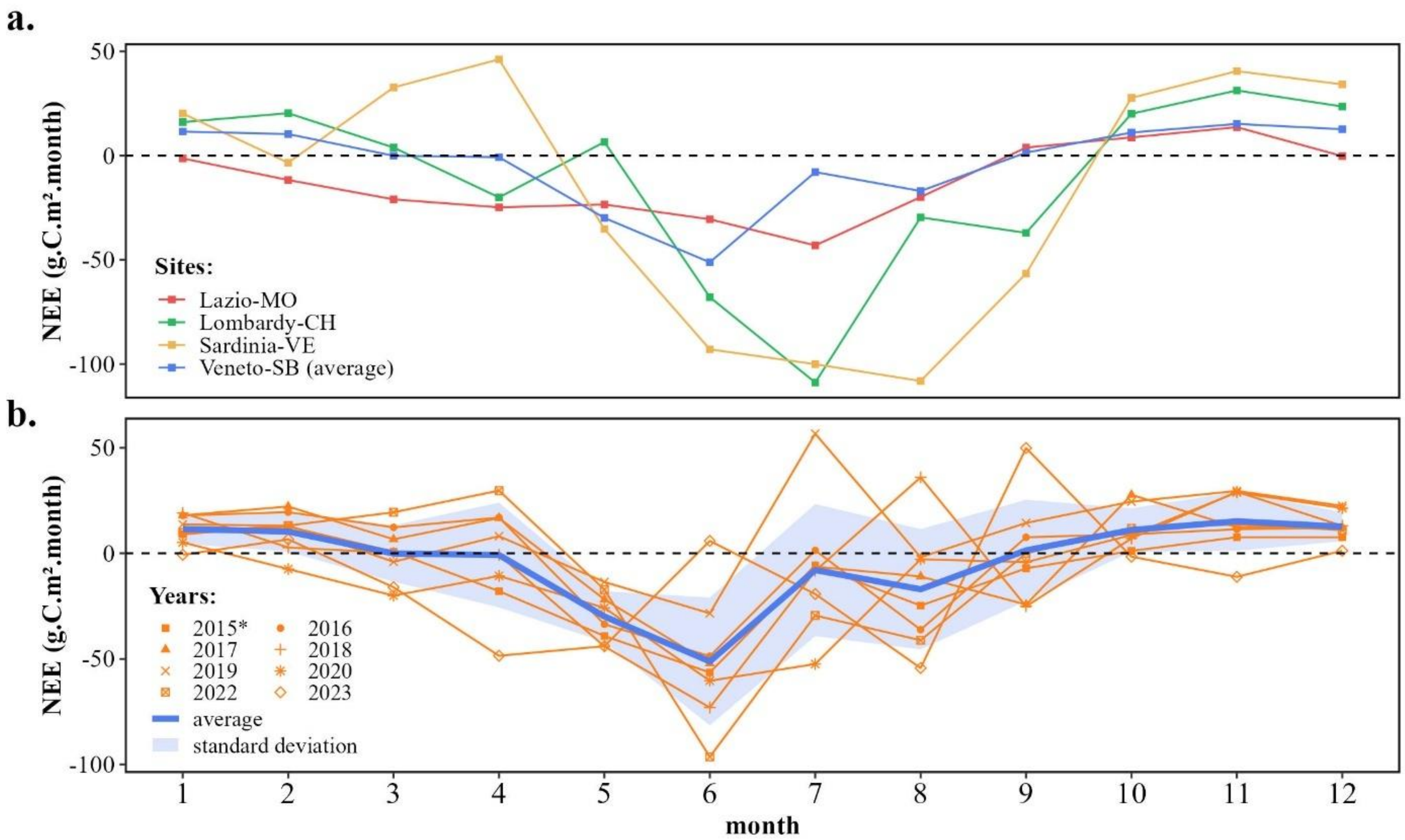
with

$$TCC = maperenne * 0.42 + msrac * 0.38 + masecnp * 0.44$$

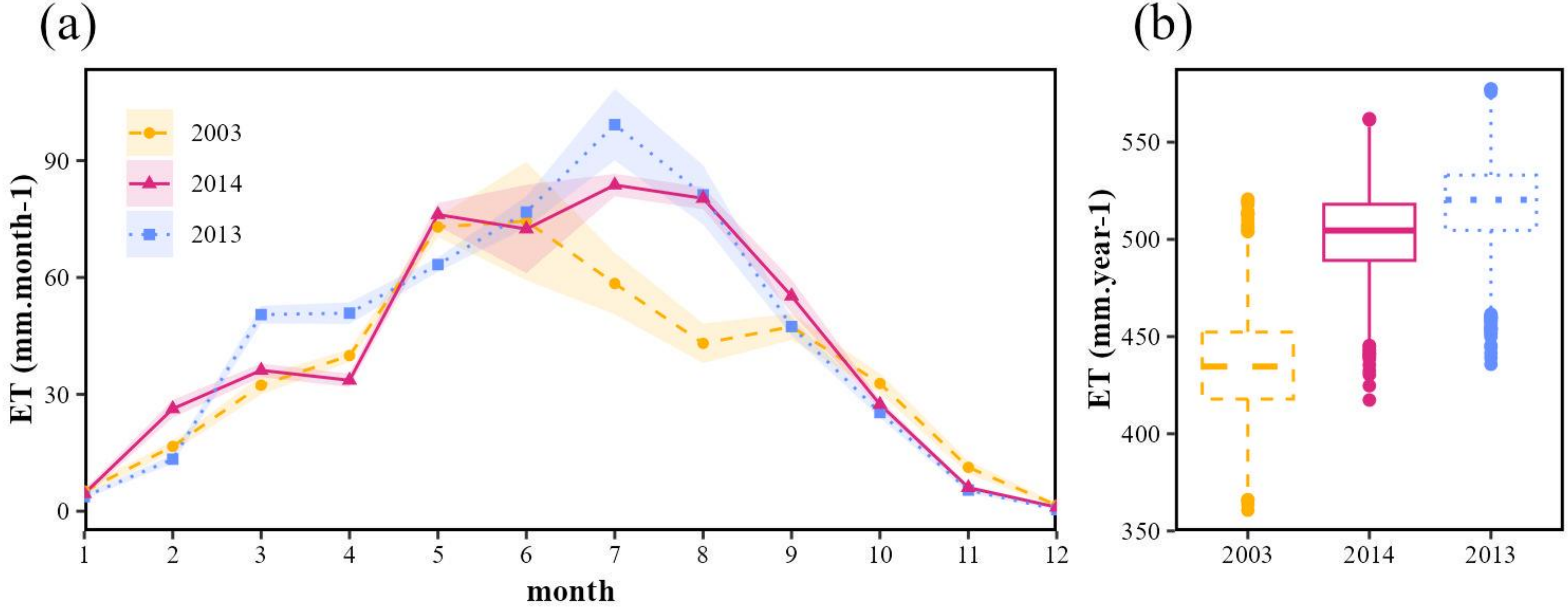
Annexe


masec
masecnp
masecveg
maperenne
mafeuil
matigestruc
restemp
mafruit
resperenne
resperennestruc
msrac

ANNEXE

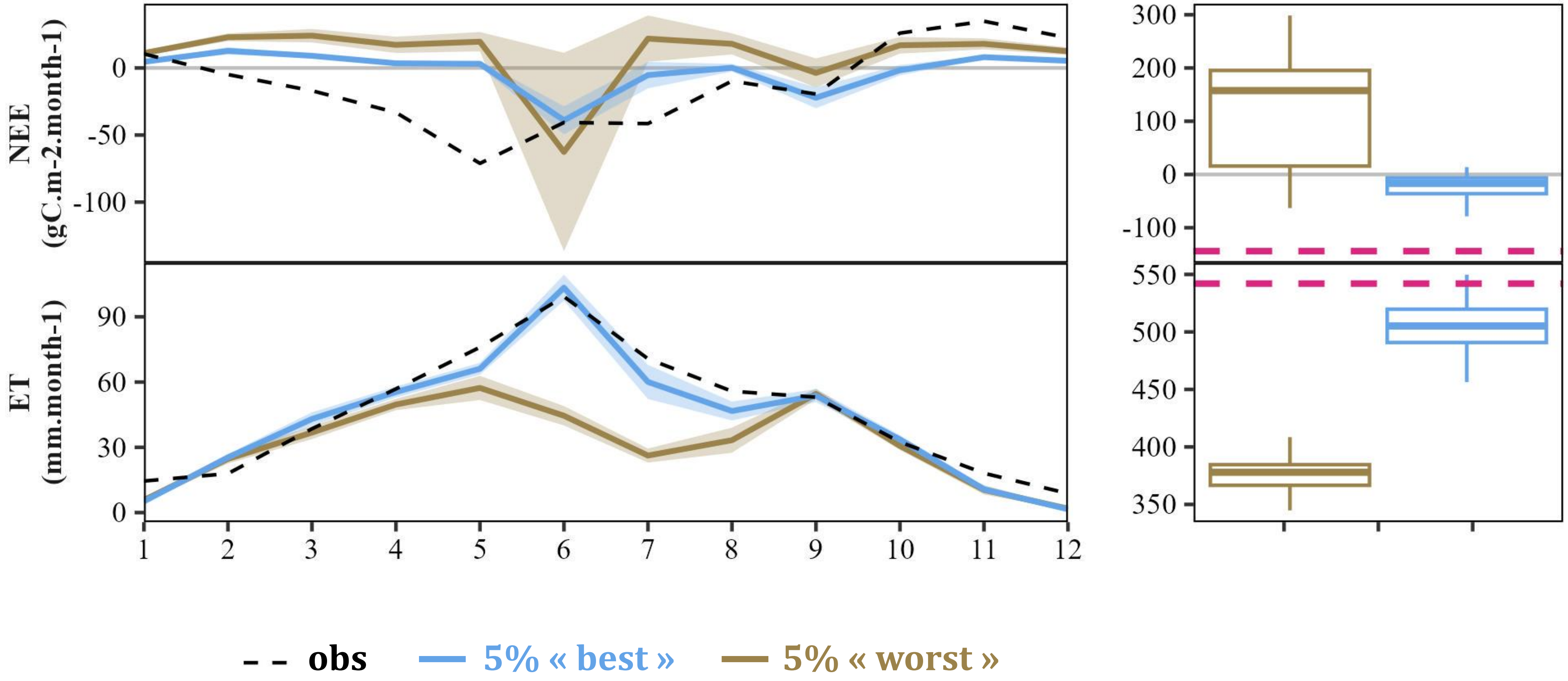

a.
50
0
-50
-100
NEE (g.C.m².month)
Sites:
Lazio-MO
Lombardy-CH
Sardinia-VE
Veneto-SB (average)
b.
50
0
-50
-100
NEE (g.C.m².month)
Years:
2015*
2016
2017
2018
2019
2020
2022
2023
average
standard deviation
1
2
3
4
5
6
7
8
9
10
11
12
month

ANNEXE



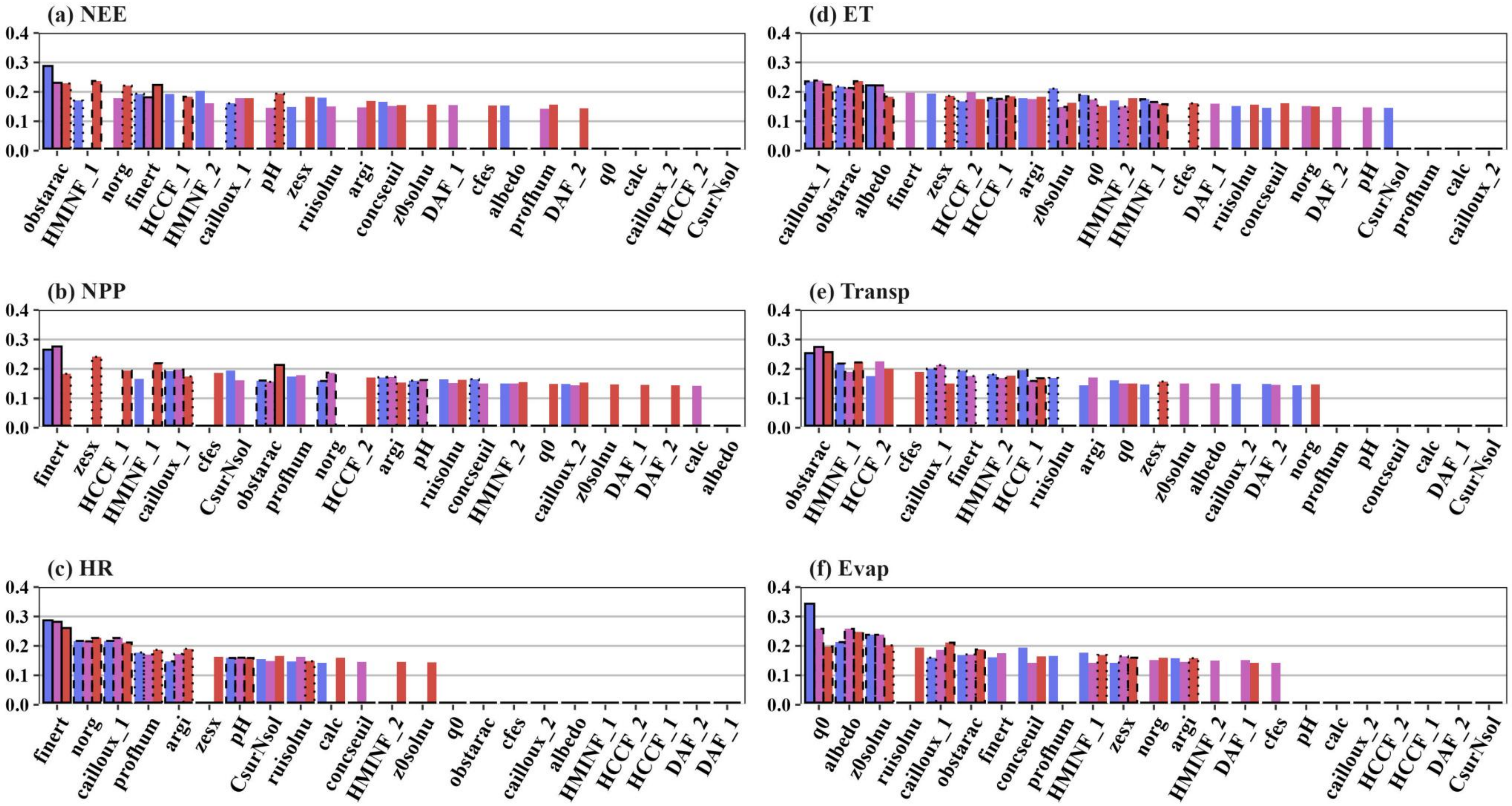
→ *Weak ET in 2003 summer (hydric stress)*

Annexe

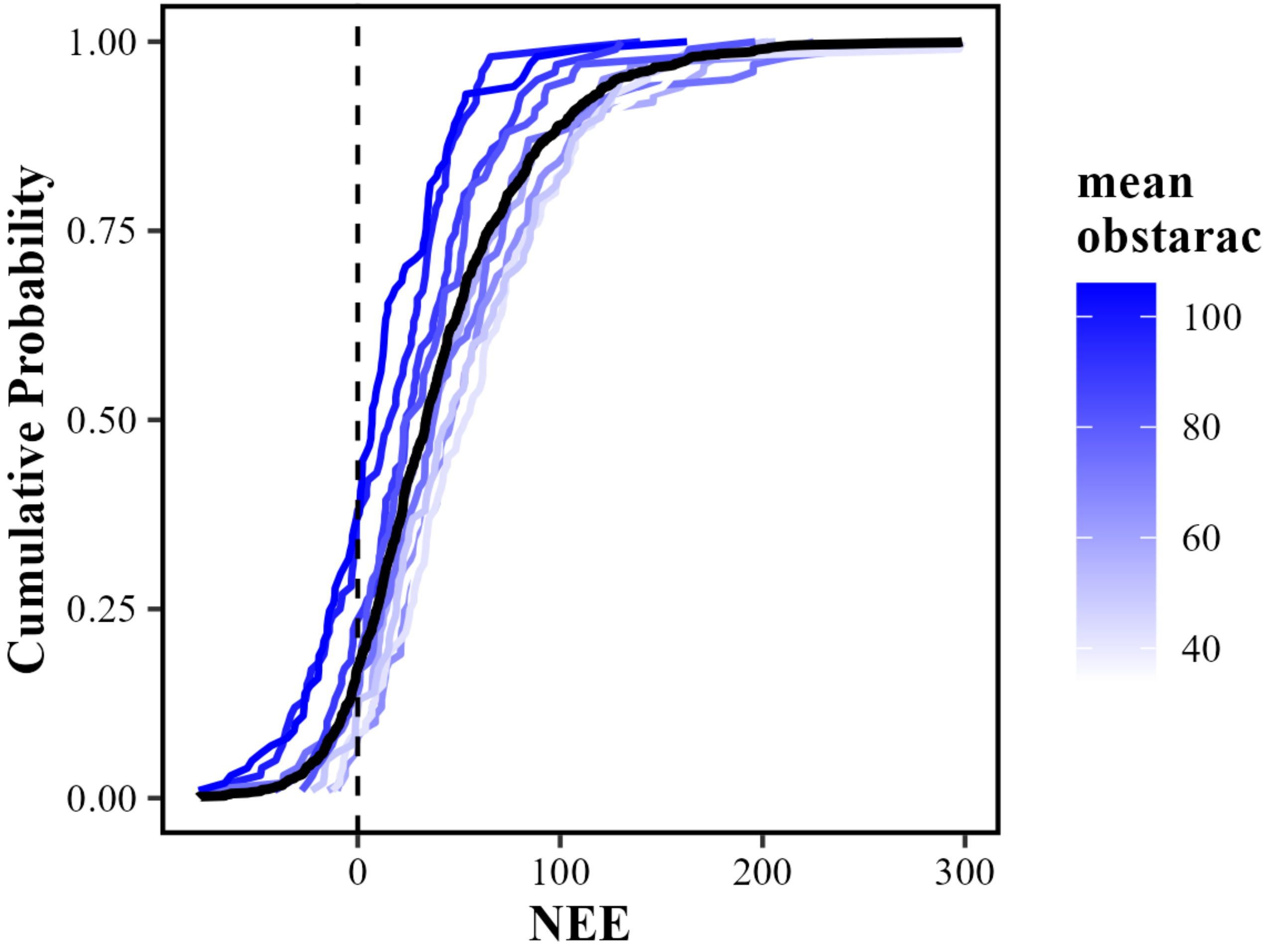


NEE
(gC.m-2.month-1)
0
-50
-100
ET
(mm.month-1)
90
60
30
0
1
2
3
4
5
6
7
8
9
10
11
12
300
200
100
0
-100
550
500
450
400
350
obs
5% « best »
5% « worst »

ANNEXE


(a) NEE
0.4
0.3
0.2
0.1
0.0
obstarac HMINF_1 norg finert HCCF_1 HMINF_2 cailloux_1 pH zesx ruisolnu argi concseuil z0solnu DAF_1 cfes albedo profhum DAF_2 q0 calc cailloux_2 HCCF_2 CsurNsol
(b) NPP
finert zesx HCCF_1 HMINF_1 cailloux_1 cfes CsurNsol obstarac profhum norg HCCF_2 argi pH ruisolnu concseuil HMINF_2 q0 cailloux_2 z0solnu DAF_1 DAF_2 calc albedo
(c) HR
finert norg cailloux_1 profhum argi zesx pH CsurNsol ruisolnu calc concseuil HMINF_2 z0solnu q0 obstarac cfes cailloux_2 albedo HMINF_1 HCCF_2 HCCF_1 DAF_2 DAF_1
(d) ET
cailloux_1 obstarac albedo finert zesx HCCF_2 HCCF_1 argi z0solnu q0 HMINF_2 HMINF_1 cfes DAF_1 ruisolnu concseuil norg DAF_2 pH CsurNsol profhum calc cailloux_2
(e) Transp
obstarac HMINF_1 HCCF_2 cfes cailloux_1 finert HMINF_2 HCCF_1 ruisolnu argi q0 zesx z0solnu albedo cailloux_2 DAF_2 norg profhum pH concseuil calc DAF_1 CsurNsol
(f) Evap
q0 albedo z0solnu ruisolnu cailloux_1 obstarac finert concseuil profhum HMINF_1 zesx norg argi HMINF_2 DAF_1 cfes pH calc cailloux_2 HCCF_2 HCCF_1 DAF_2 CsurNsol

Annexe



Cumulative Probability
1.00
0.75
0.50
0.25
0.00
0
100
200
300
NEE
mean obstarac
100
80
60
40

TEMPLATE

TEMPLATE