

> Enregistrement



L

1

Qu'est ce qu'un modèle ?



Un modèle c'est quoi?

1. Représentation simplifiée et partielle de la réalité
2. Conceptualisation de processus

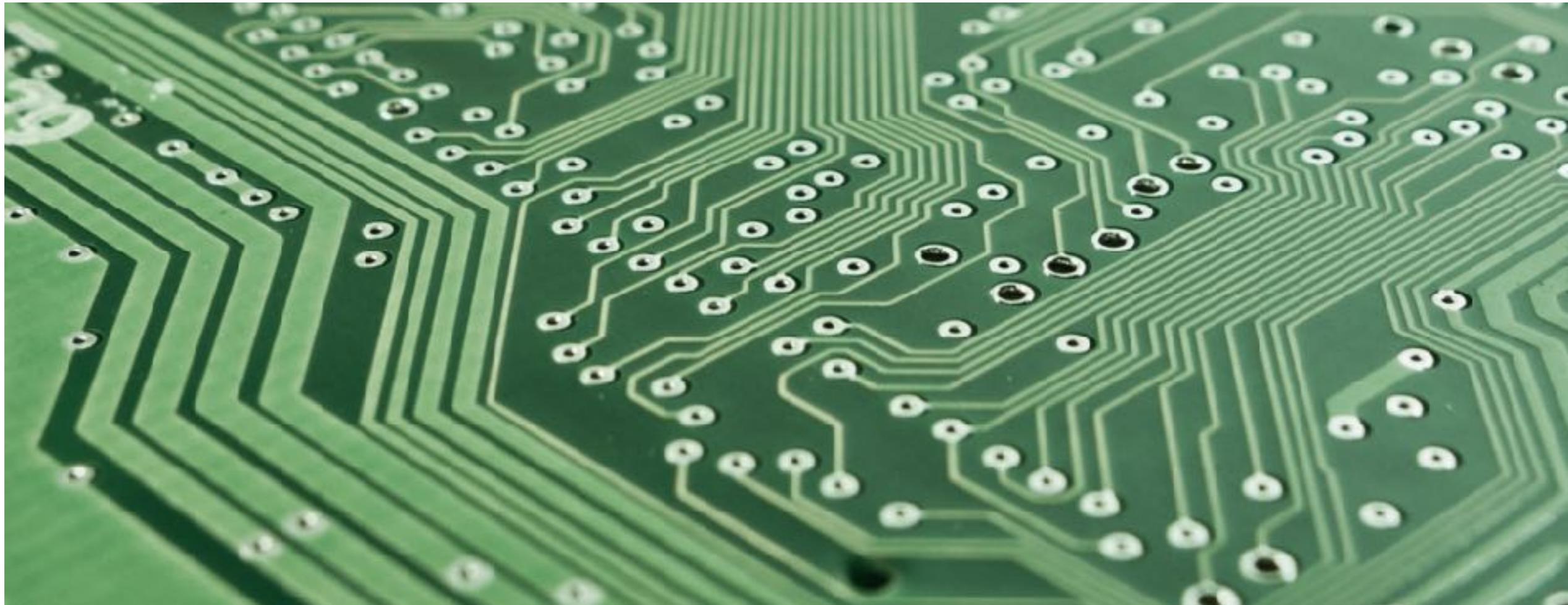
L Plan du cours

1. Qu'est ce qu'on modèle?
2. A quoi sert la modélisation?
3. Différents types de modèles
4. Les modèles de plantes
5. Exercices
6. Projet

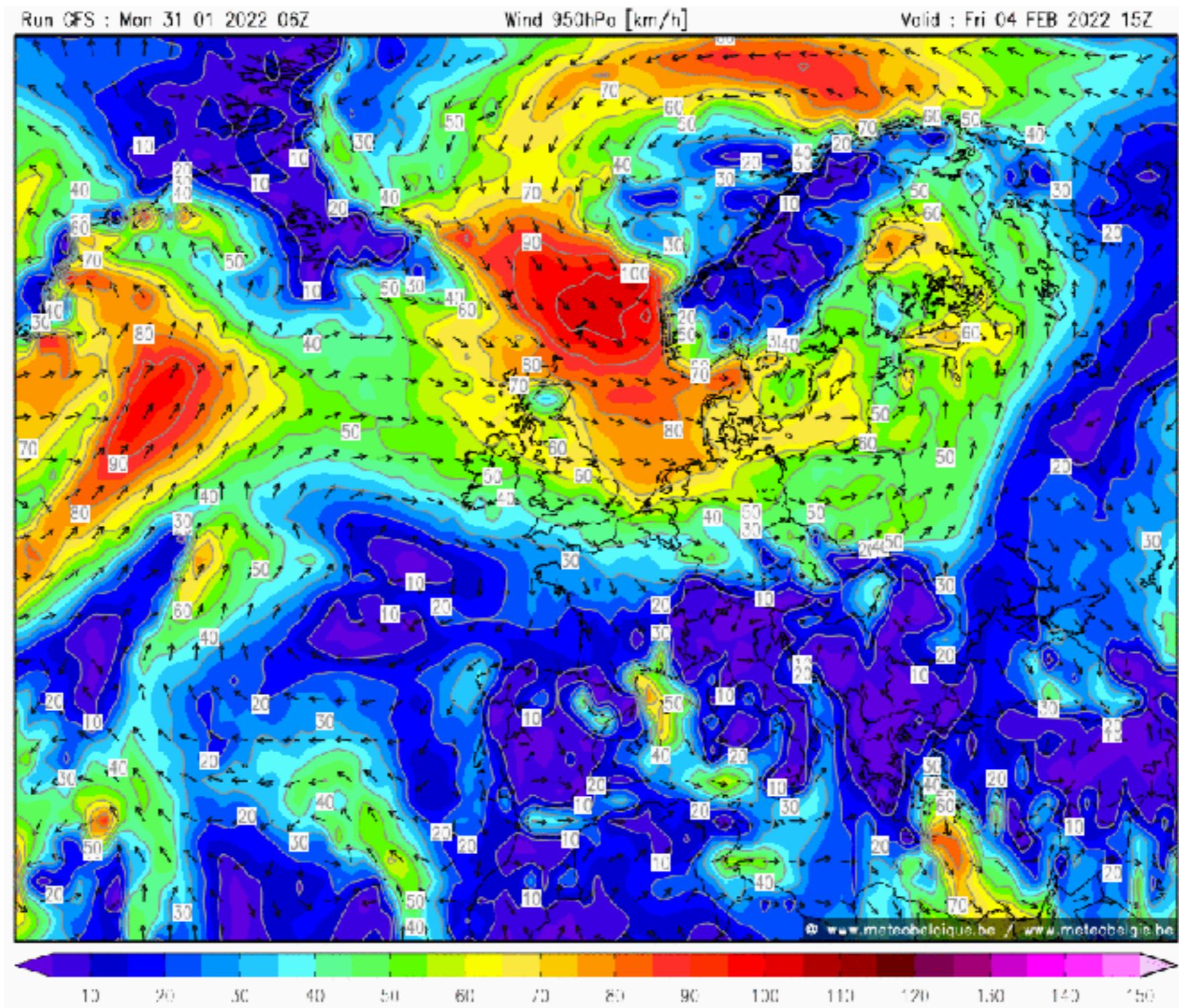
L

2

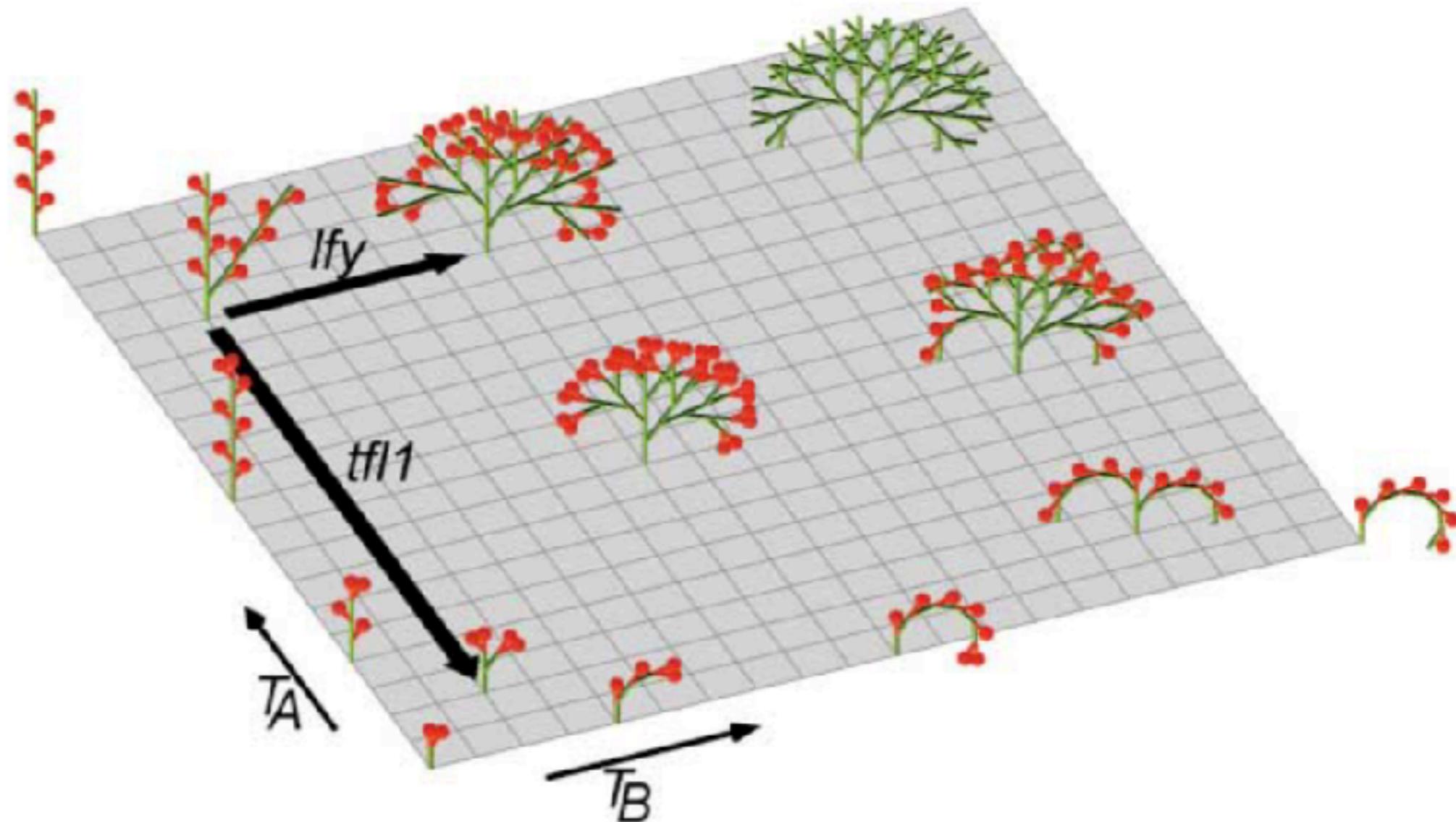
A quoi servent les modèles ?



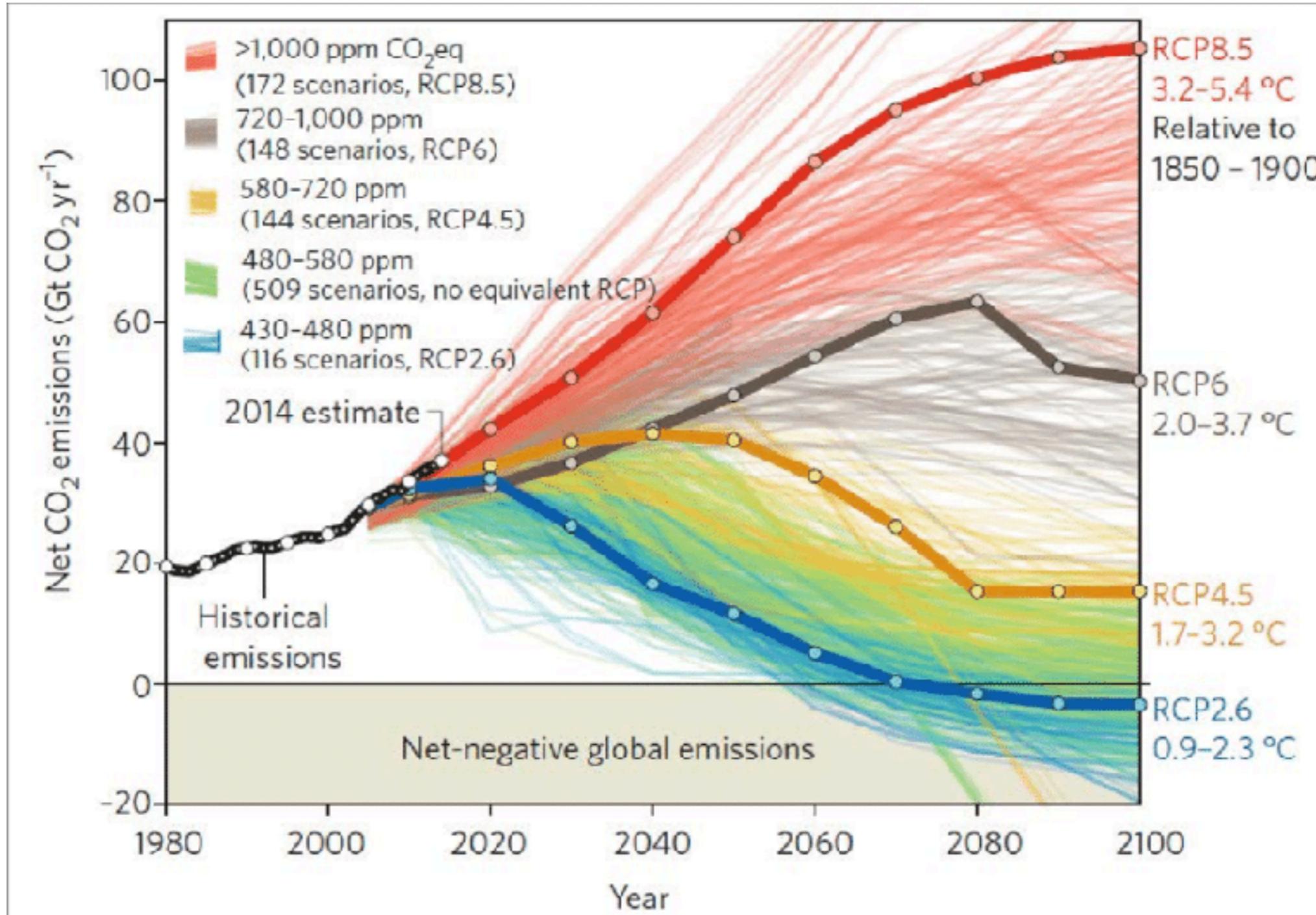
L'Prédiction



L Compréhension du système

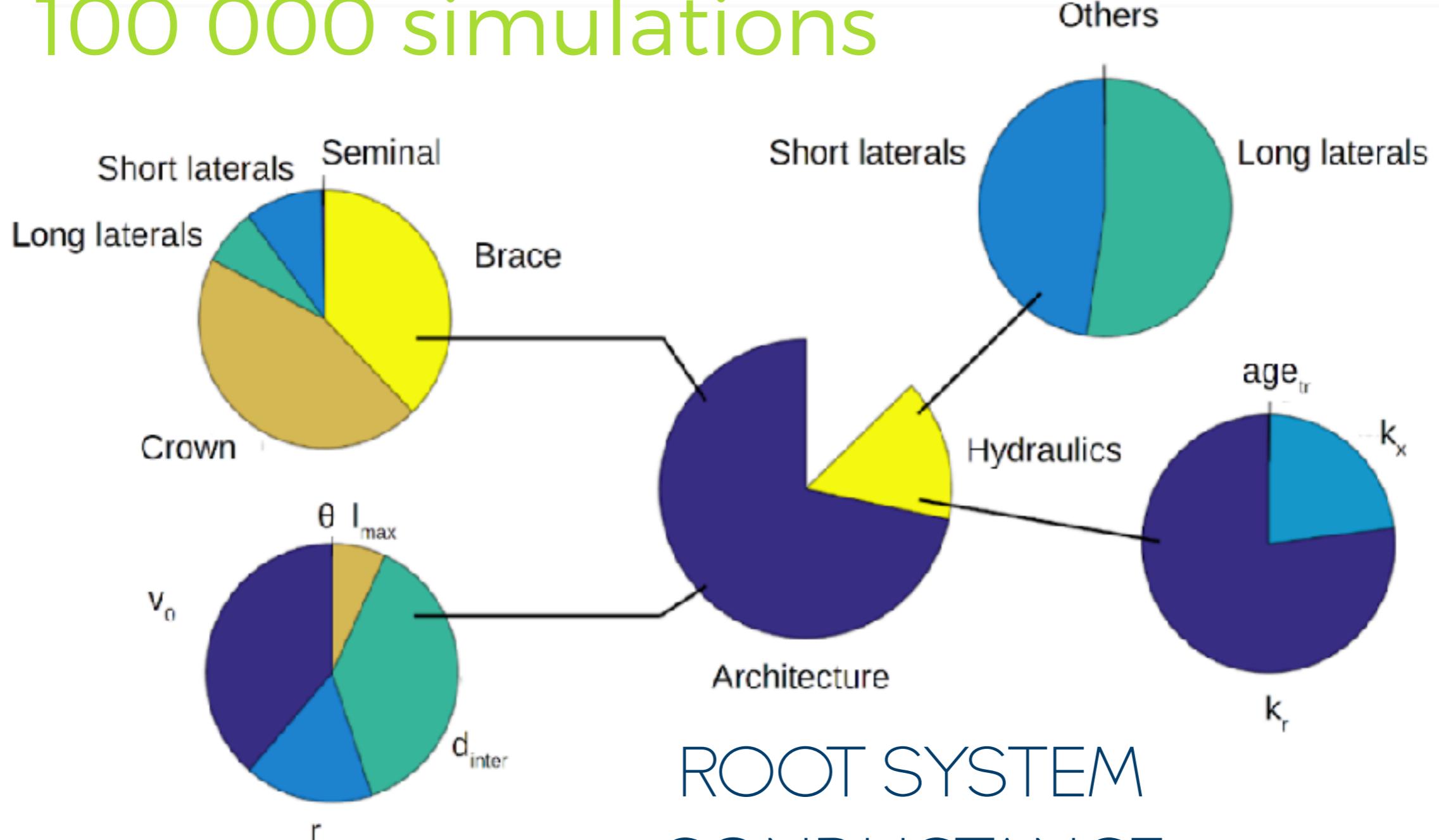


L'Exploration de scénarios



L'Analyse de sensibilité

100 000 simulations



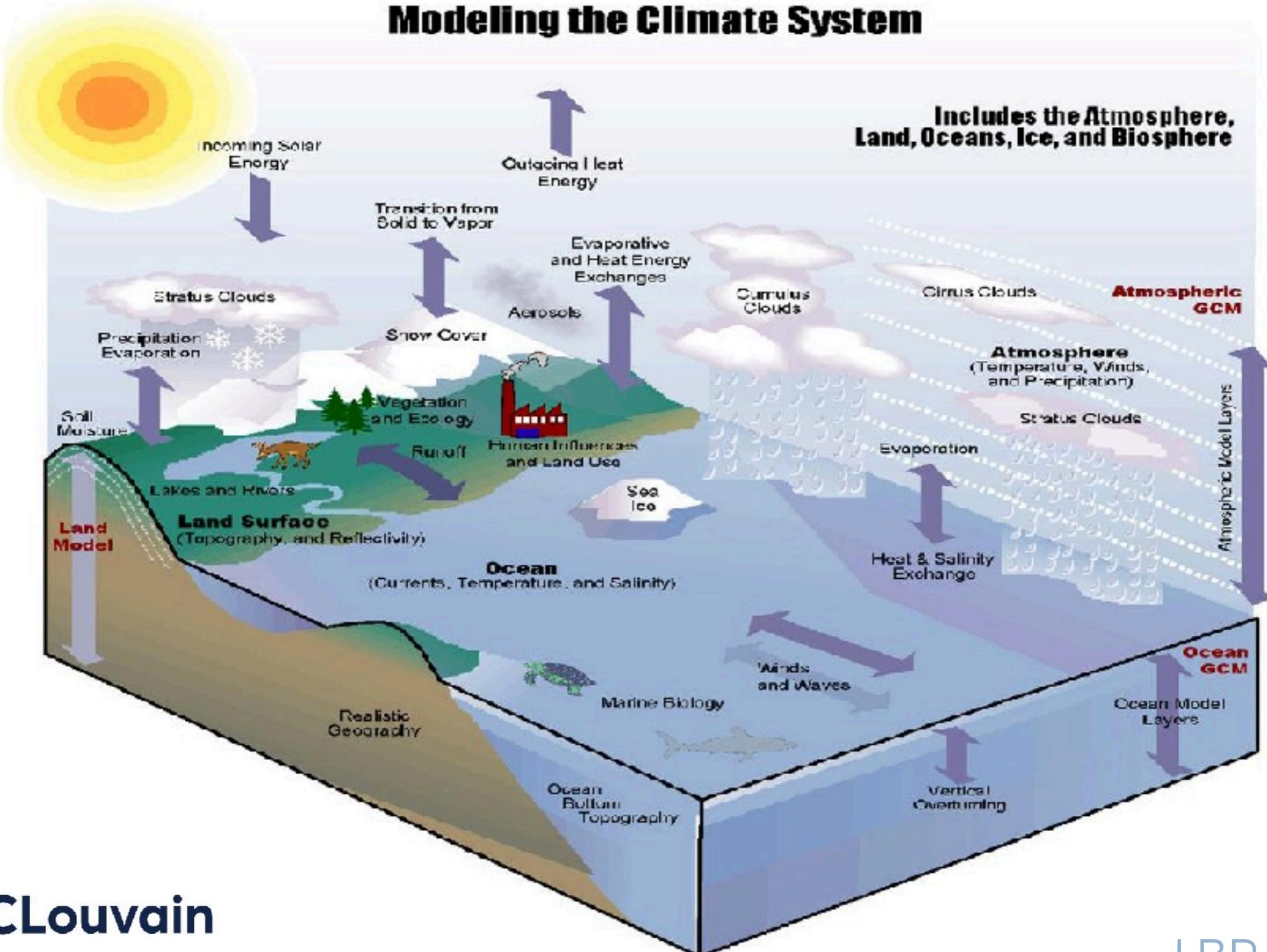
L

3

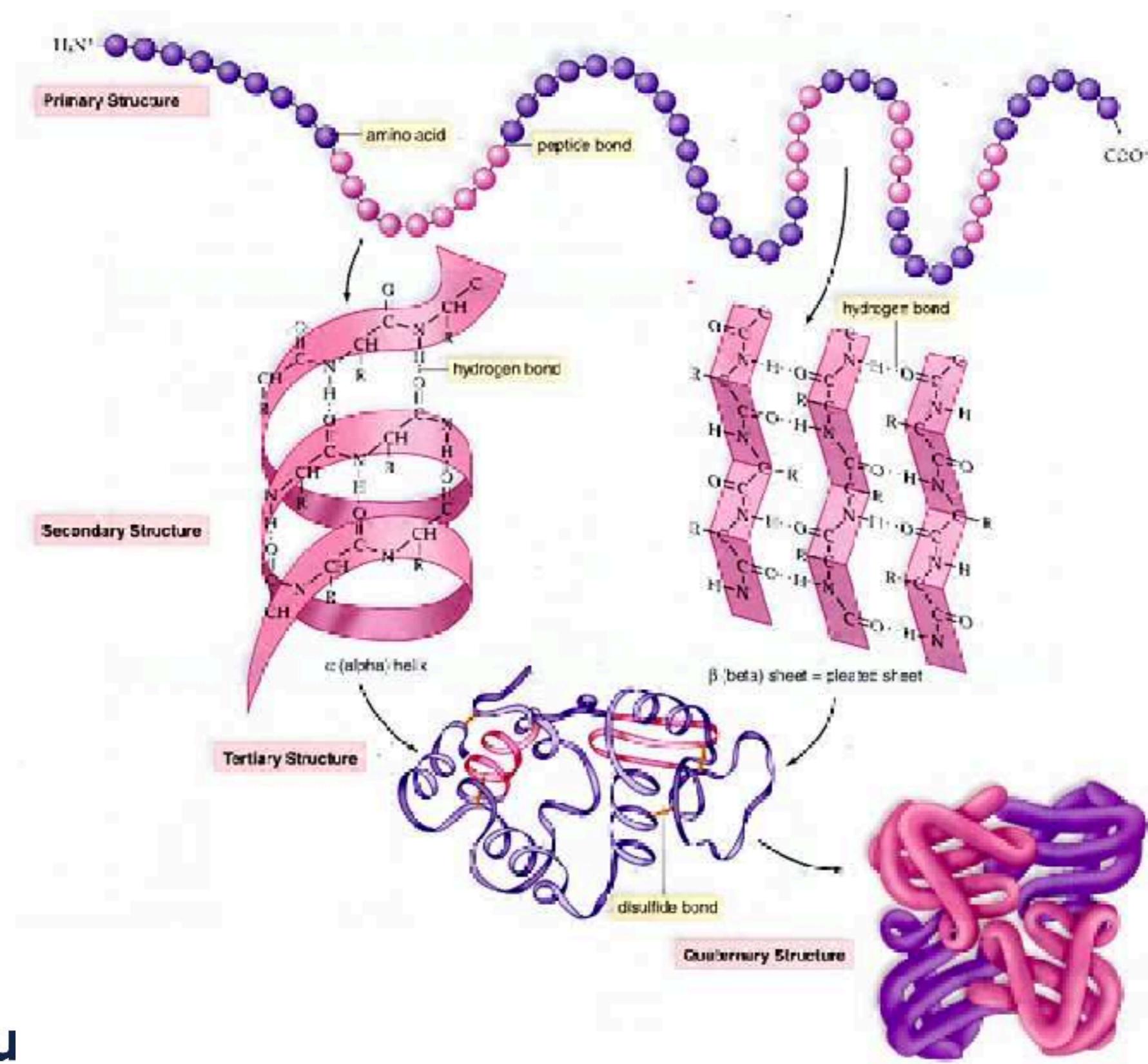
Différents types de modèles



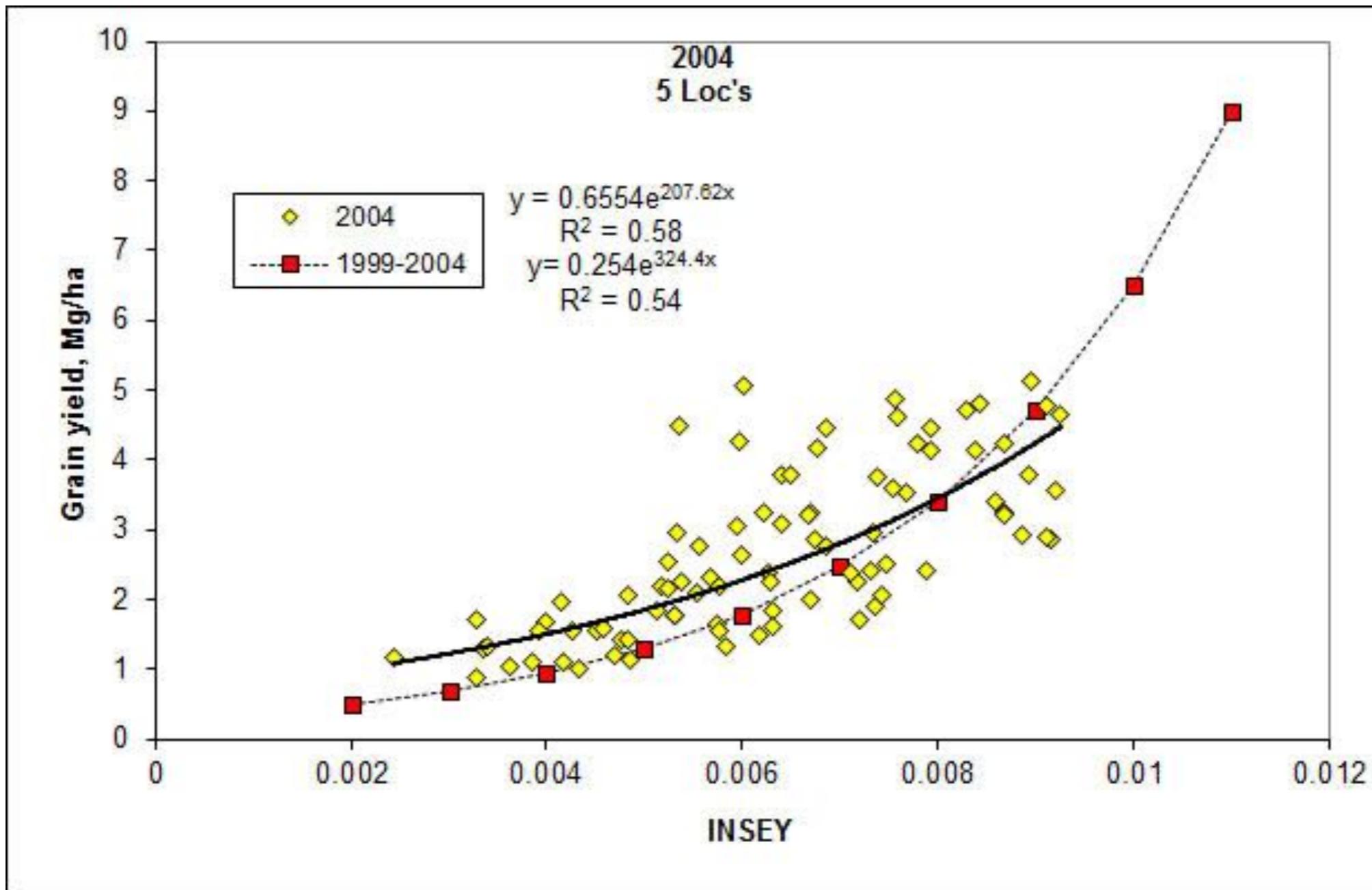
Modèle mécaniste



Modèle mécaniste



L Modèle statistique

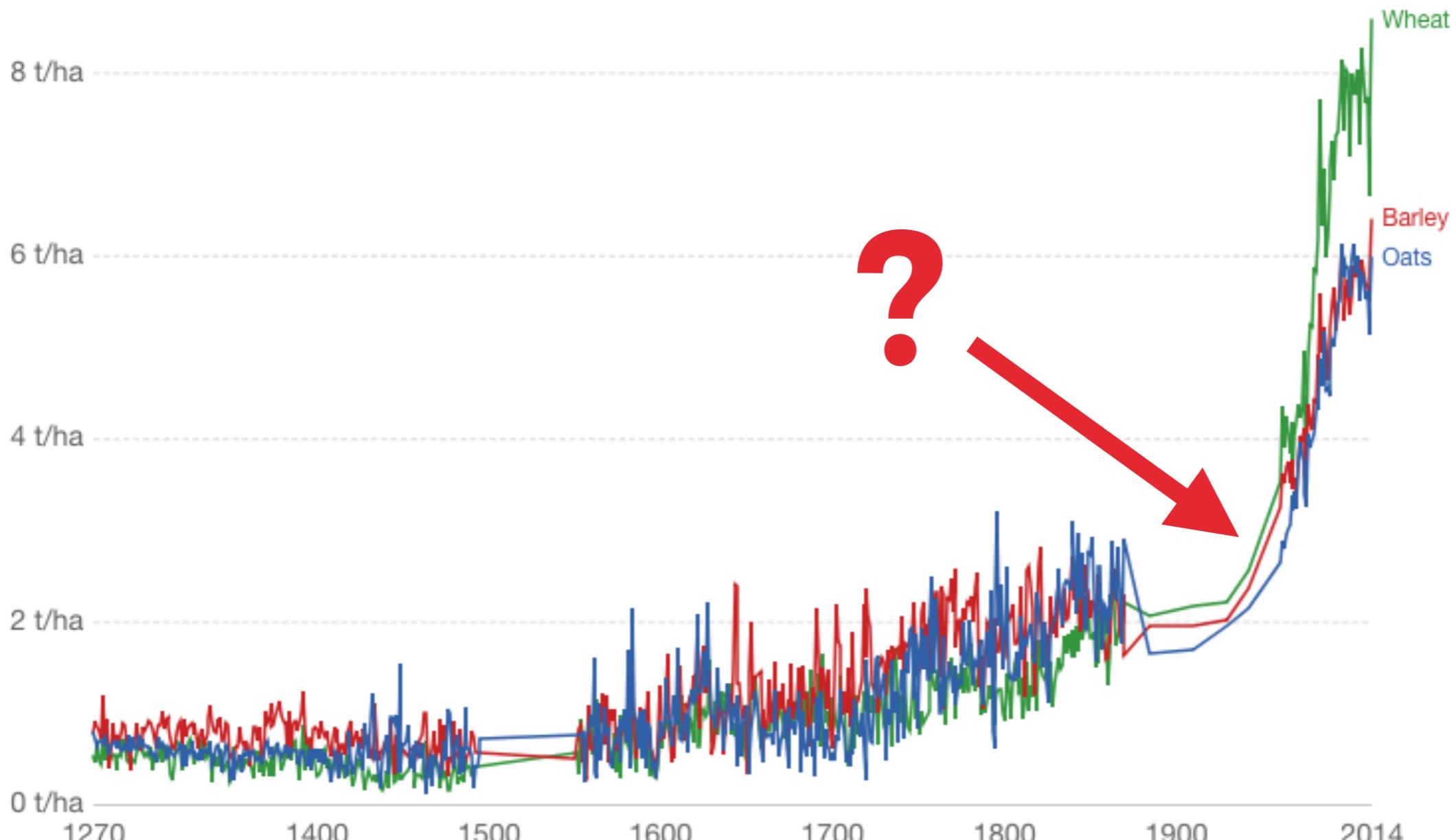


L Modèle statistique

Long-term cereal yields in the United Kingdom

Average agricultural yields in key crops in the United Kingdom from 1270-2014, measured in tonnes per hectare.

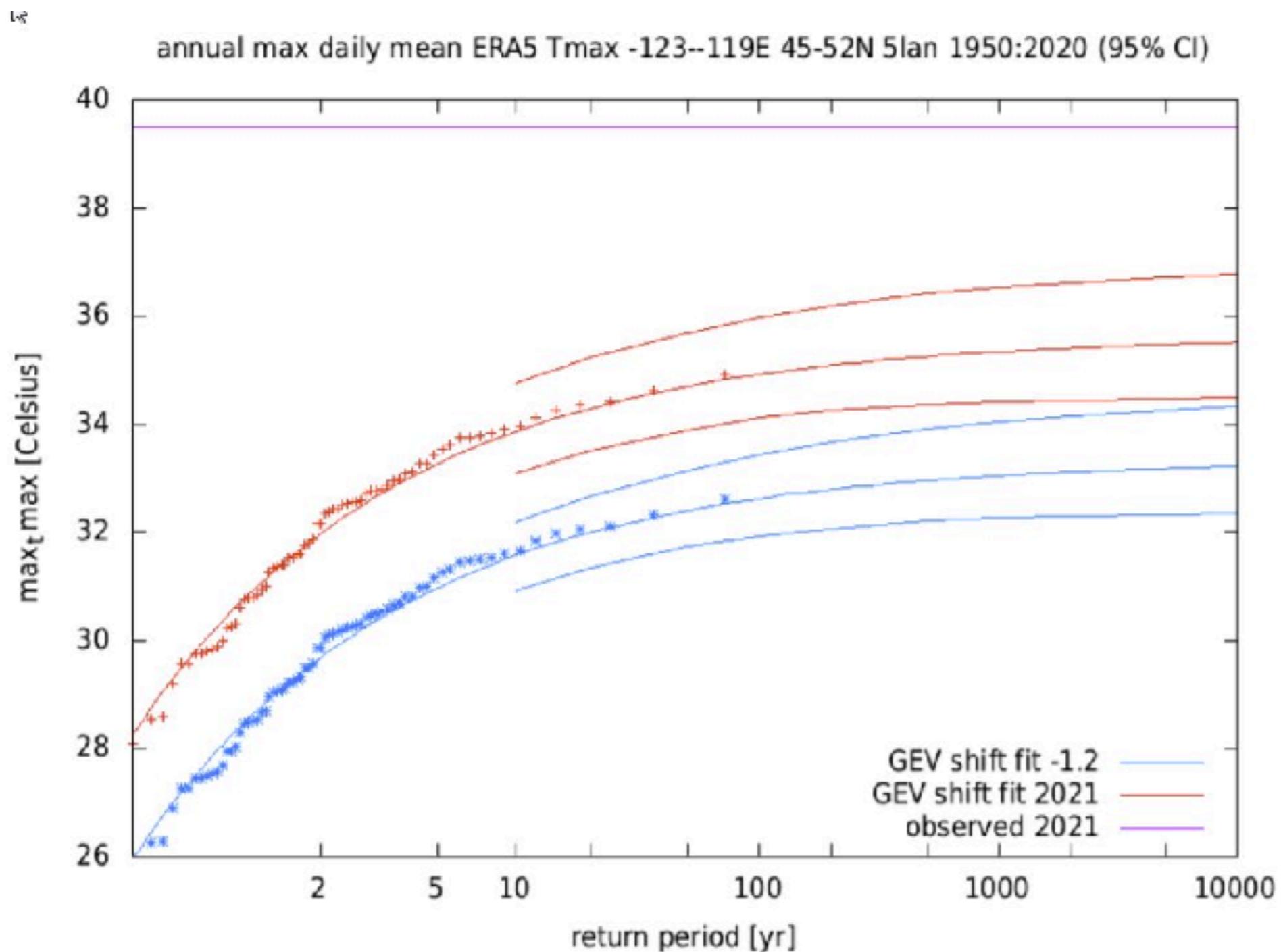
OurWorld
in Data



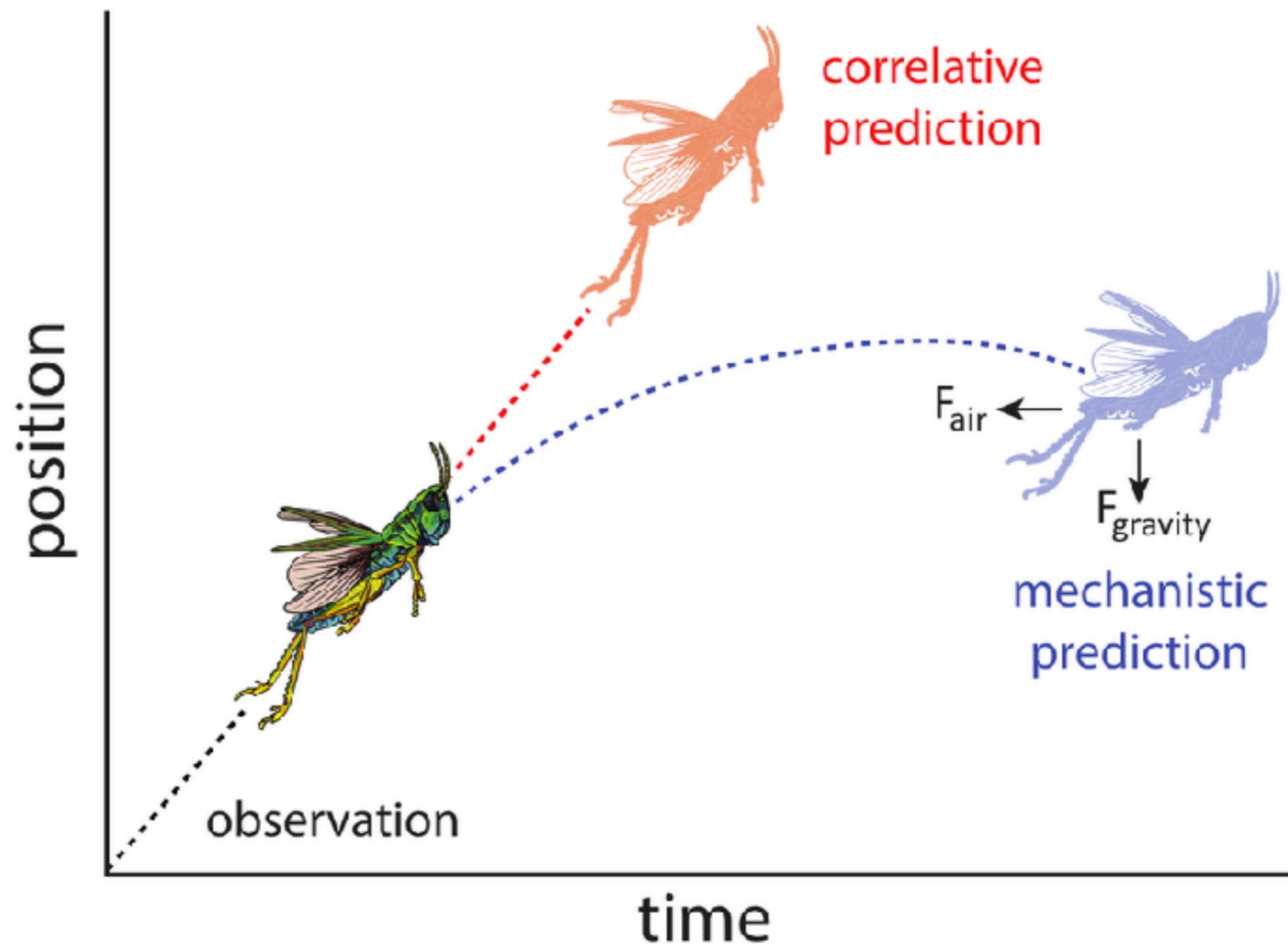
Source: OWID Long-term crop yields in UK - OWID (2017)

CC BY-SA

L Modèle statistique



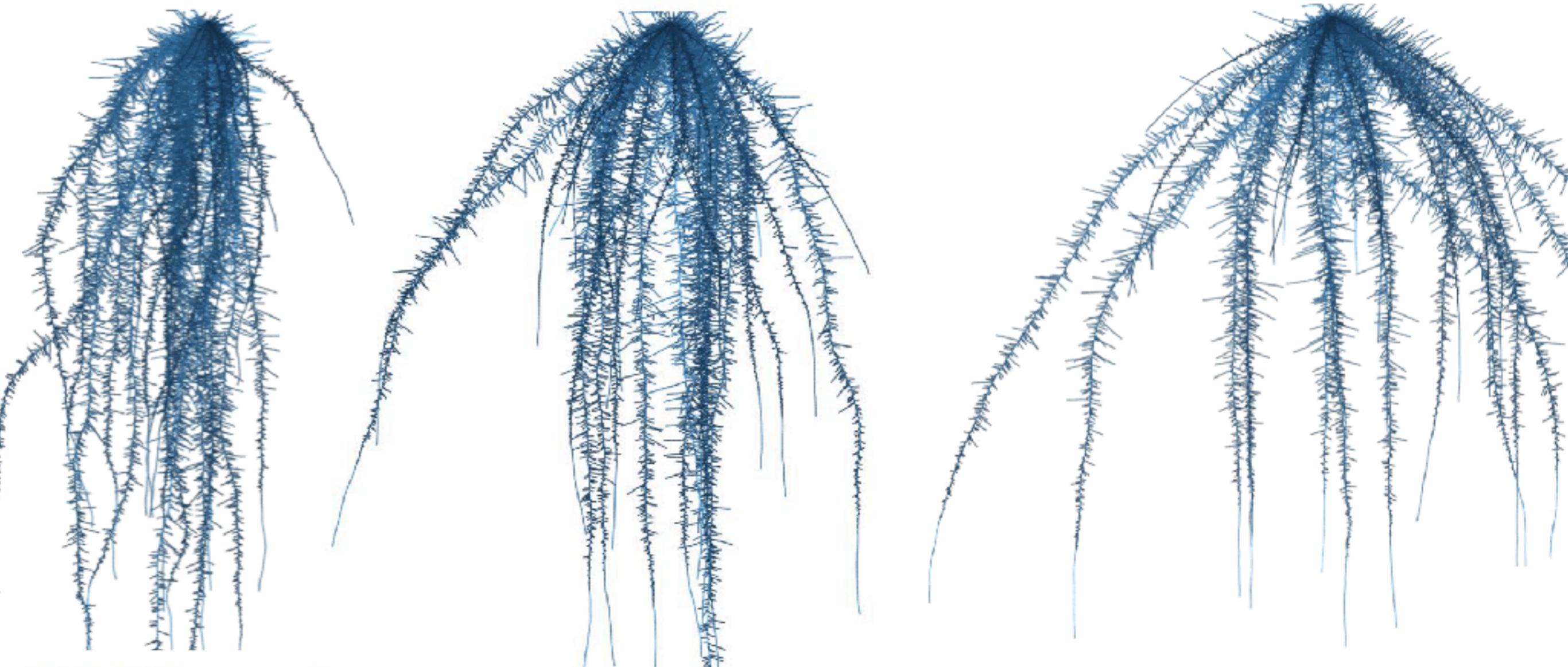
L statistique vs mecaniste



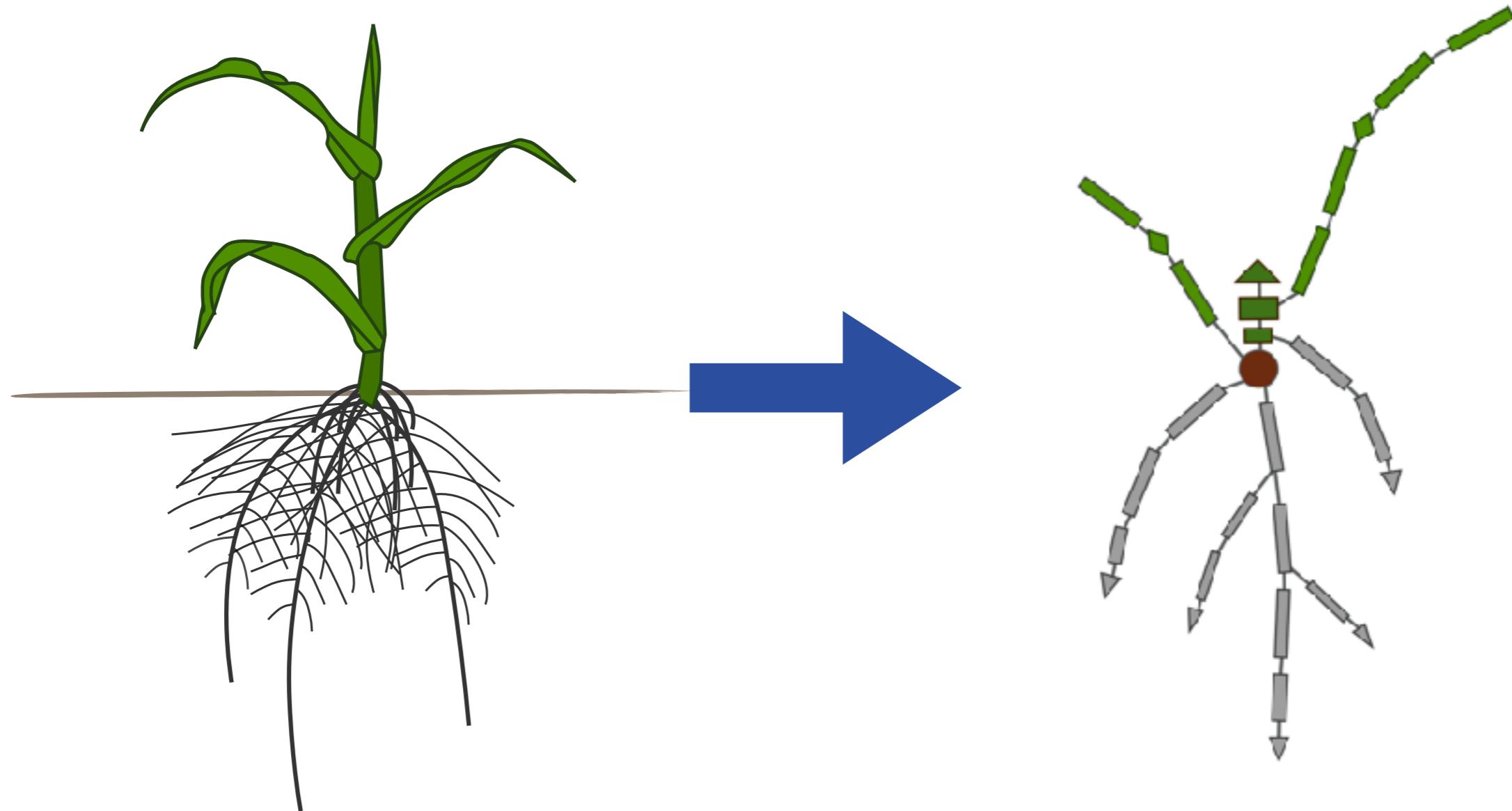
L

4

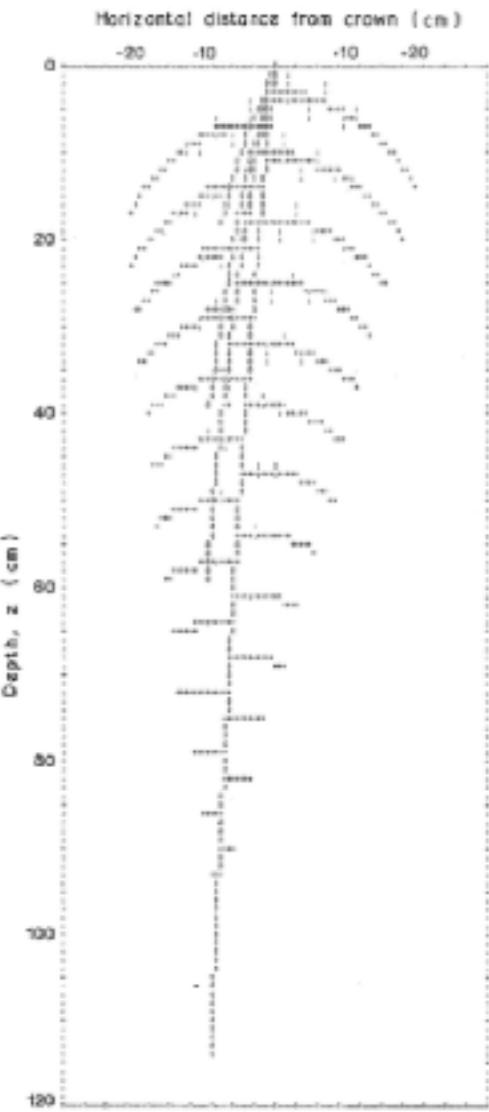
Les modèles de plantes



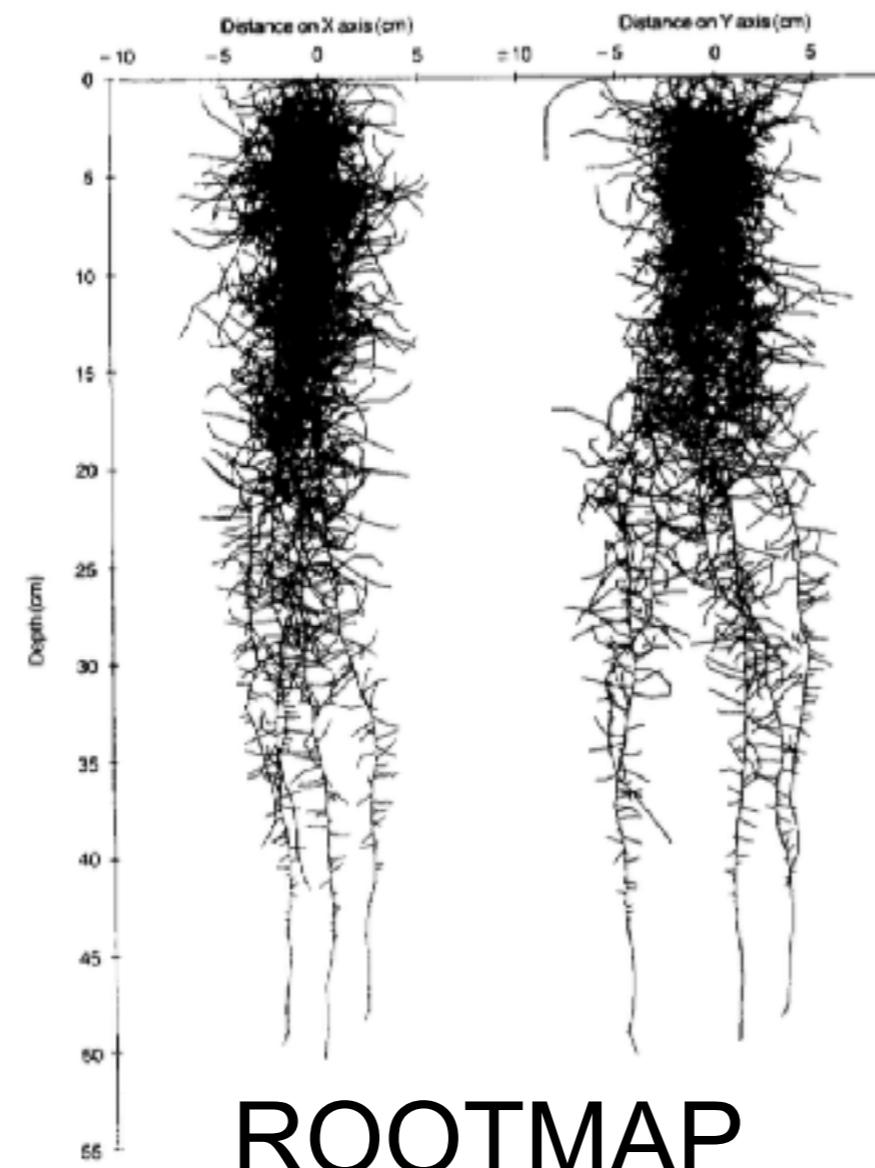
L Modèles “structure”



L Modèles “structure”



1973



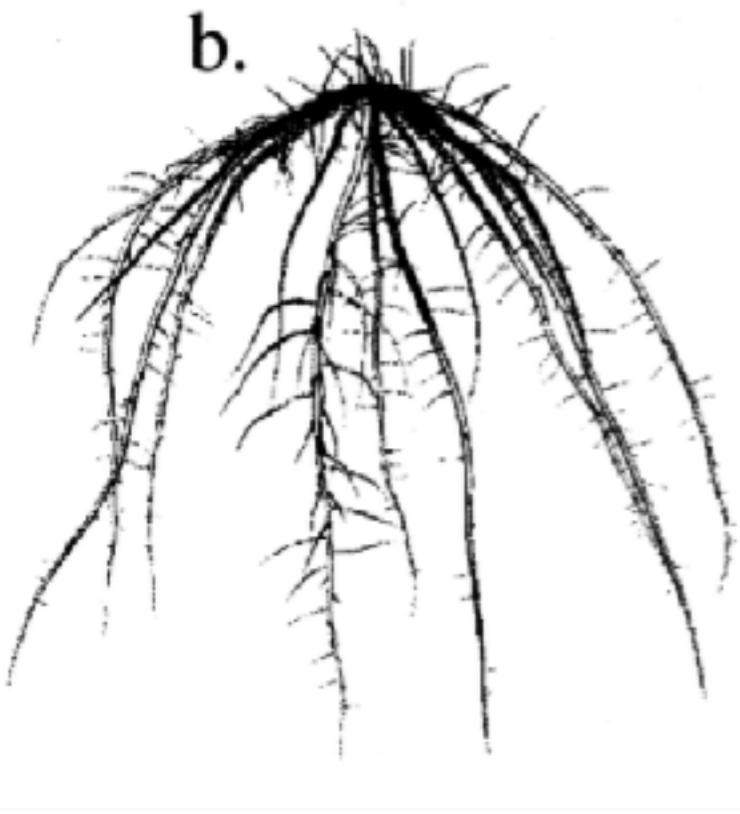
ROOTMAP

1988



1989

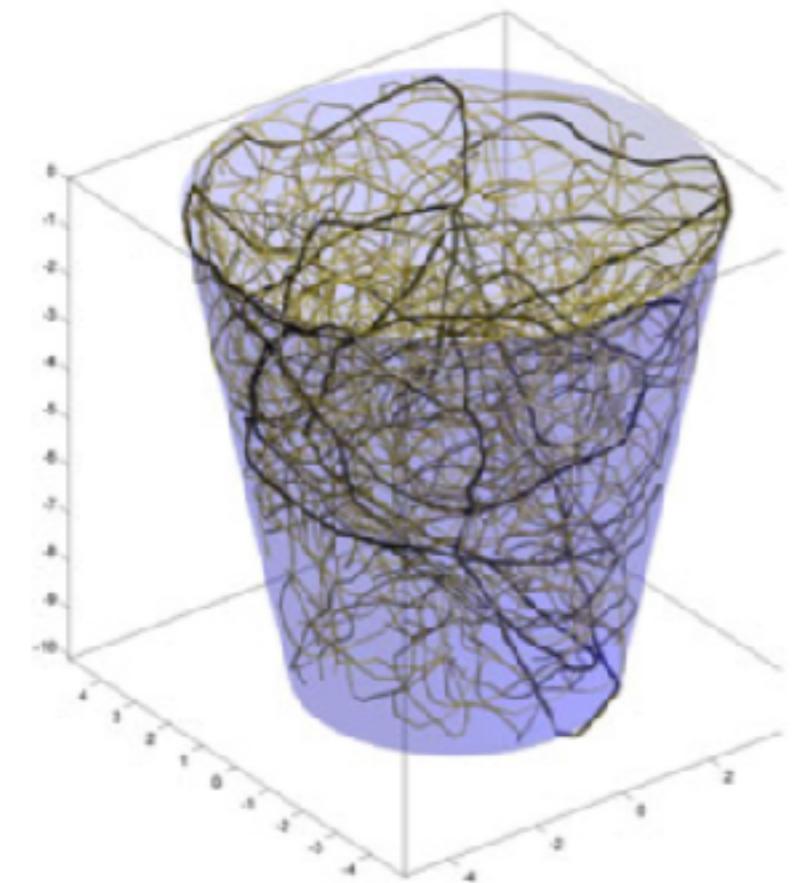
L Modèles “structure”



1997



2004

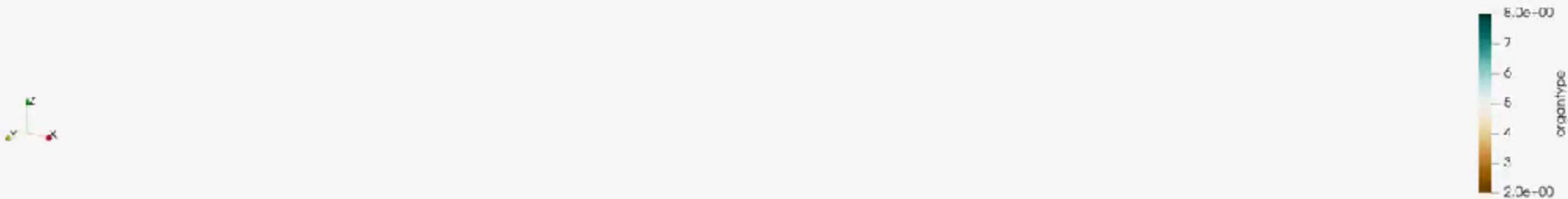


2010

L Modèles “structure”



L Modèles “structure”



Modèles “structure”

<http://bit.ly/crootbox>

This app displays the capabilities of the CRootBox model. Choose a dataset, unleash CRootBox, then try changing the parameters.

Forschungszentrum Juelich GmbH

1. Load parameter set

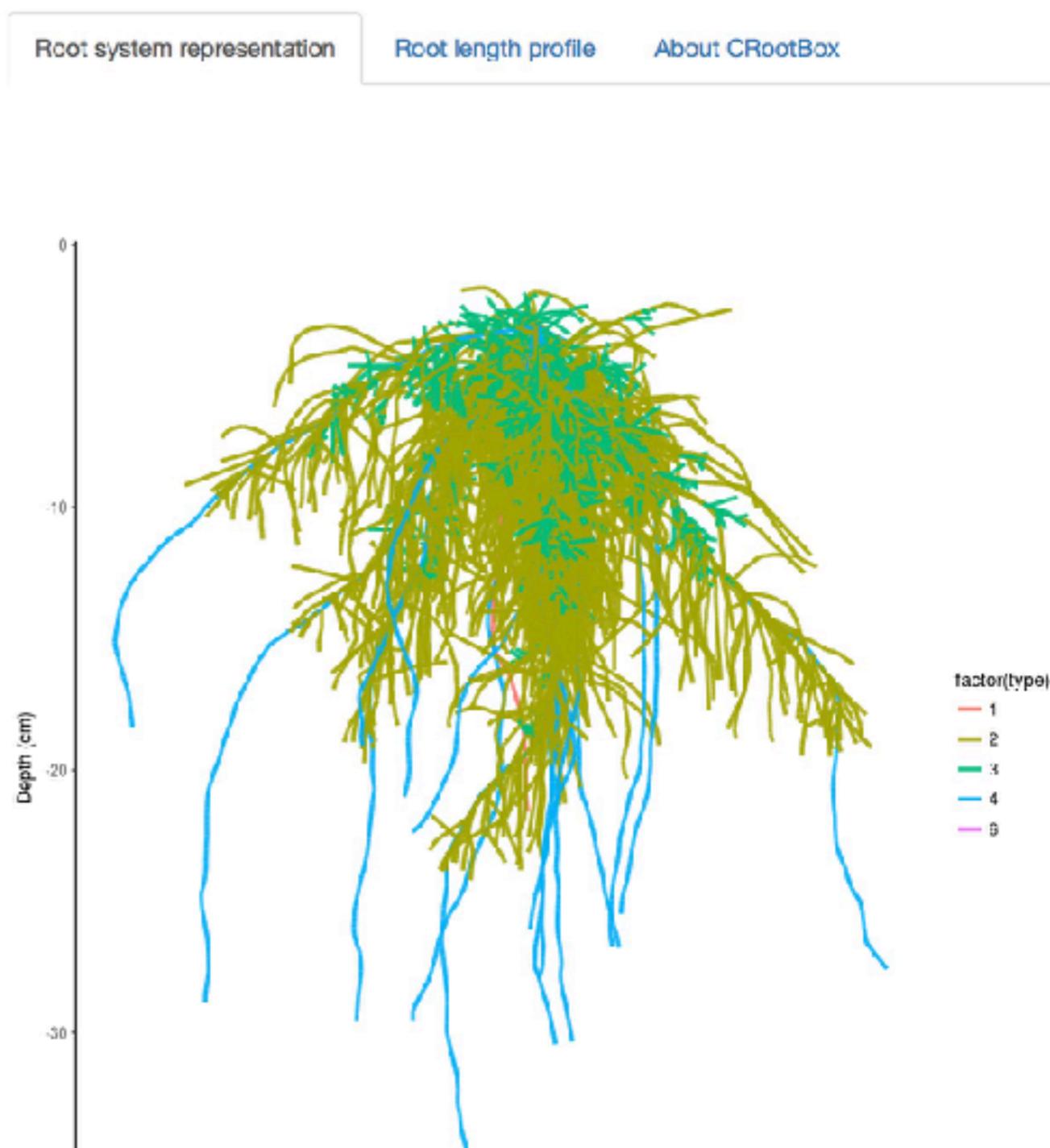
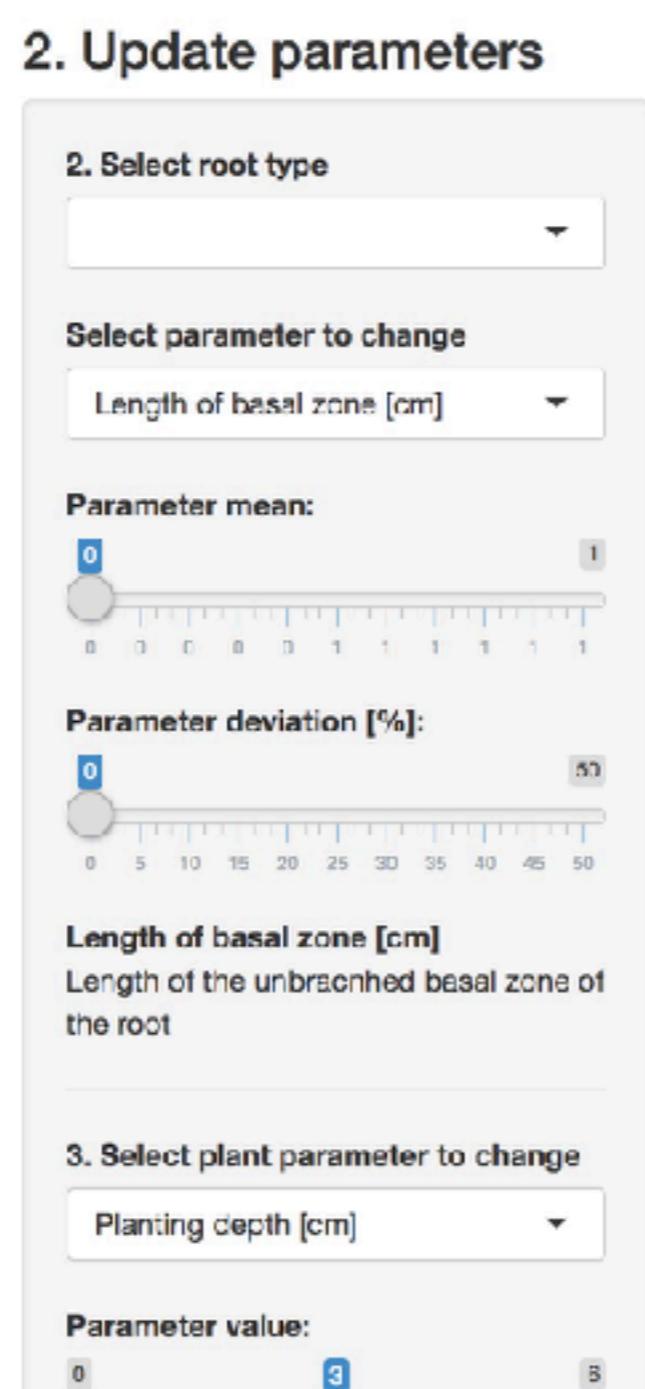
1. Select root system dataset

Triticum aestivum a ▾

**Simulation of wheat growth using the 3D root architecture model
SPACSYS: Validation and sensitivity analysis**

Bingham I J, Wu L
European Journal of Agronomy, 34,
181-189, 2011

[View paper](#)



L Modèles “structure”

<https://granar.github.io/>

Generator of Root ANAtomy in R [GRANAR] [The model](#) [About](#)

Cortex Stele Xylem Aerenchyma Variable to display Type

Parameters for the cortex. You can adjust the number of cell layers and the size of individual cells

Layers: 6

Diameter: 0.03

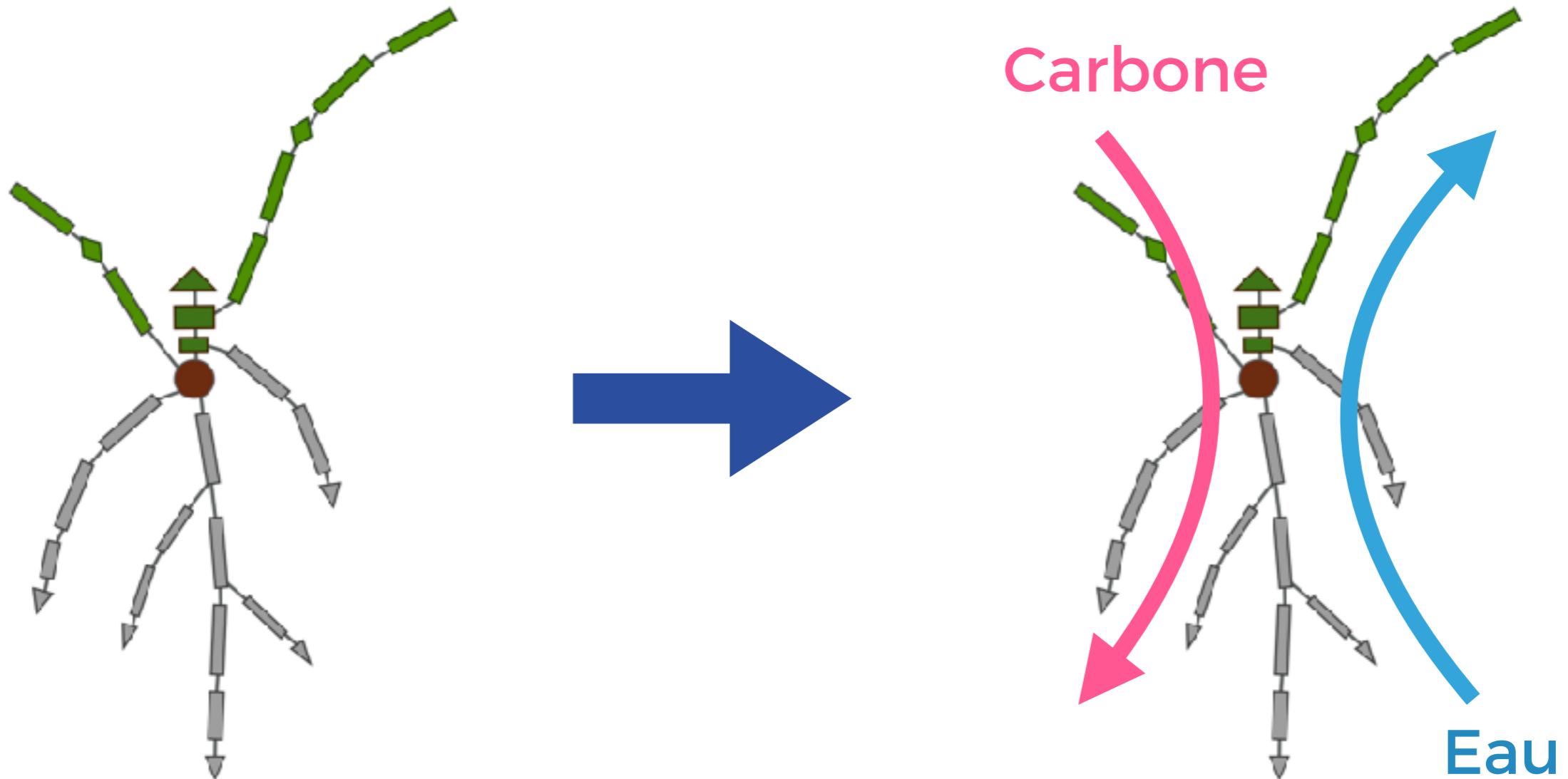
Plant type

You can choose here wether to simulate a dicot or monocot plant

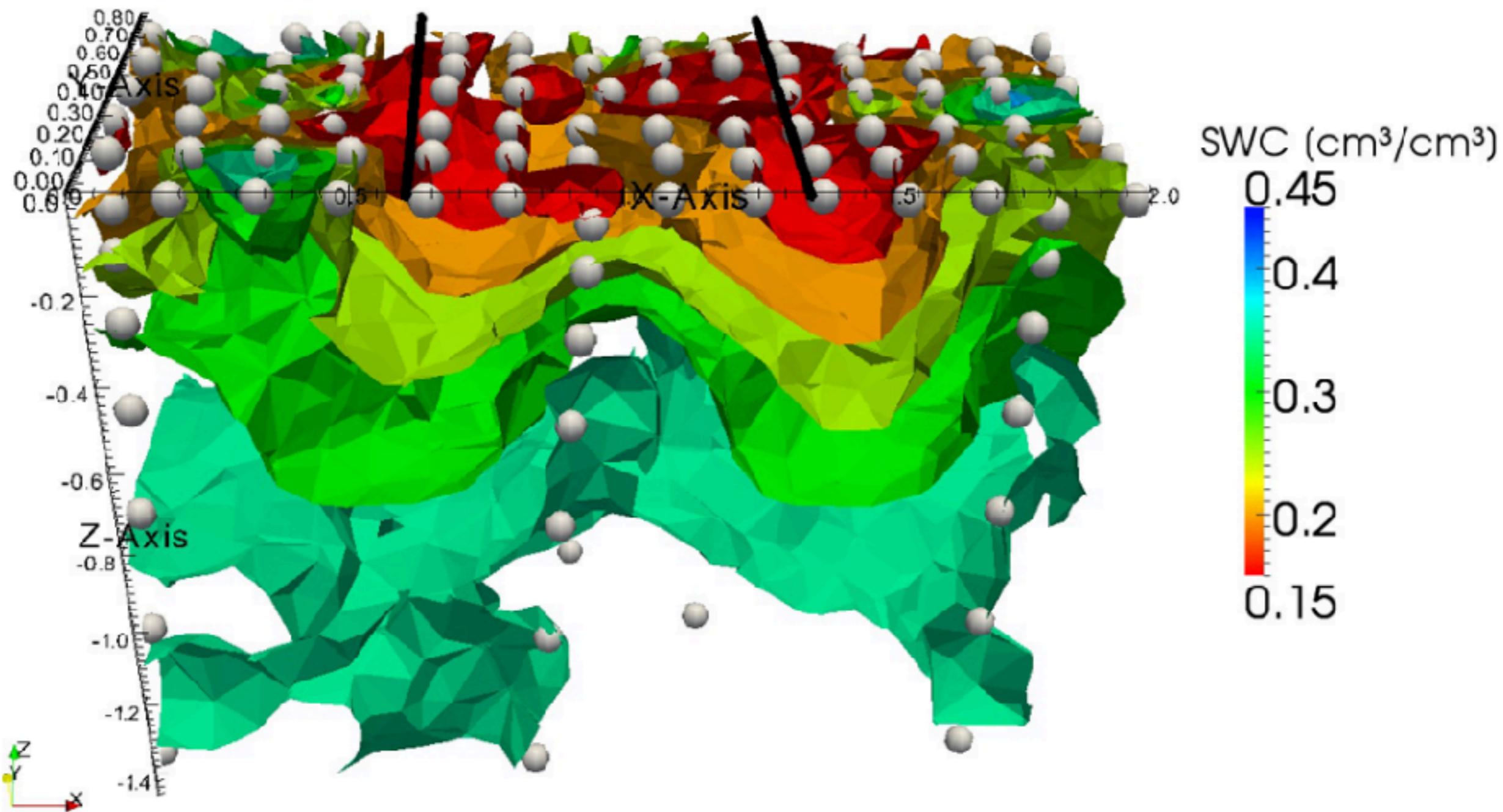
type

- companion_cell
- cortex
- endodermis
- epidermis
- exodermis
- pericycle
- phloem
- stele
- xylem

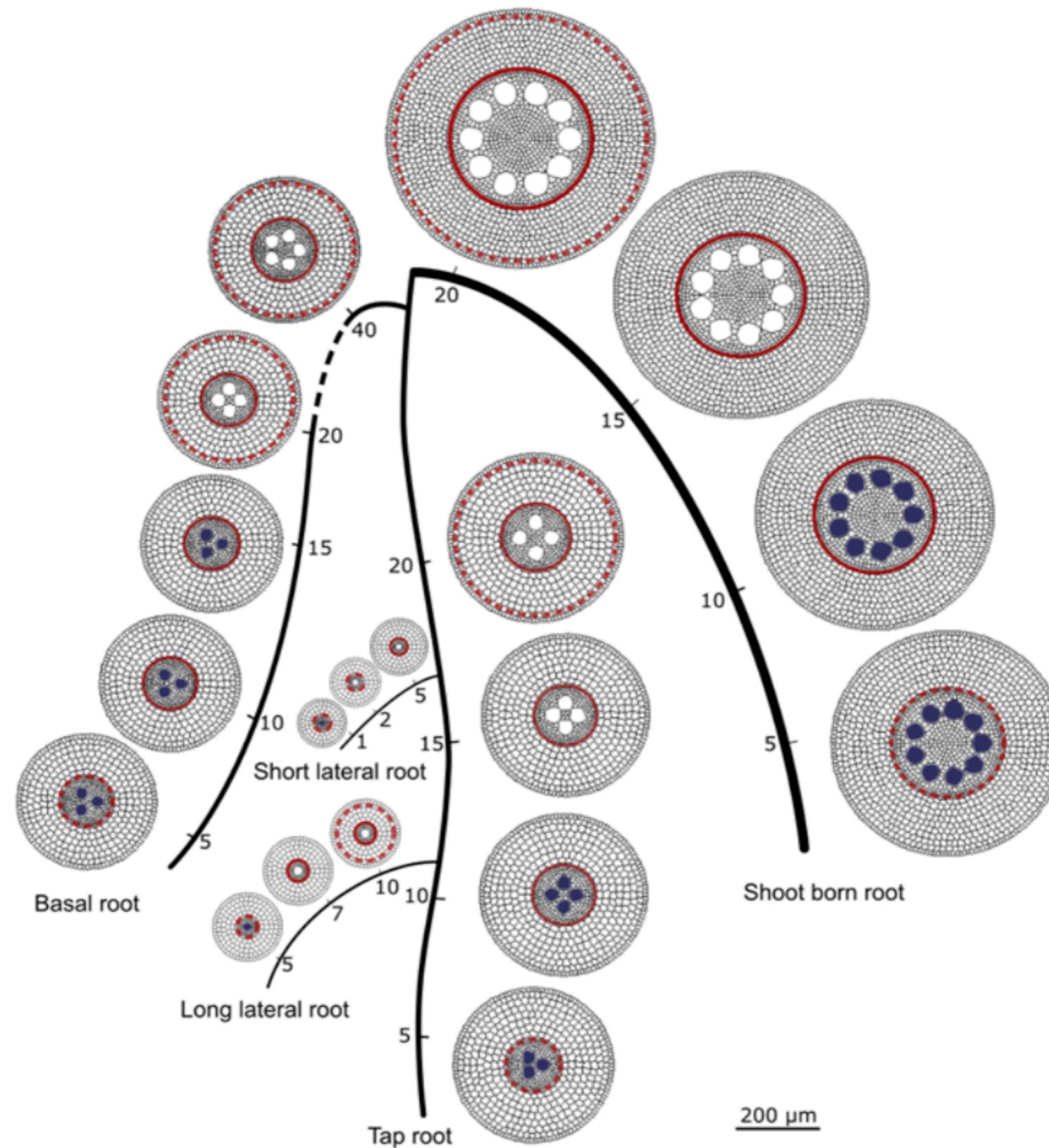
L Modèles “structure - fonctions”



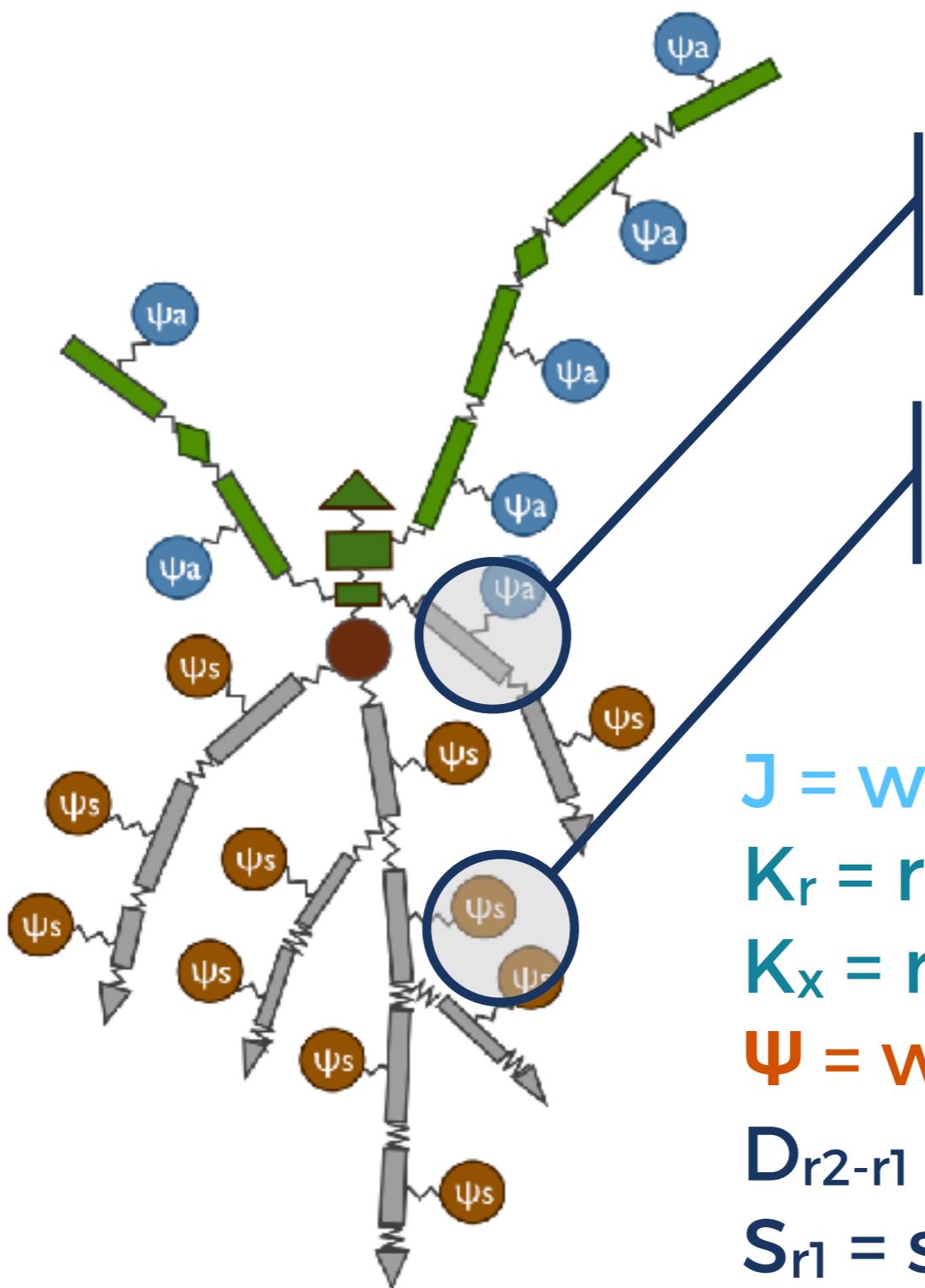
L Environnement hétérogène



L Environnement hétérogène



L Modèle mécaniste



Axial flux

$$J = K_x \cdot \frac{(\Psi_{r1} - \Psi_{r2})}{D_{r2-r1}}$$

Radial flux

$$J = K_r \cdot (\Psi_{r1} - \Psi_{soil}) \cdot S_{r1}$$

J = water flux [$m^3 s^{-1}$]

K_r = radial conductivity [$m^4 s^{-1} \cdot MPa^{-1}$]

K_x = radial conductivity [$m \cdot s^{-1} \cdot MPa^{-1}$]

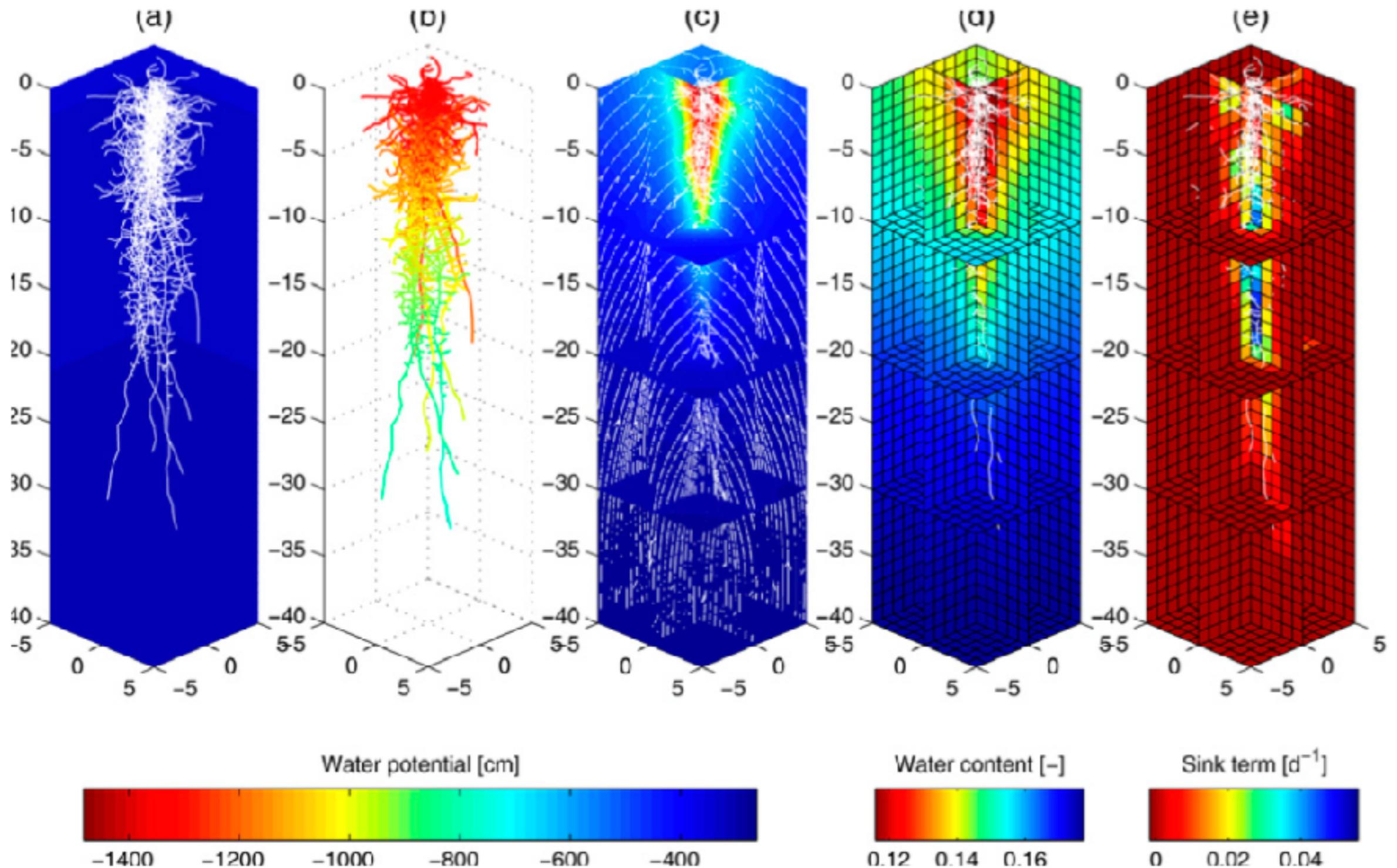
Ψ = water potential [MPa]

D_{r2-r1} = distance between nodes [m]

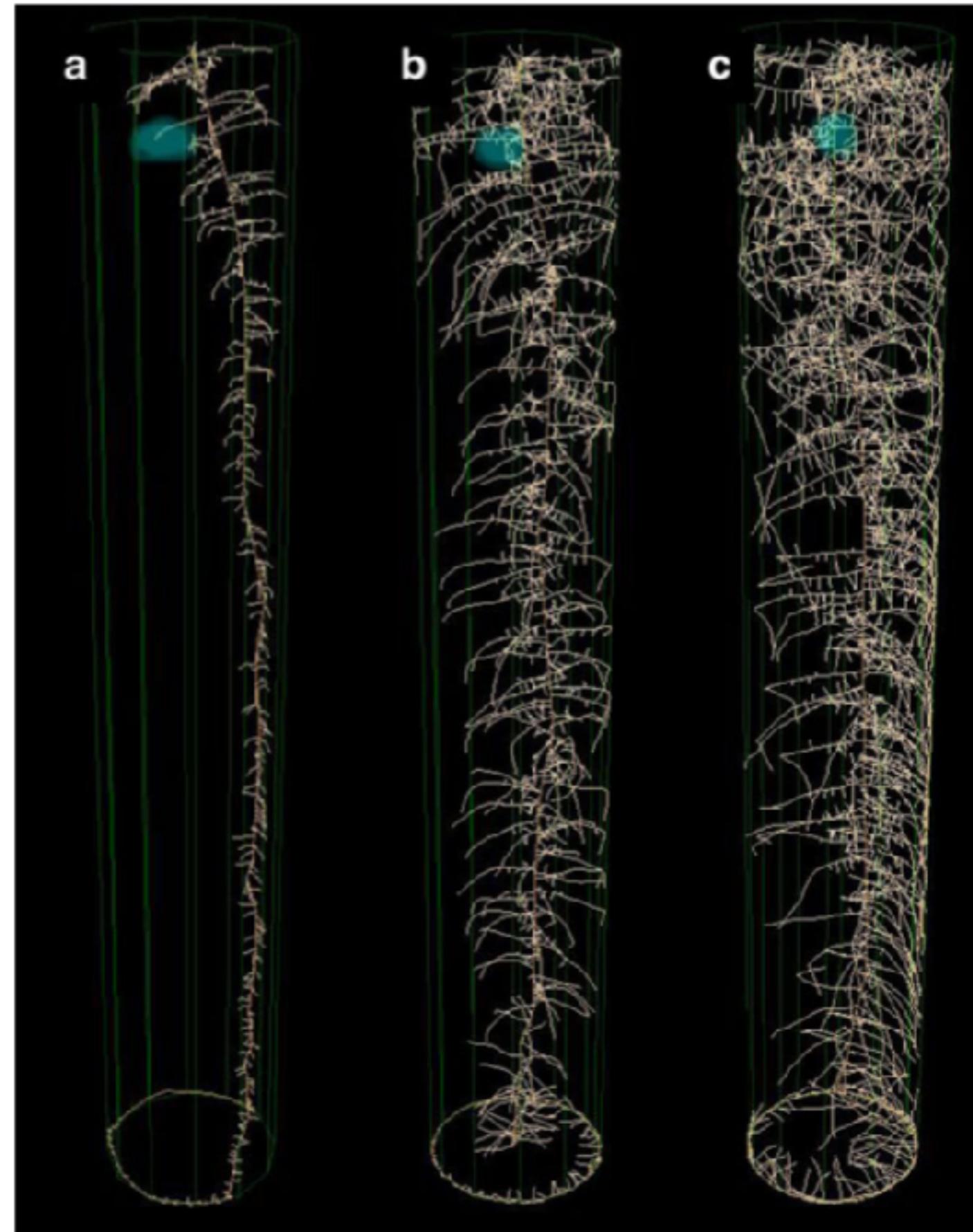
S_{r1} = surface [m^2]

L

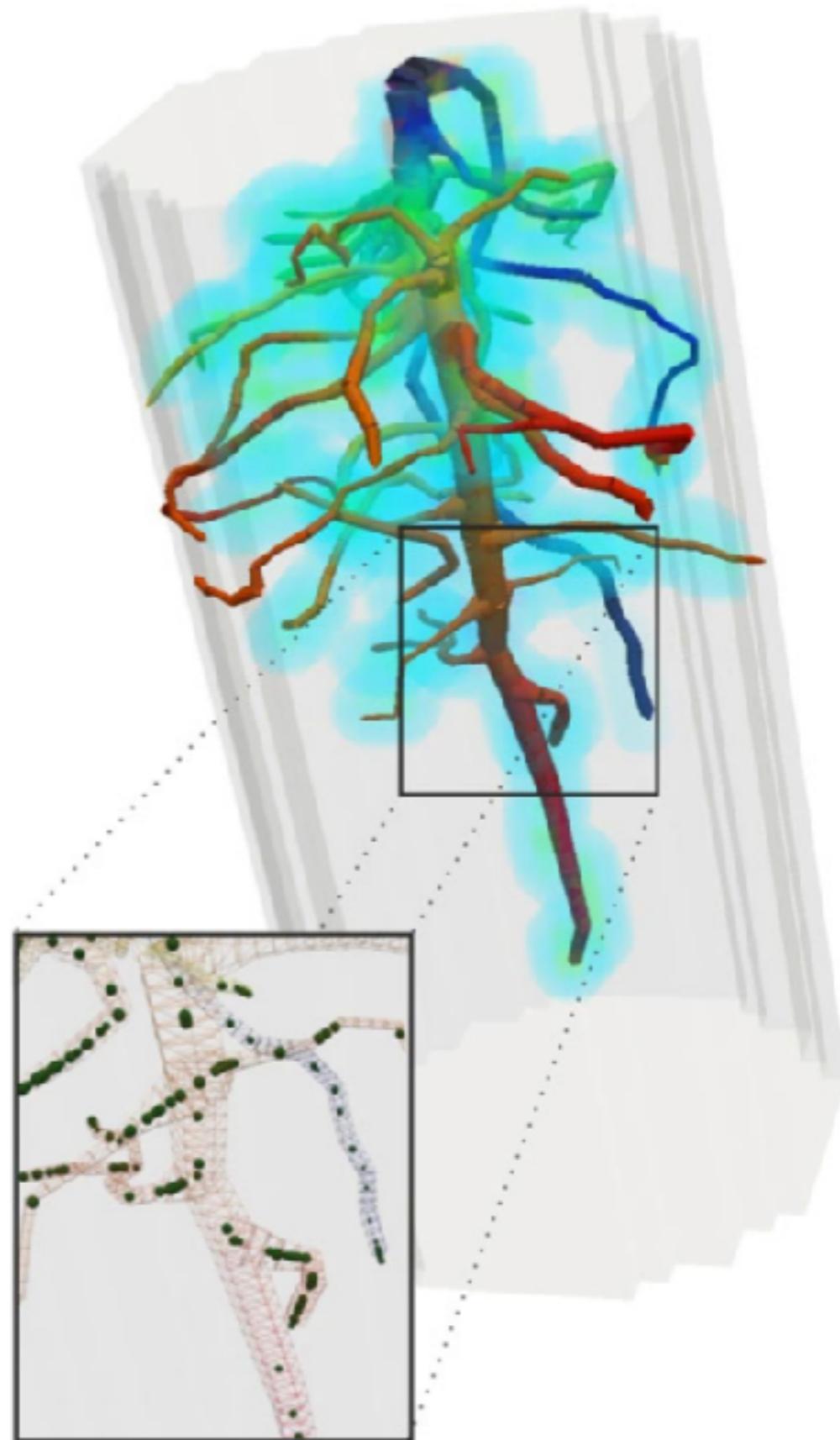
Modèles “structure - fonctions”



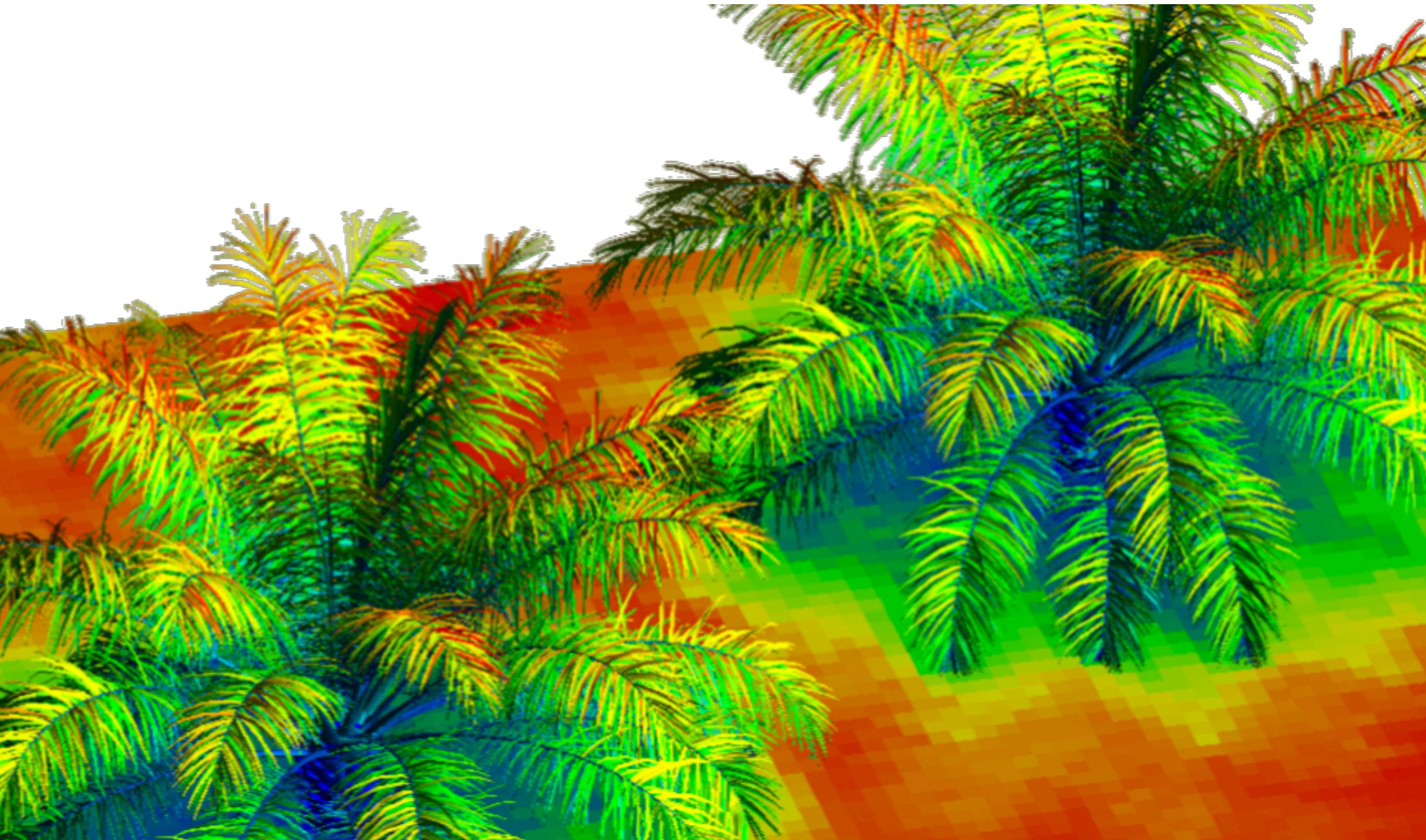
L Modèles “structure - fonctions”



L Modèles “structure - fonctions”



L Modèles “structure - fonctions”



L Modèles “structure - fonctions”

<https://plantmodelling.shinyapps.io/mecha/>

MECHA - Model of Explicit Cross-section Hydraulic Anatomy

Valentin Courreou, Marc Fager, Guillaume Loyer, Mathieu Jourde, François Chaumon, and Xavier Draye

Université catholique de Louvain, Forschungszentrum Jülich GmbH

Choose plant Change parameters About

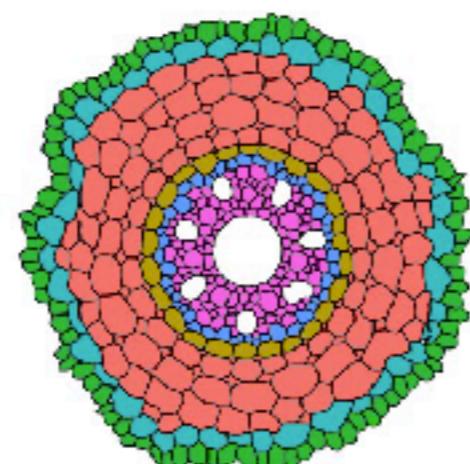
Choose a simulation to visualize

1. Select a plant type
millet-primary

MECHA was run for different cross section geometries and plant type. The results were pre-processed to be easily visualised here.

Tissue layers

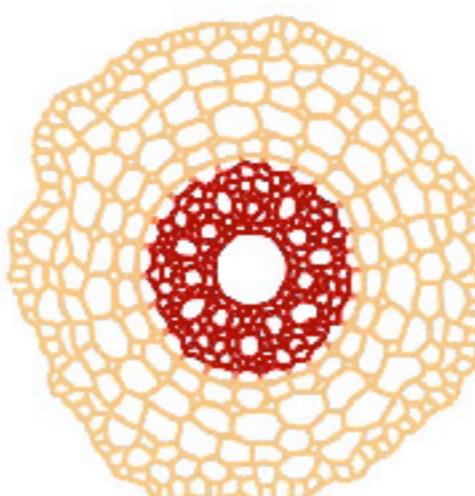
Visualisation of the different cell layers used in the simulation



MECHA
cortex
endodermis
epidermis
sclerenchyma
pericycle
pith

Cell walls pressure

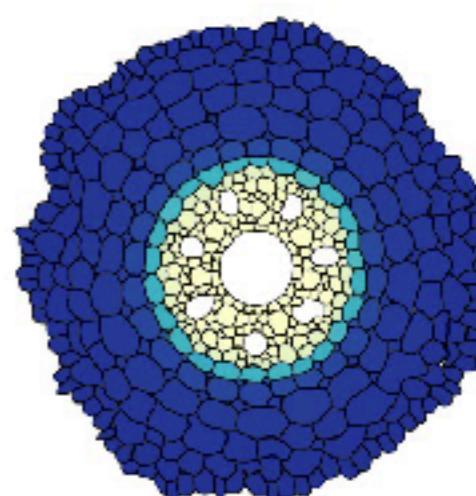
Pressure within the cell walls of the cross section



Wall
pressure
[Pa]
200
400
600

Cells potentials

Pressure within the cell of the cross section



Cell
potentials
[Pa]
-200
0
200
400
600

Select the information to visualize

potentials

Synthetic information about the simulation

param	value	unit
Cross-section height	0.02	cm
Cross-section perimeter	0.945	cm
Cross-section area (approximate)	0.000202	cm² (0.000202)

Display range:

-7,000 100
-1,000 -800 -600 -400 -200 0 200 400 600 800 1,000 1,200 1,400 1,600 1,800 2,000 2,200 2,400 2,600 2,800 3,000 3,200 3,400 3,600 3,800 4,000 4,200 4,400 4,600 4,800 5,000

Display range:

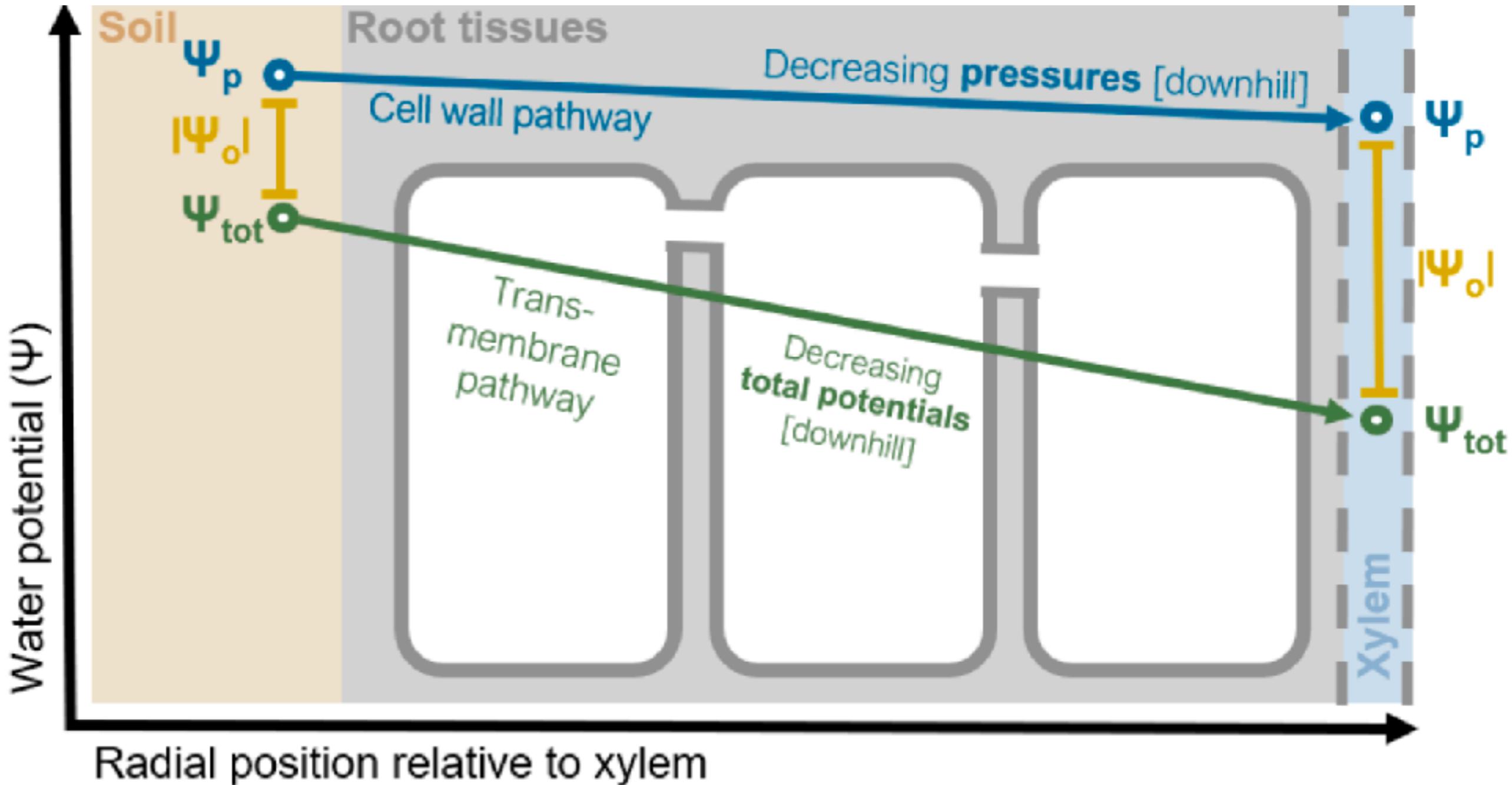
-600 4,897
-600 -500 -400 -300 -200 -100 0 100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 1,500 1,600 1,700 1,800 1,900 2,000 2,100 2,200 2,300 2,400 2,500 2,600 2,700 2,800 2,900 3,000 3,100 3,200 3,300 3,400 3,500 3,600 3,700 3,800 3,900 4,000 4,100 4,200 4,300 4,400 4,500 4,600 4,700 4,800 4,900 5,000

Average cell and wall pressure

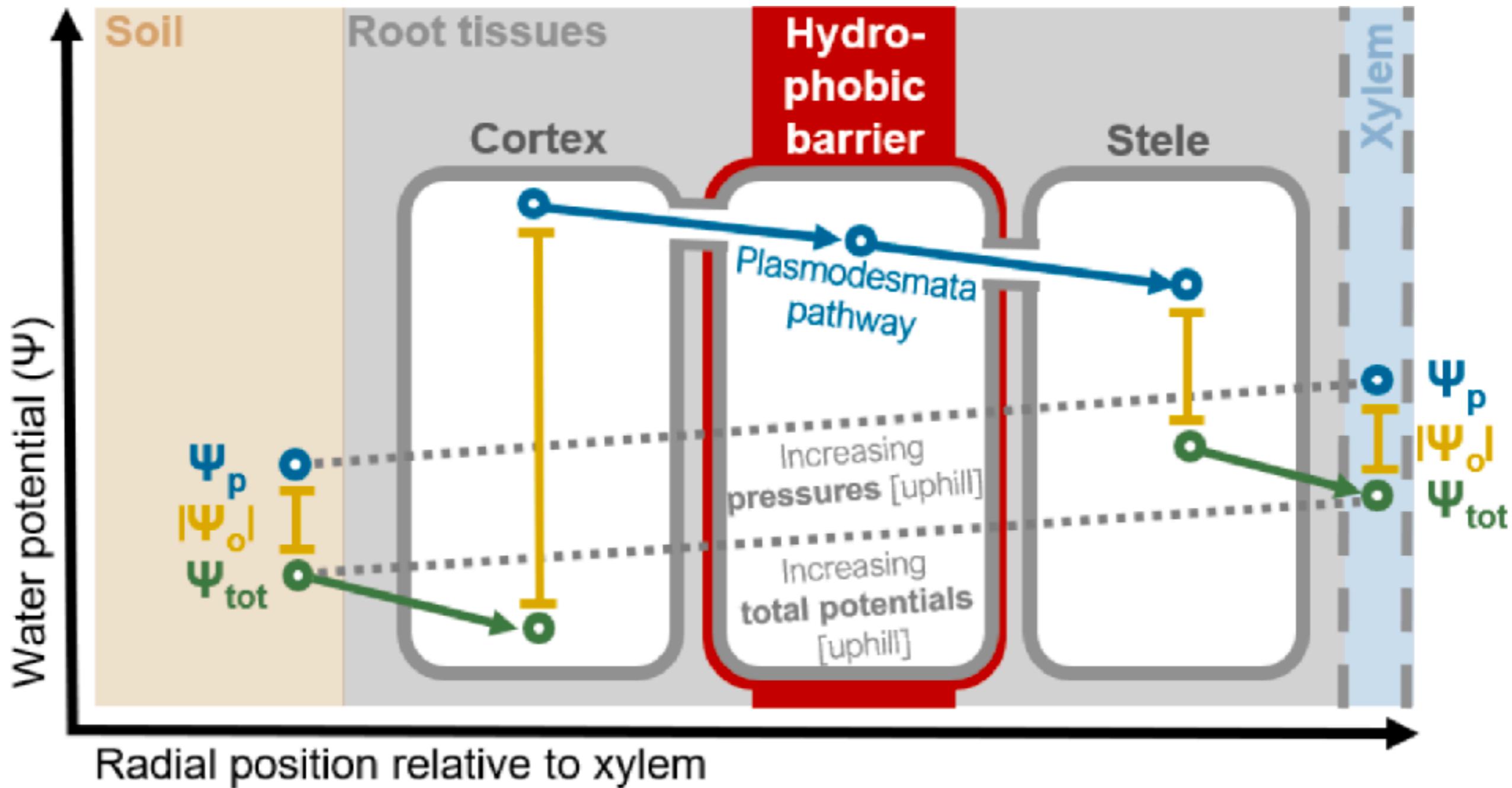
Visualisation of the average cell and wall pressure across the cross-section



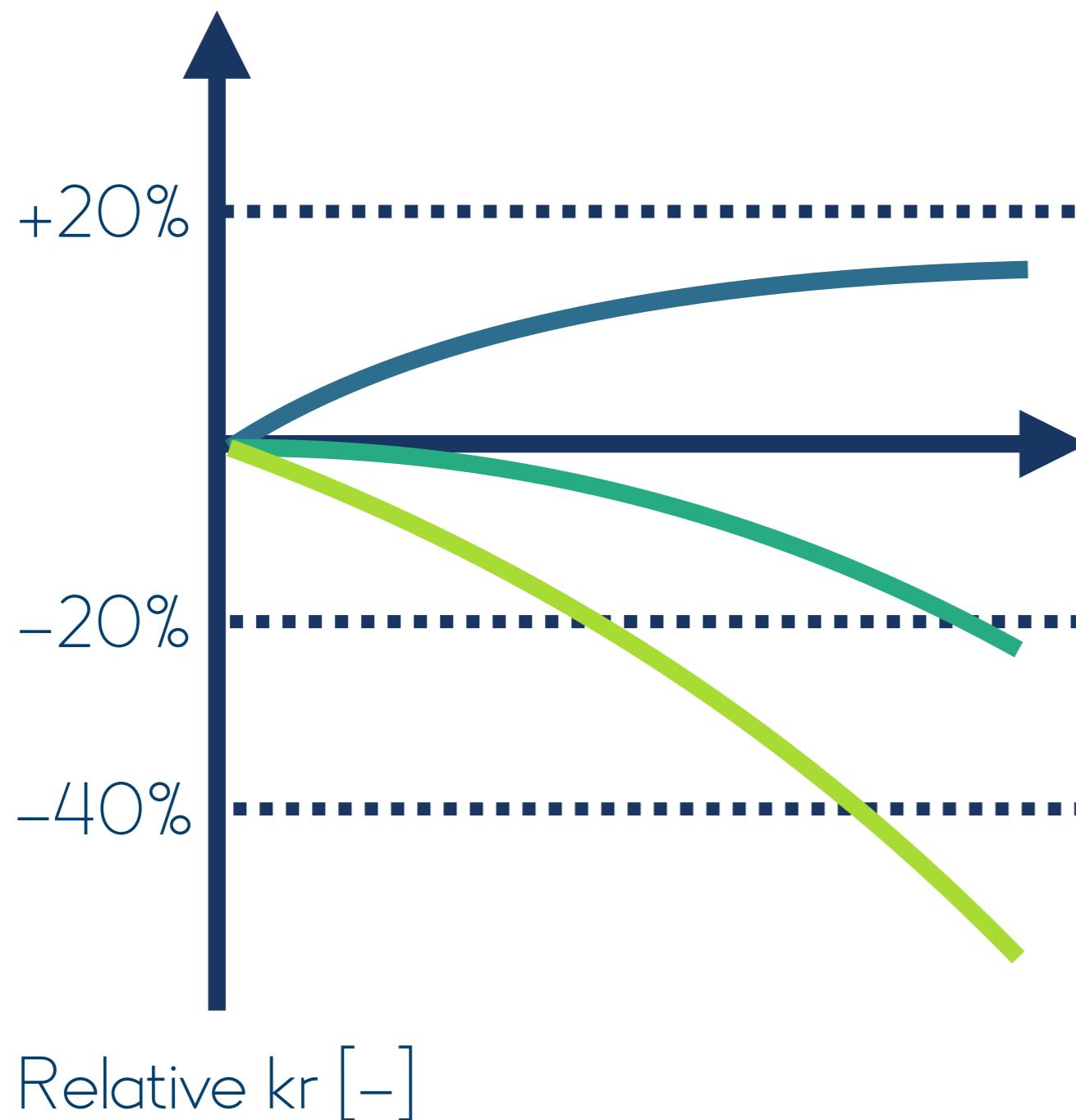
L Compréhension du système



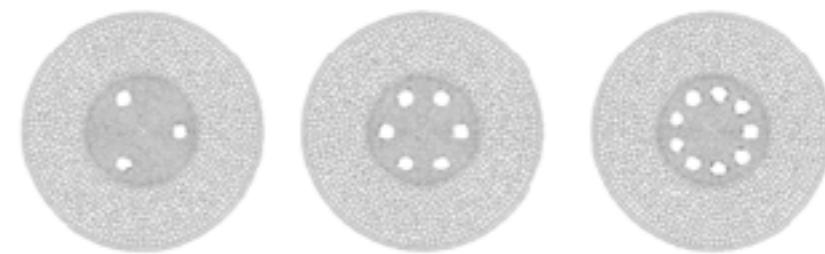
L Compréhension du système



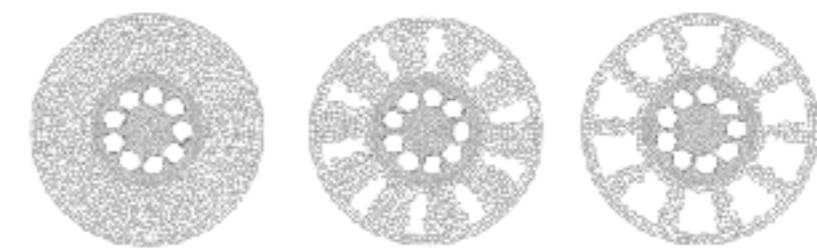
L'Analyse de sensibilité



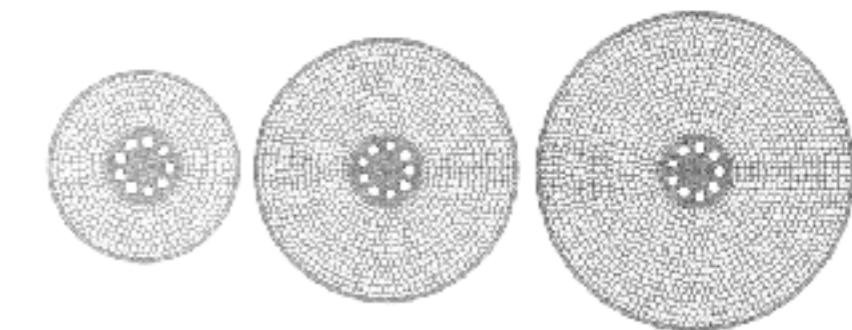
MORE XYLEM VESSELS



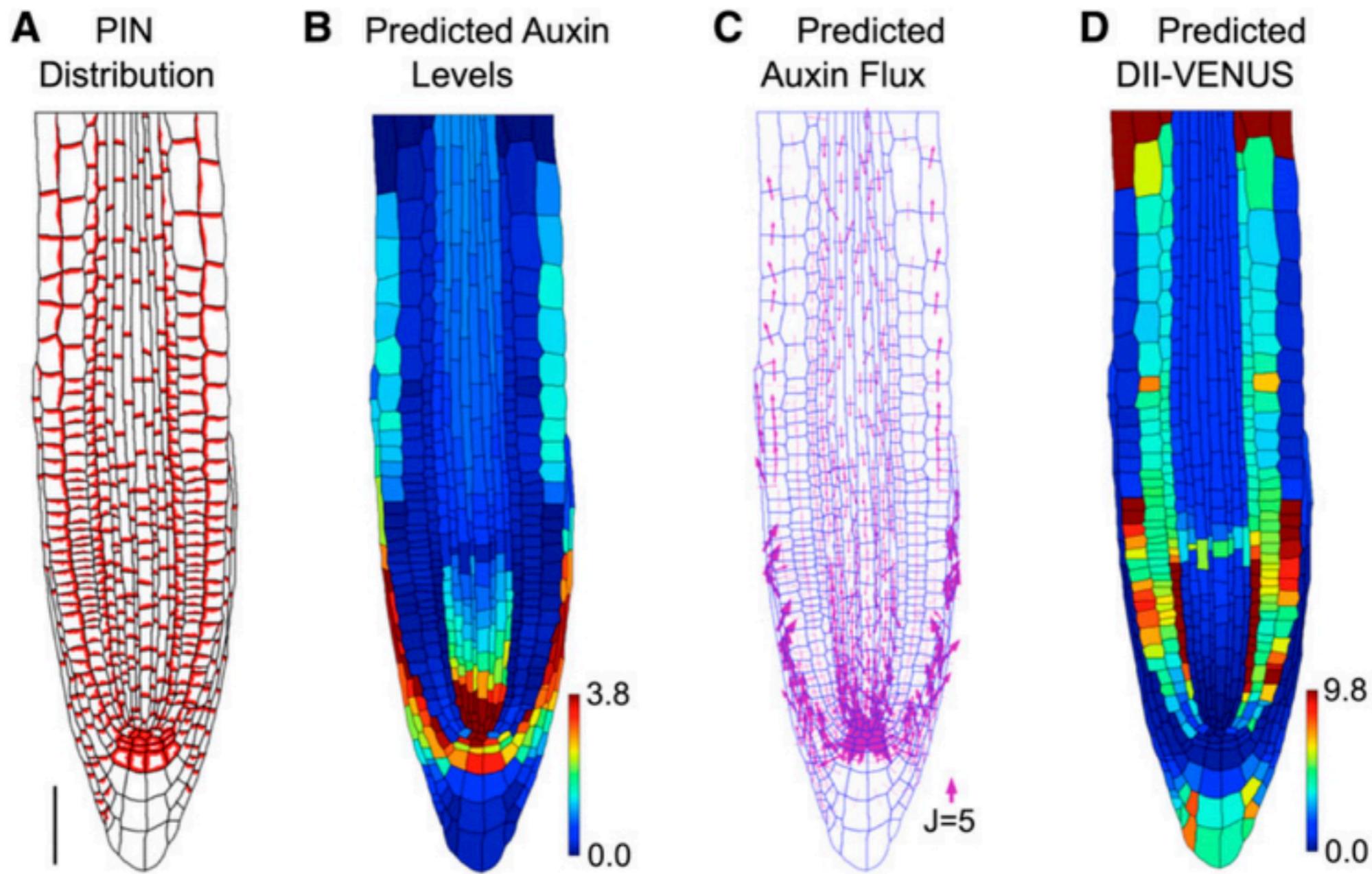
MORE AERENCHYMA



WIDER CORTEX



L Modèles “structure - fonctions”



L

Modèles “structure - fonctions”



Experimental
parameters
range

GRANAR

Anatomical
network

MECHA

Root
hydraulics

Soil
properties

Experimental
parameters
range

CPlantBox

Root
architecture

MARSHAL

Root
hydraulic
architecture

HYDRUS

HYDRAULIC VIPER

MULTISCALE SENSITIVITY ANALYSIS OF
WATER FLOW IN THE SOIL PLANT SYSTEM

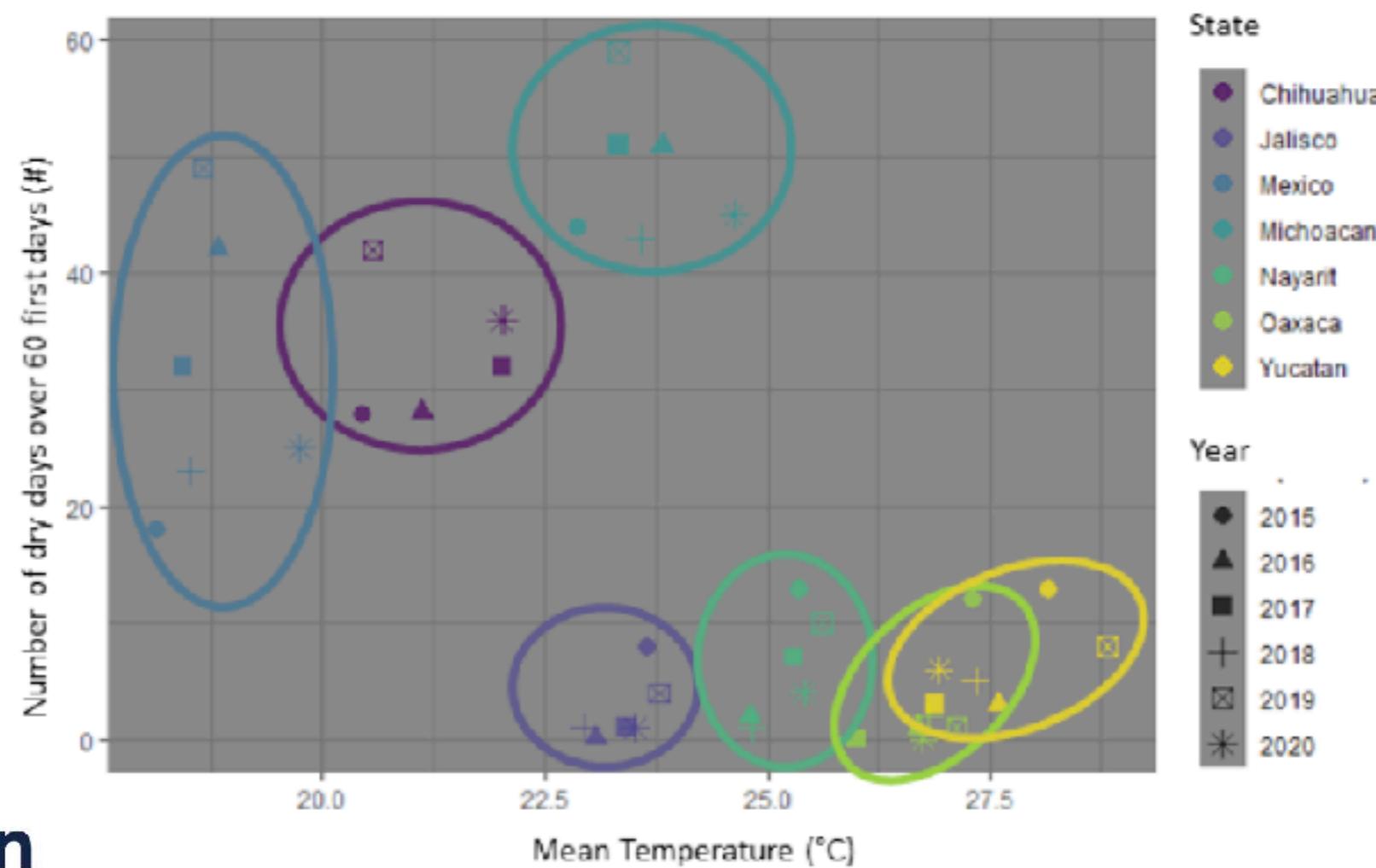


Adrien
Heymans

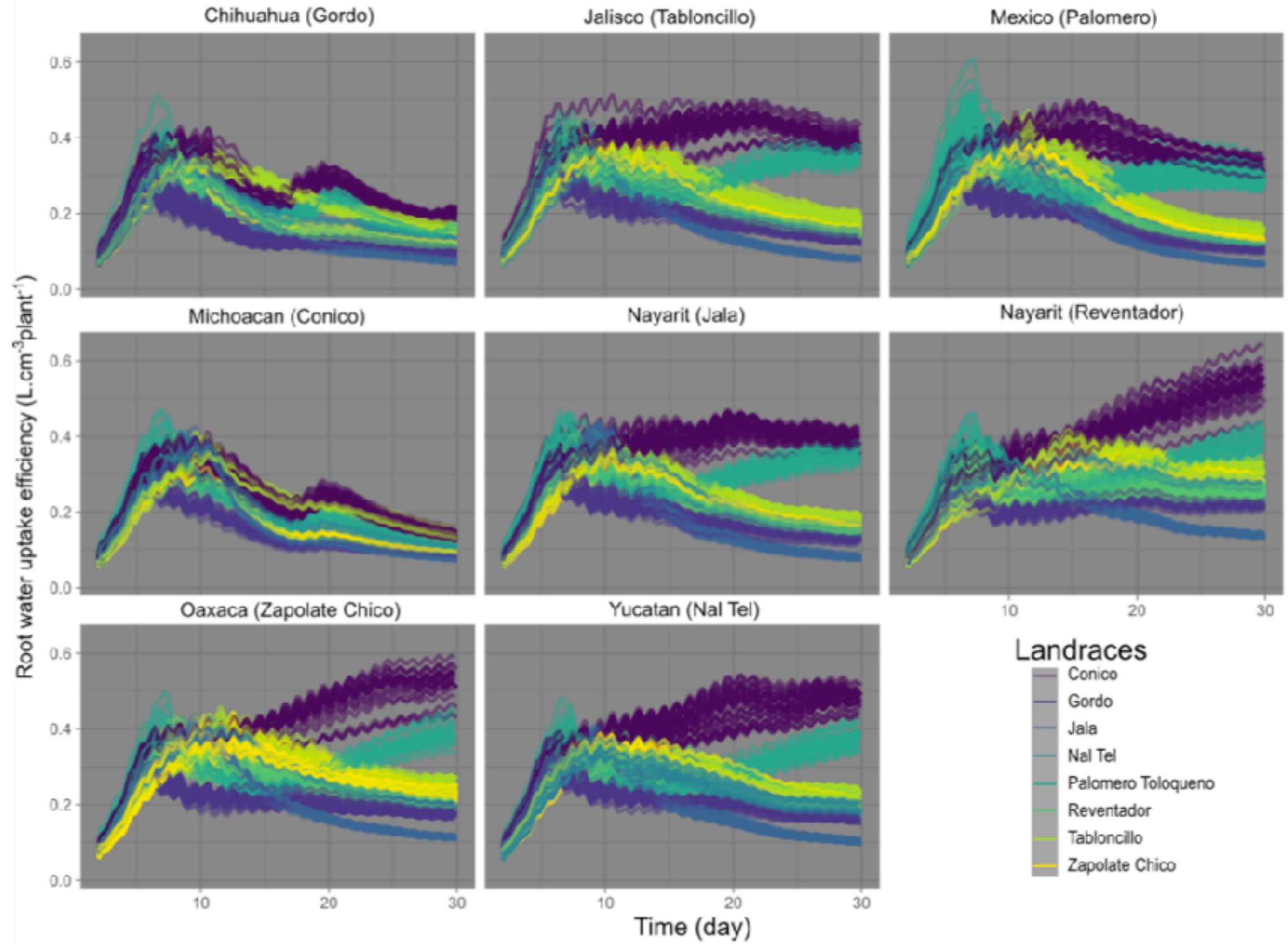


WATER
UPTAKE
DYNAMICS

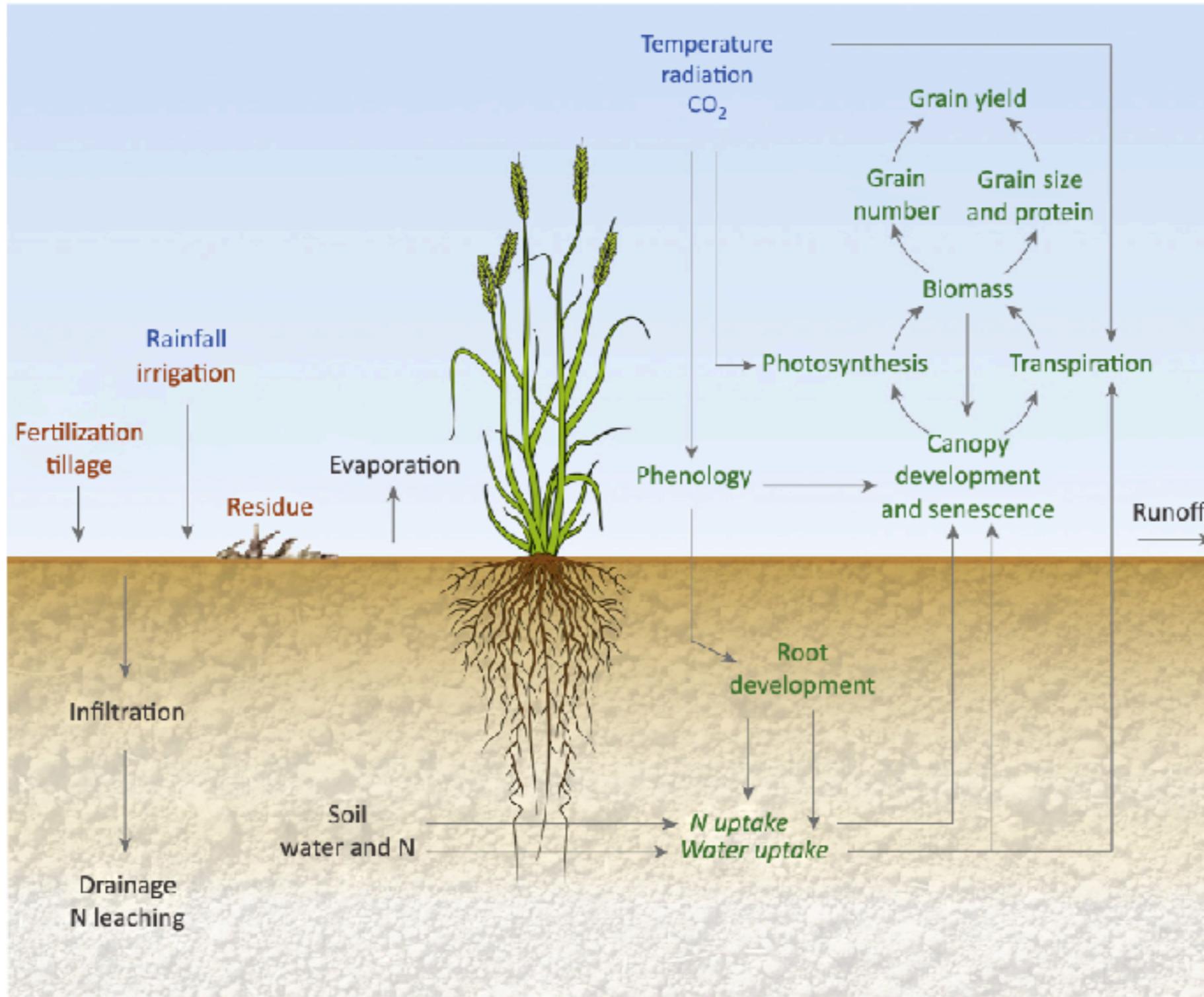
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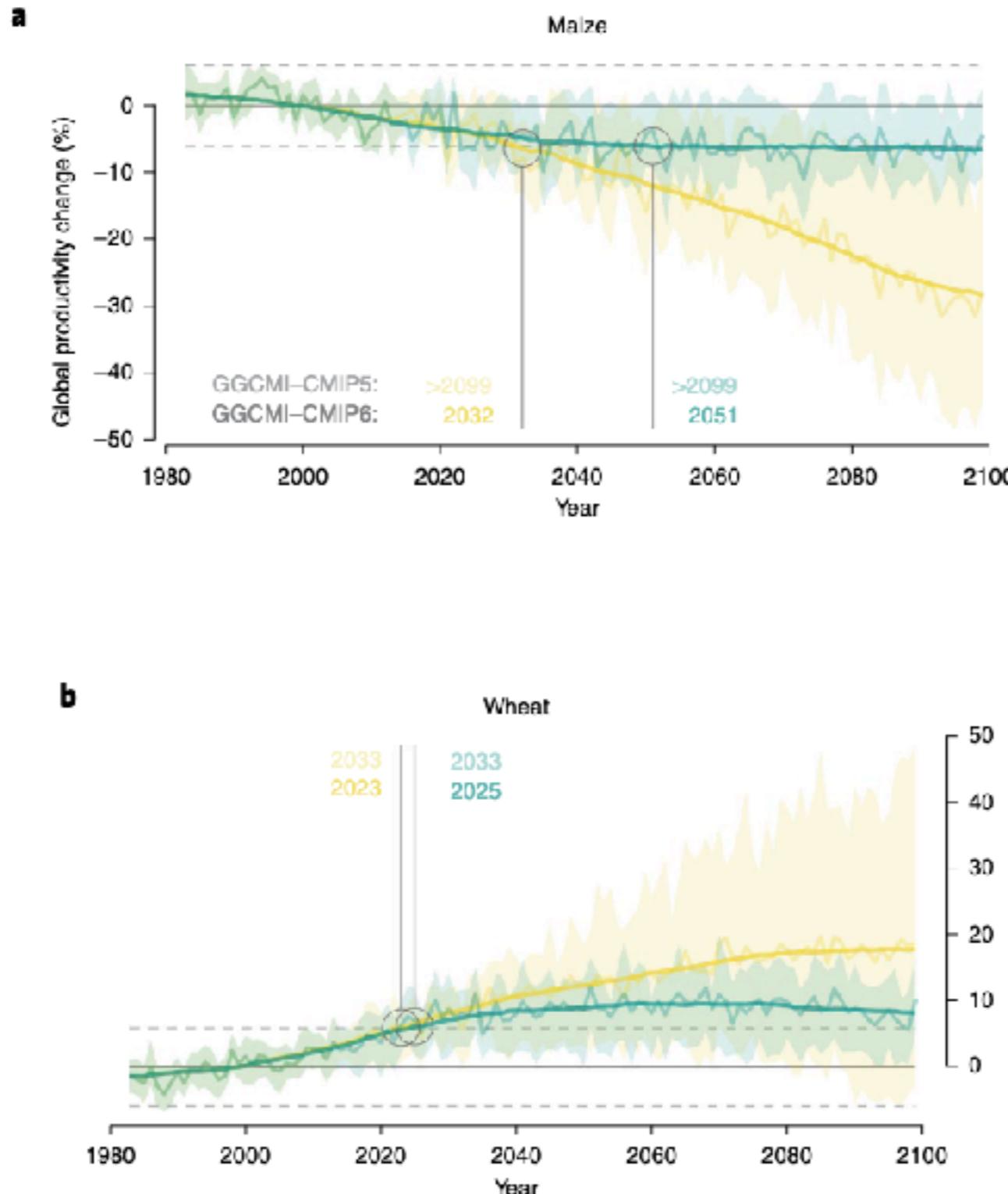
L



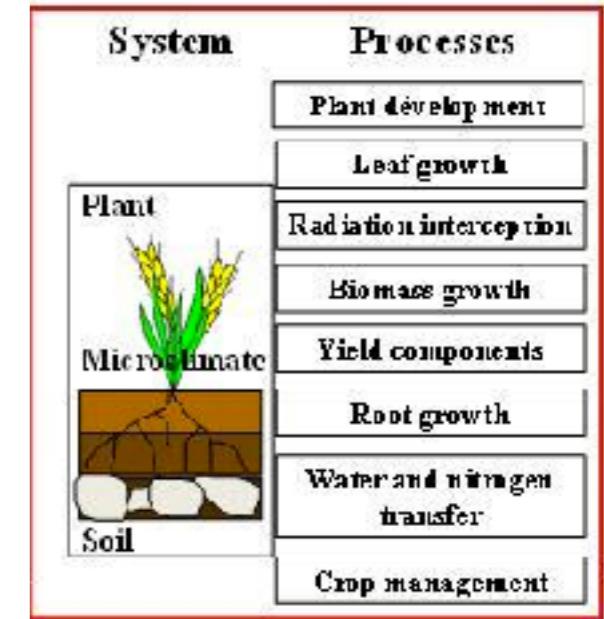
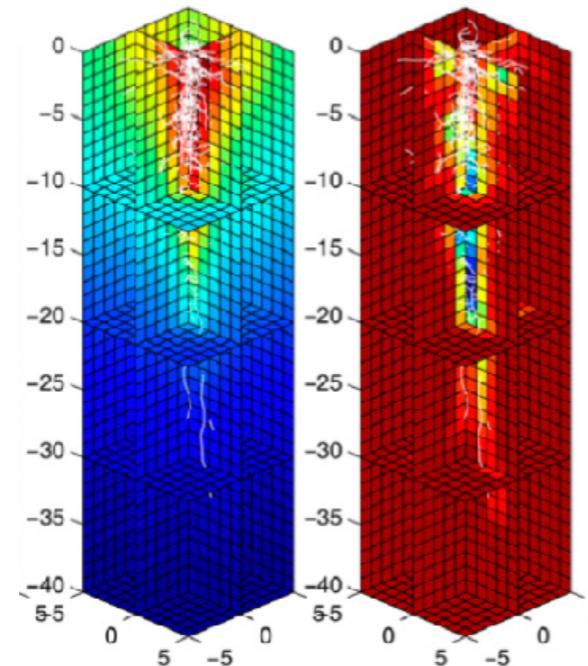
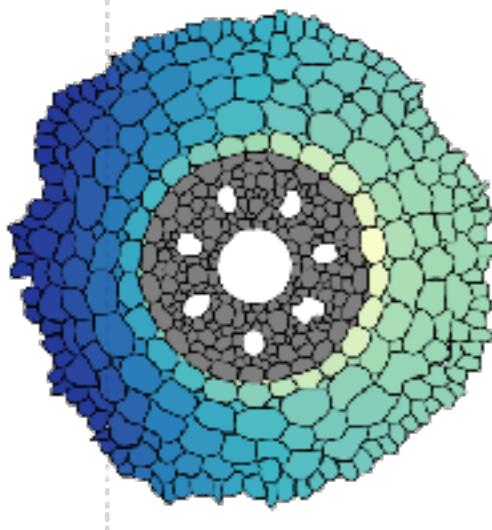
L Modèles de culture



LPrédictions



L Les modèles près de chez vous



MECHA

Valentin Couvreur
Xavier Draye

UCL

GRANAR

Adrien Heymans
Guillaume Lobet
UCL - Juelich

R-SWMS

Valentin Couvreur
Félicien Meunier
Mathieu Javaux
UCL

CPLANTBOX

Guillaume Lobet
Andrea Schnepf
Daniel Leitner
UCL - Juelich

STICS

Benjamin Dumont
Gembloox
AgroBioTech

<https://paperpile.com/shared/6MaUSf>

L Les modèles

1. Différents types
2. Différentes questions
3. Différentes échelles (temps, espace)

L

5

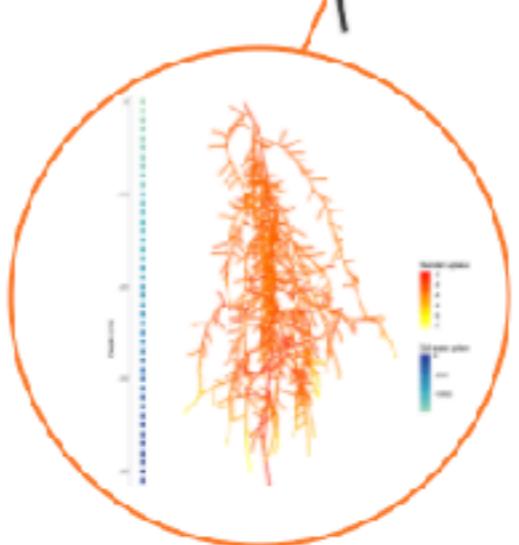
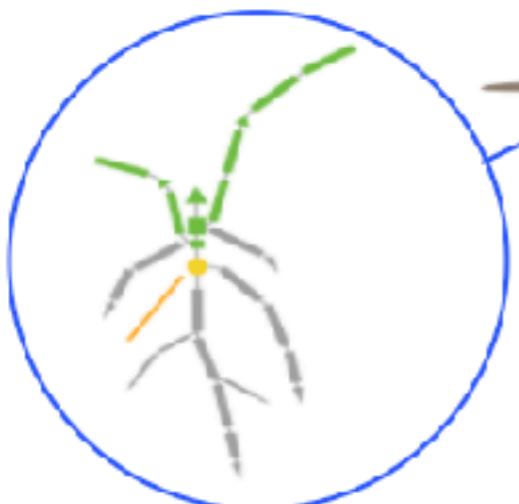
Au travail !



PlaNet-Maize

Whole plant model of maize.
Includes root and shoot
architectures, as well as
water, carbon and nitrogen
management

[See the model](#)



MARSHAL

Model simulation root
hydraulic architecture. MARSHAL
can also predict the capacity of a
plant to take up water in
a specific environment

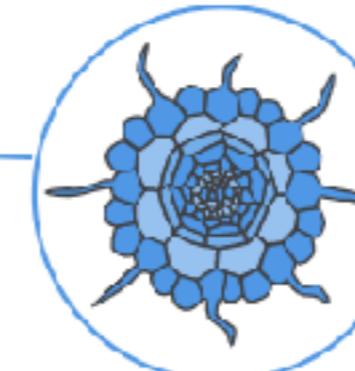
[See the model](#)



Tardieu-Davies

Model simulating whole plant
water management, linking
hydraulic and hormonal
signalling.

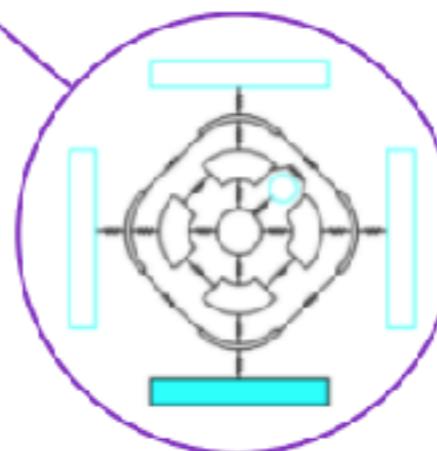
[See the model](#)



MECHA

Anatomical model to
predict water flow in
a root cross-section

[See the model](#)



Hydropatterning model

Model illustrating how a water
potential gradient around the
root triggers hydropatterning,
and the uneven production of
lateral roots around the primary

[See the model](#)

<http://www.botalgorithme.be/>

L'Exercice

1. Influence de la profondeur racinaire sur rendement chez le maïs
2. Influence des aquaporines sur la perméabilité racinaire
3. Influence de la $[CO_2]$ sur le taux de photosynthèse
4. Influence de la $[CO_2]$ sur la croissance racinaire
5. Influence de la densité de racines latérales sur la longueur racinaire totale

L

6 Le projet



L>Description du projet

1. Projet de modélisation
2. Individuel avec collaborations
3. Tout au long du quadri
4. Utilisation de modèles existants
5. Développement de nouveau modèle

L>Description du projet

- 1. Influence du système racinaire sur le rendement chez le maïs**
2. Modélisation de l'architecture racinaire
3. Modélisation de l'anatomie racinaire
4. Modélisation de l'évolution de la culture
5. Couplage entre le modèle racinaire et le modèle de culture
6. Analyse de l'interaction entre rendements et racines

L'Evaluation du projet

- **Deliverable final:** Jupyter notebook [qui tourne](#)
- **Checkpoints techniques** (11/20):
 1. Utilisation des modèles individuels
 2. Couplage entre les modèles racinaires et le modèle de culture
 3. Utilisation des modèles couplés sur une saison de culture (dynamique)
 4. Analyse de l'interaction entre rendements et racines
 5. Optimisation du système racinaire en situation de déficit hydrique
- **Checkpoints méthodologique et théorique** (6/20)
 6. Bibliographie pertinente (justification des scénarios)
 7. Plan de simulations
 8. Code commenté
 9. Discussion argumentée et en lien avec la littérature scientifique
- **Checkpoints collaboratif** (3/20)
 10. Partage de code
 11. Co-authorship

L Checkpoint collaboratif

- **Partage de code:**
 1. Partage de bouts de code commentés sur répertoire Github du cours
- **Co-authorship sur le rapport final:**
 2. Choix du premier auteur
 3. Aide technique
 4. Aide théorique
 5. Utilisation de code
 6. -> devra être justifié
 7. Pénalité en cas de plagiat