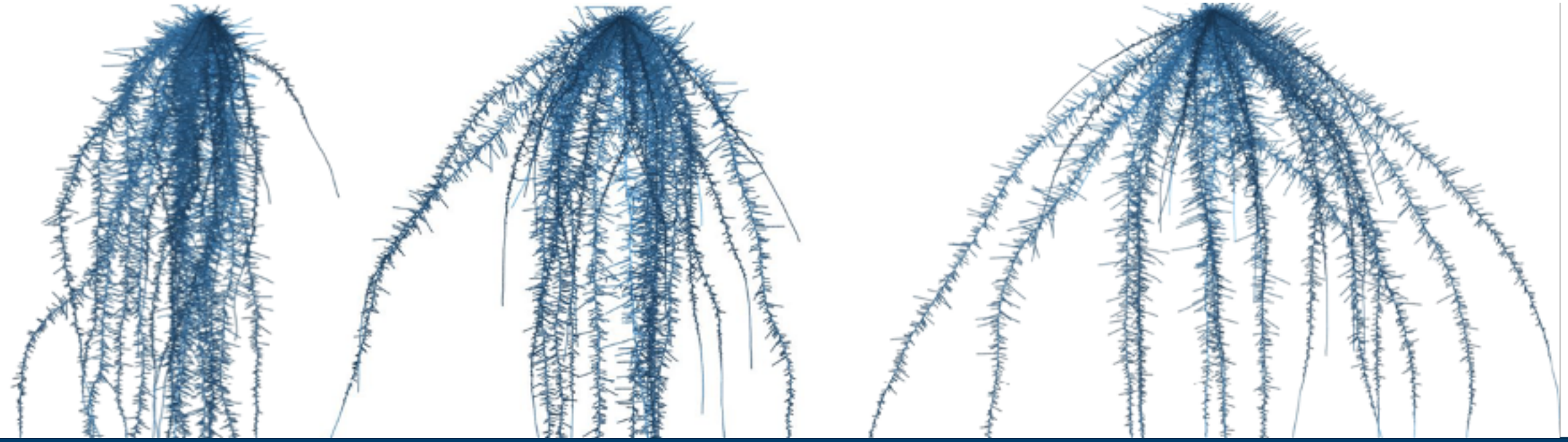


# USING FUNCTIONAL STRUCTURAL PLANT MODELS TO EXTEND EXPERIMENTAL PHENOTYPIC KNOWLEDGE

GUILLAUME LOBET

https://github.com/guillaumelobet/PhenomeForce

Mitglied der Helmholtz-Gemeinschaft

JÜLICH
Forschungszentrum

# WHAT WE WILL DO IN THE WORKSHOP

- DISCOVER HOW MODELS CAN HELP EXTEND PHENOTYPIC DATA

- DISCOVER HOW MODELS CAN HELP LINK STRUCTURAL AND FUNCTIONAL DATA

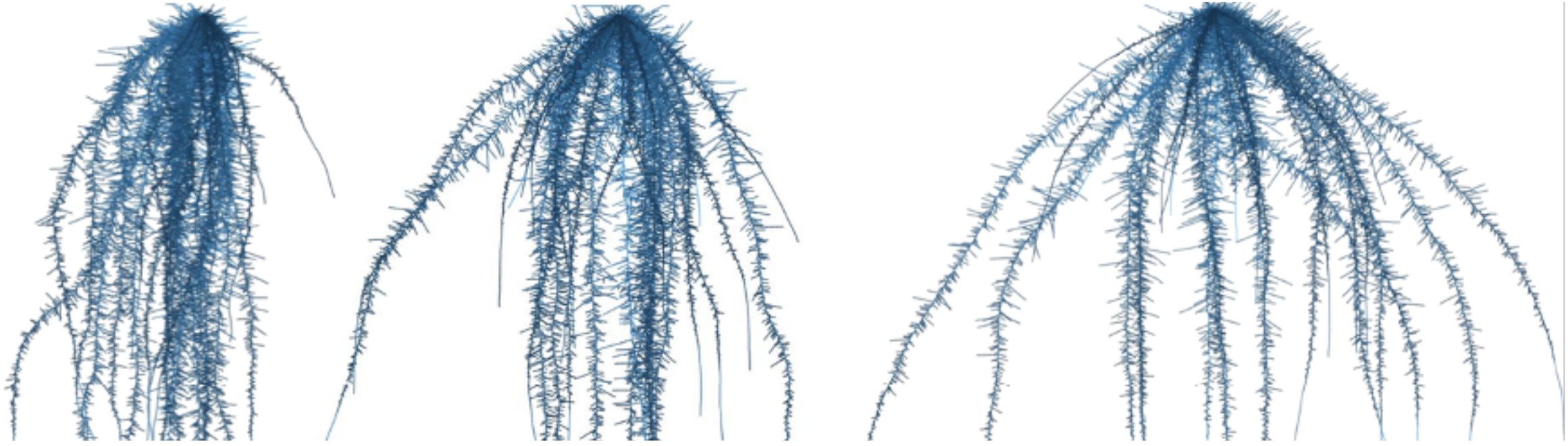
- DISCUSS HOW TO LINK EXPERIMENTS AND MODELS

# WHAT WE WILL NOT DO IN THE WORKSHOP

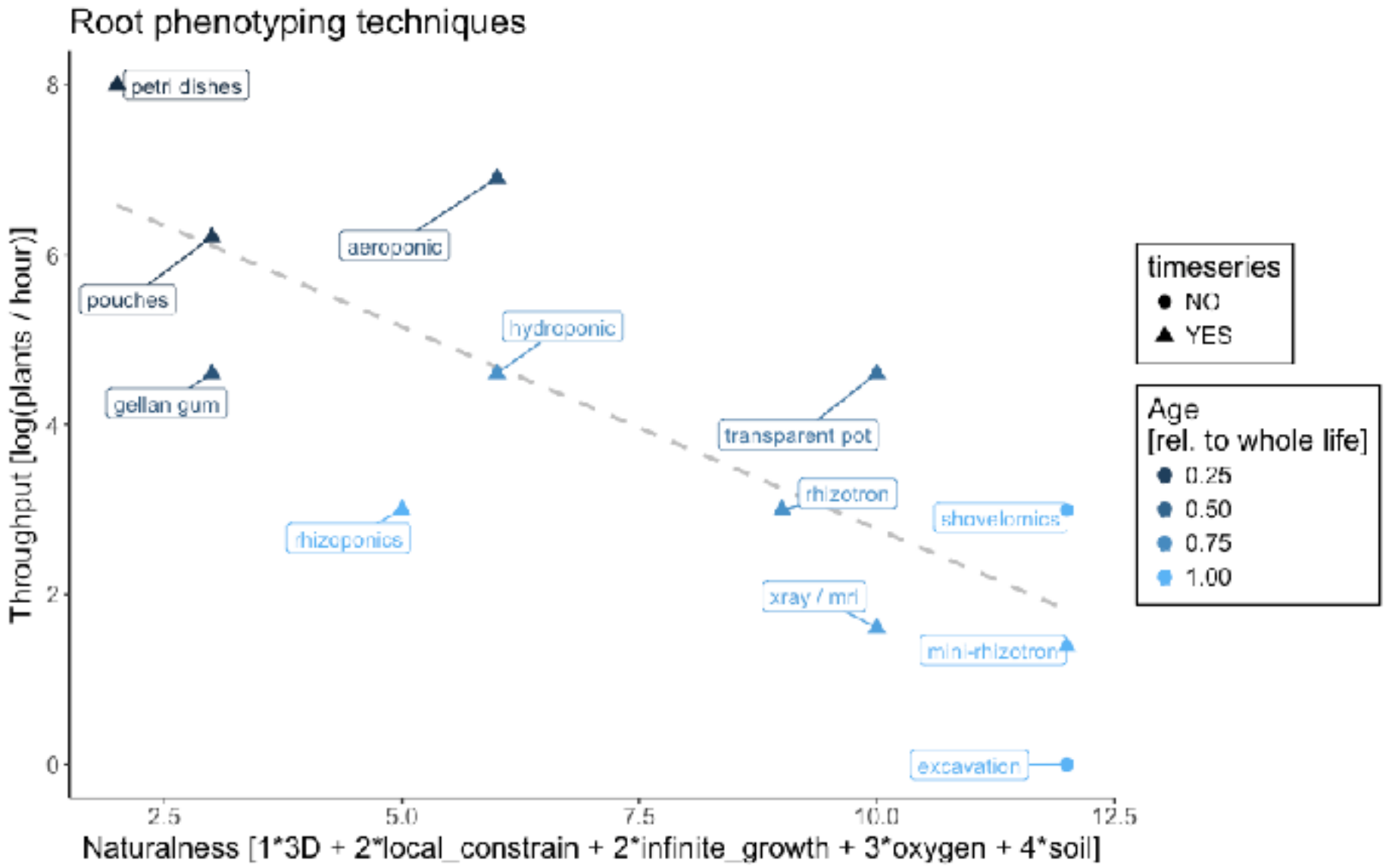
- IN DEPTH HANDS-ON WITH THE MODELS
- IN DEPTH HANDS-ON WITH THE IMAGE ANALYSIS

# 1. FROM STRUCTURES TO BETTER STRUCTURES

## 1 – ARCHITECTURES



# ROOT PHENOTYPING IS COMPLICATED !

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MANY WAYS TO DESCRIBE ROOT SYSTEMS, OFTEN PARTIAL

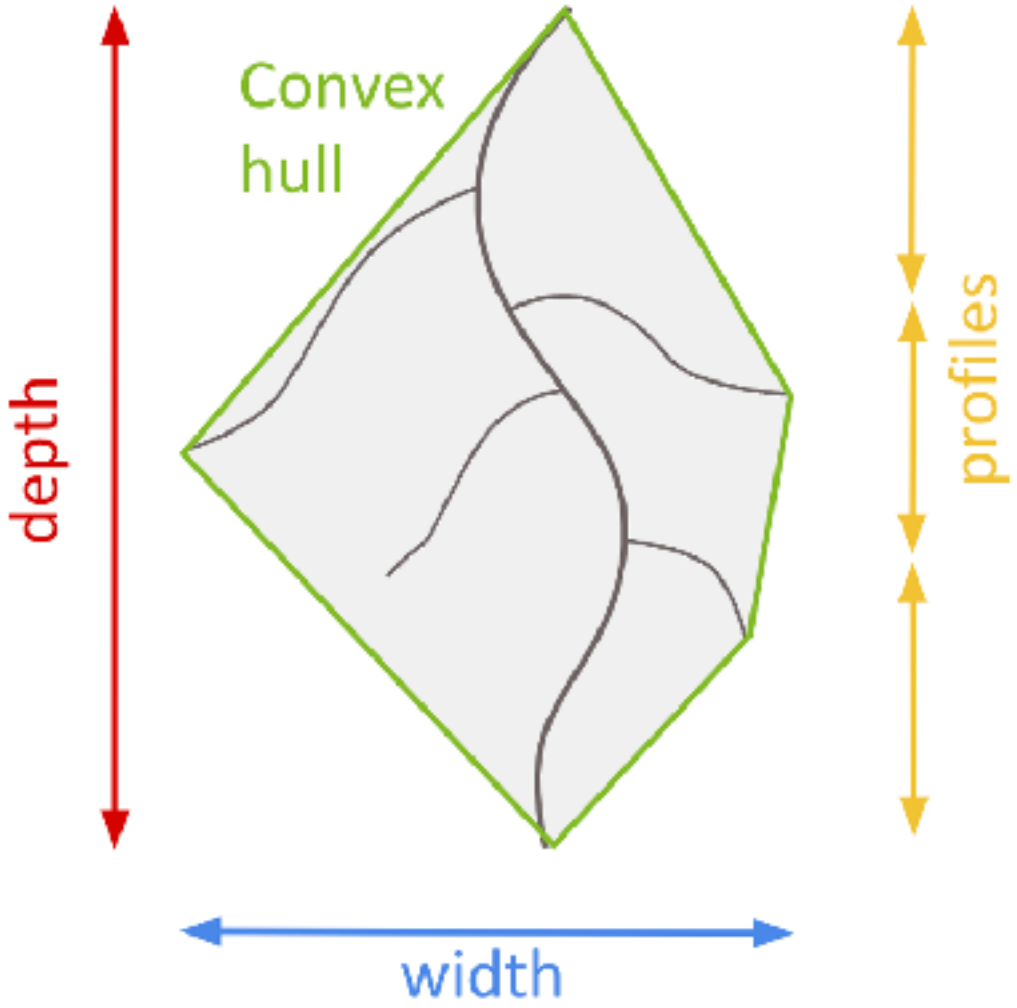
# Geometrical information

**What you need**

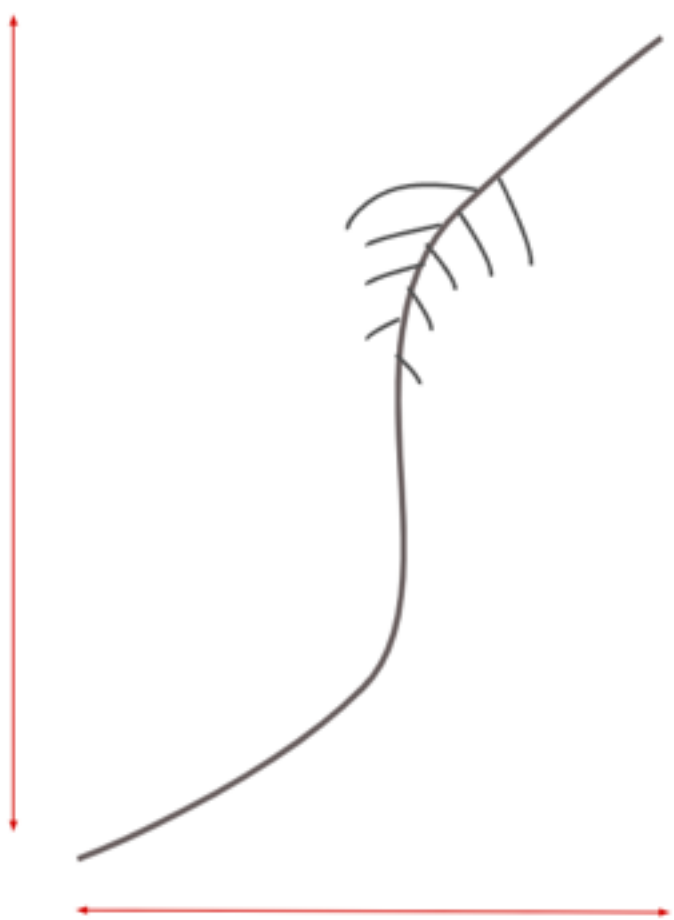
Position in space of every root segment

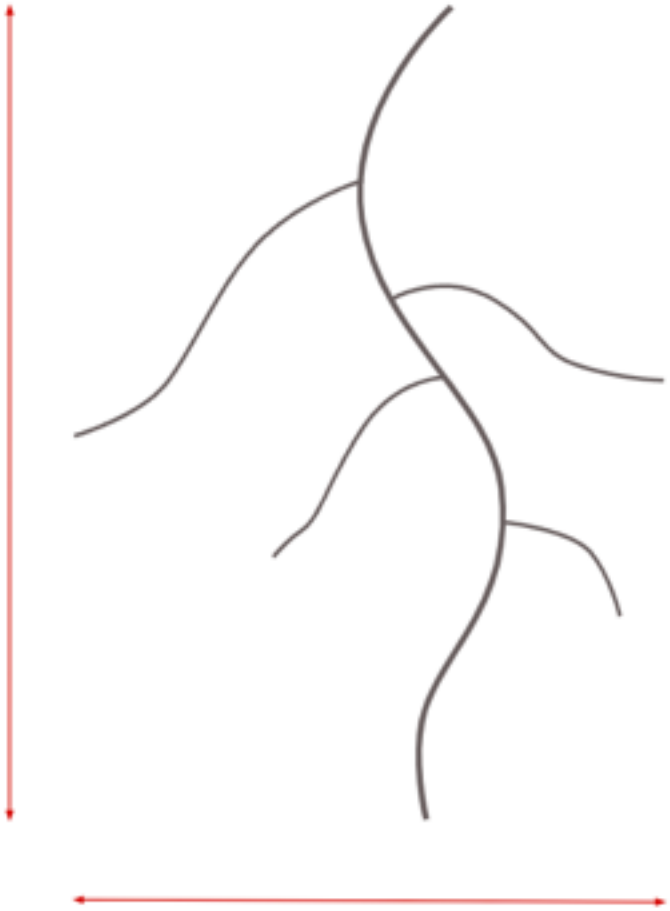
**What you get**

Depth
Width
Convex hull area
Length Profile
...



# Identical width and depth, but very different root systems





MANY WAYS TO DESCRIBE ROOT SYSTEMS, OFTEN PARTIAL

# Morphological information

**What you need**

Tracing of a sample of the roots

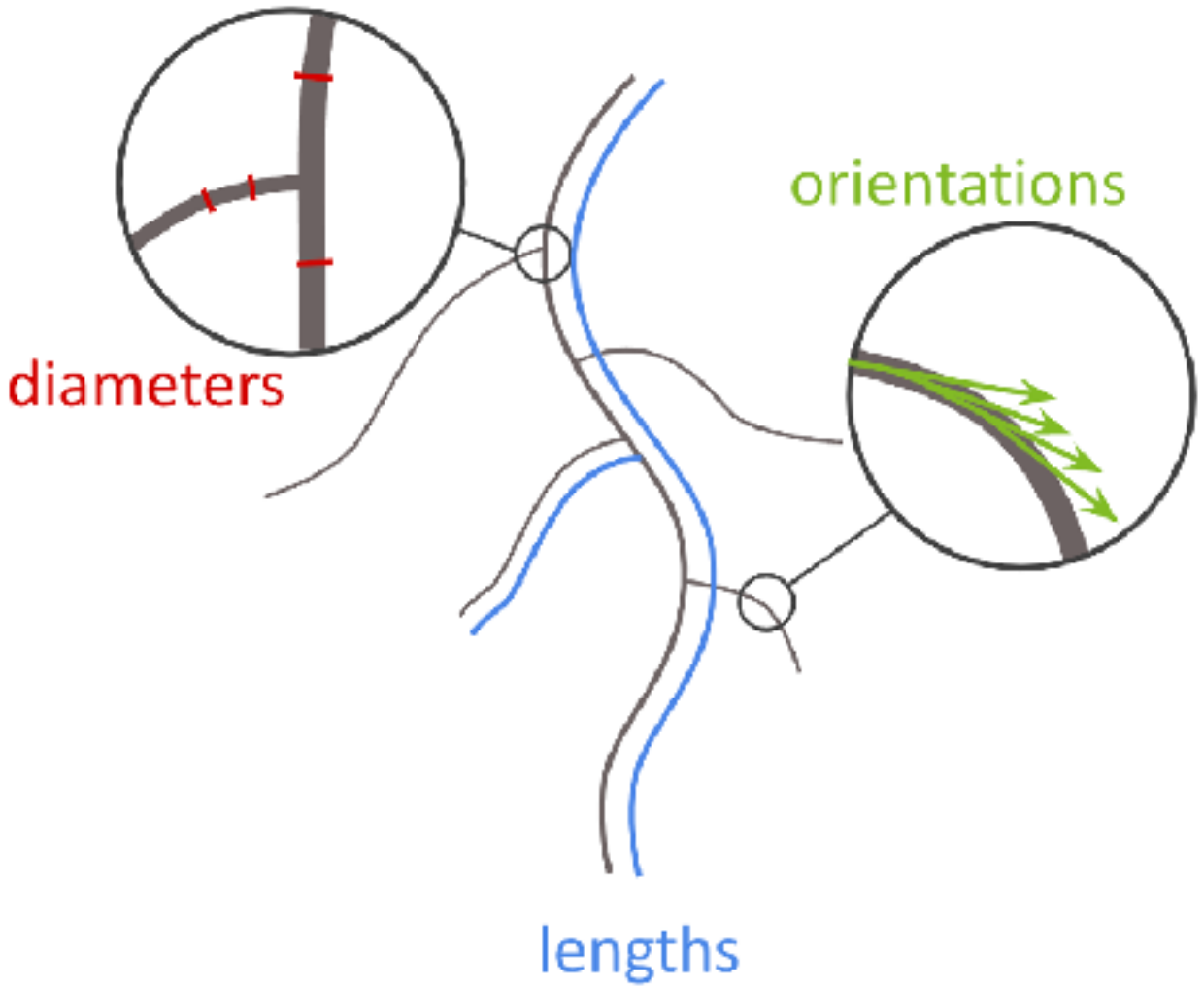
**What you get**

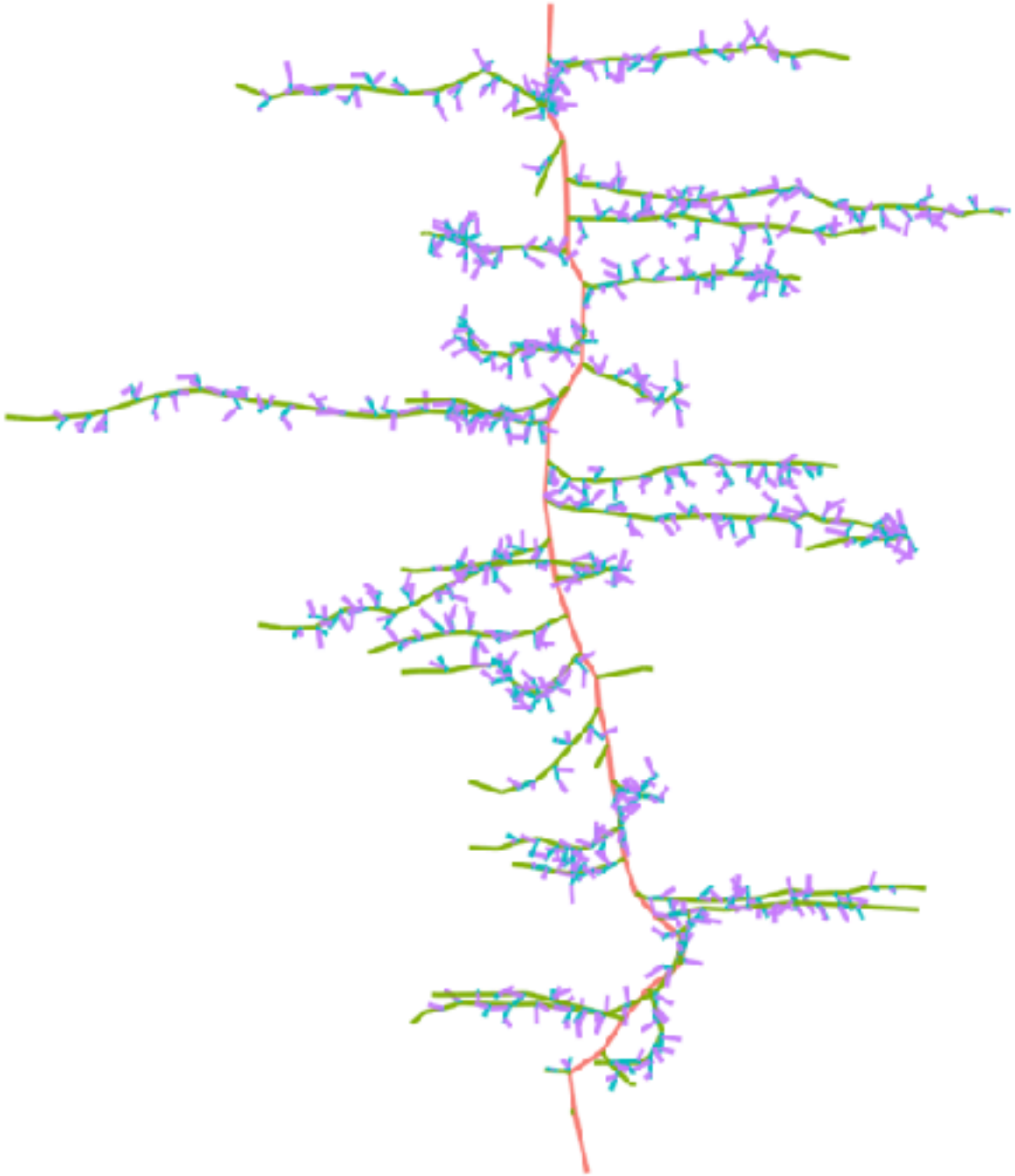
Diameter

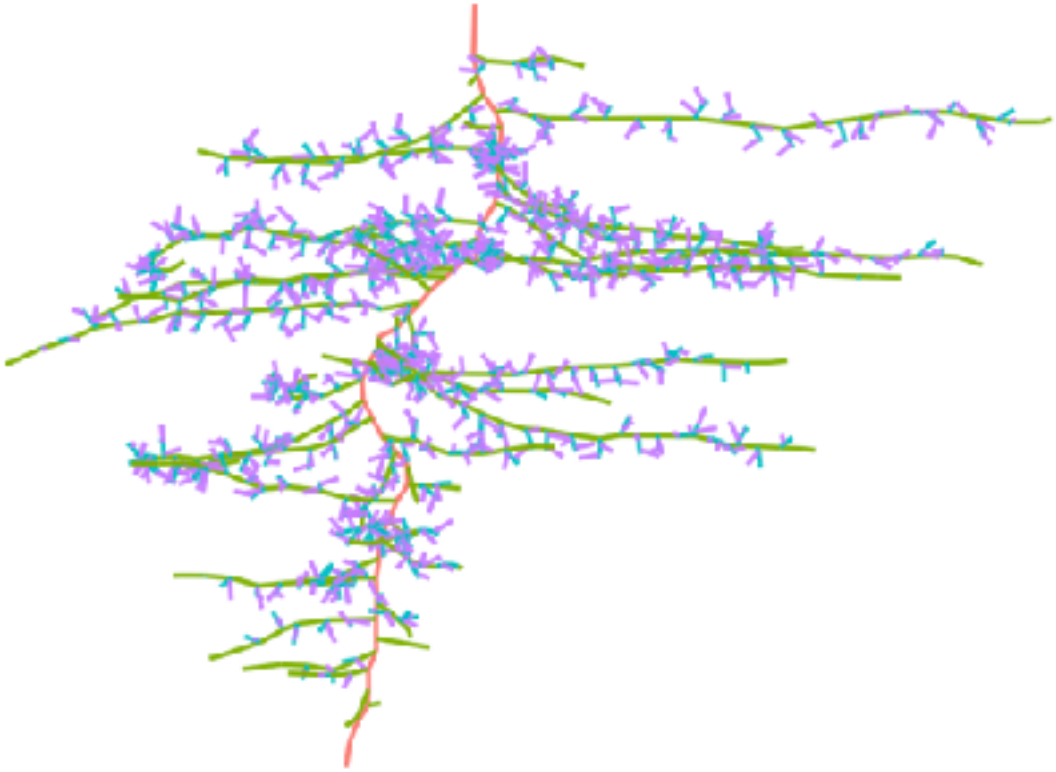
Length

Orientations

…







# SAME TOTAL ROOT LENGTH….

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MANY WAYS TO DESCRIBE ROOT SYSTEMS, OFTEN PARTIAL

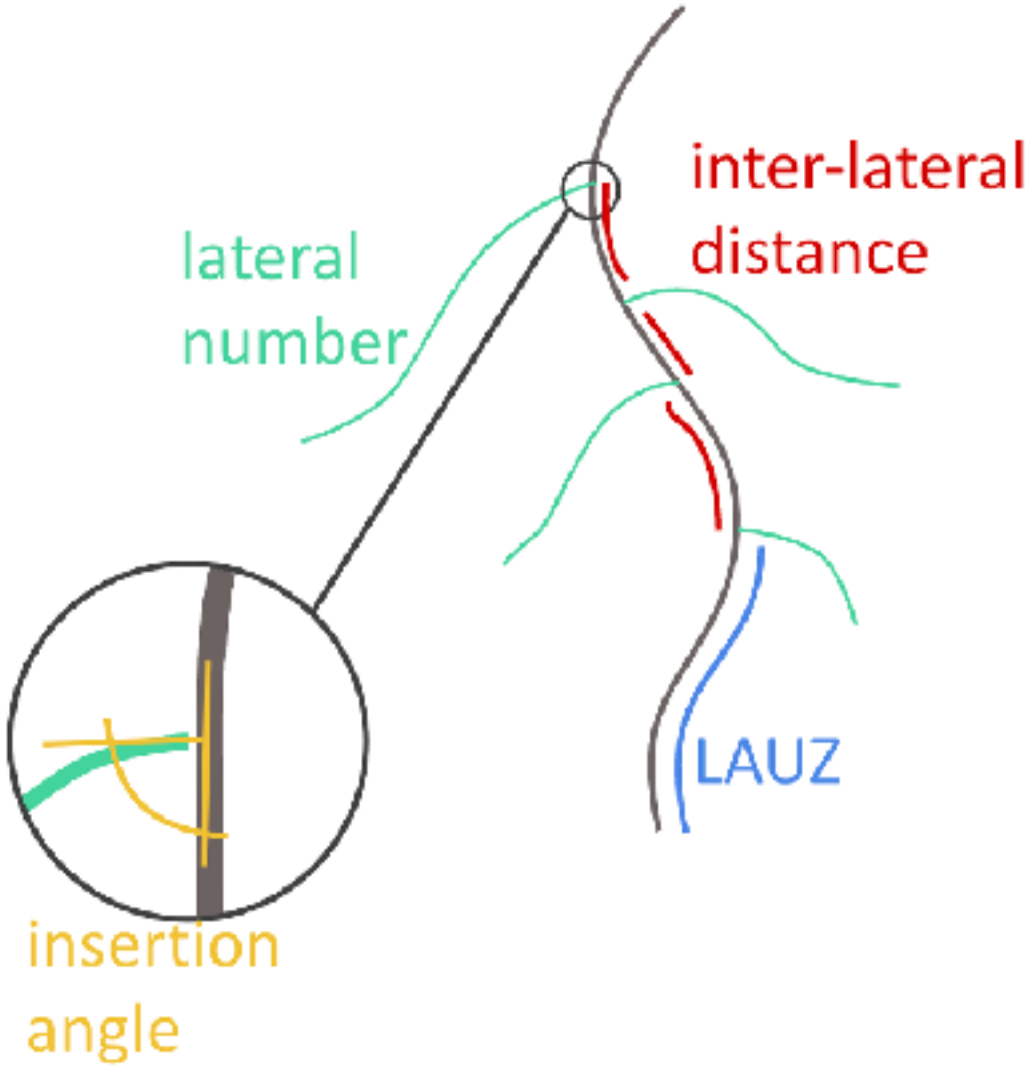
# Topological information

**What you need**

Explicit relation between different root orders

**What you get**

Lateral number
Inter-lateral distance
Insertion angle
Length of Unbranched Apical Zone (LAUZ)
...



MANY WAYS TO DESCRIBE ROOT SYSTEMS, OFTEN PARTIAL

# Topological information

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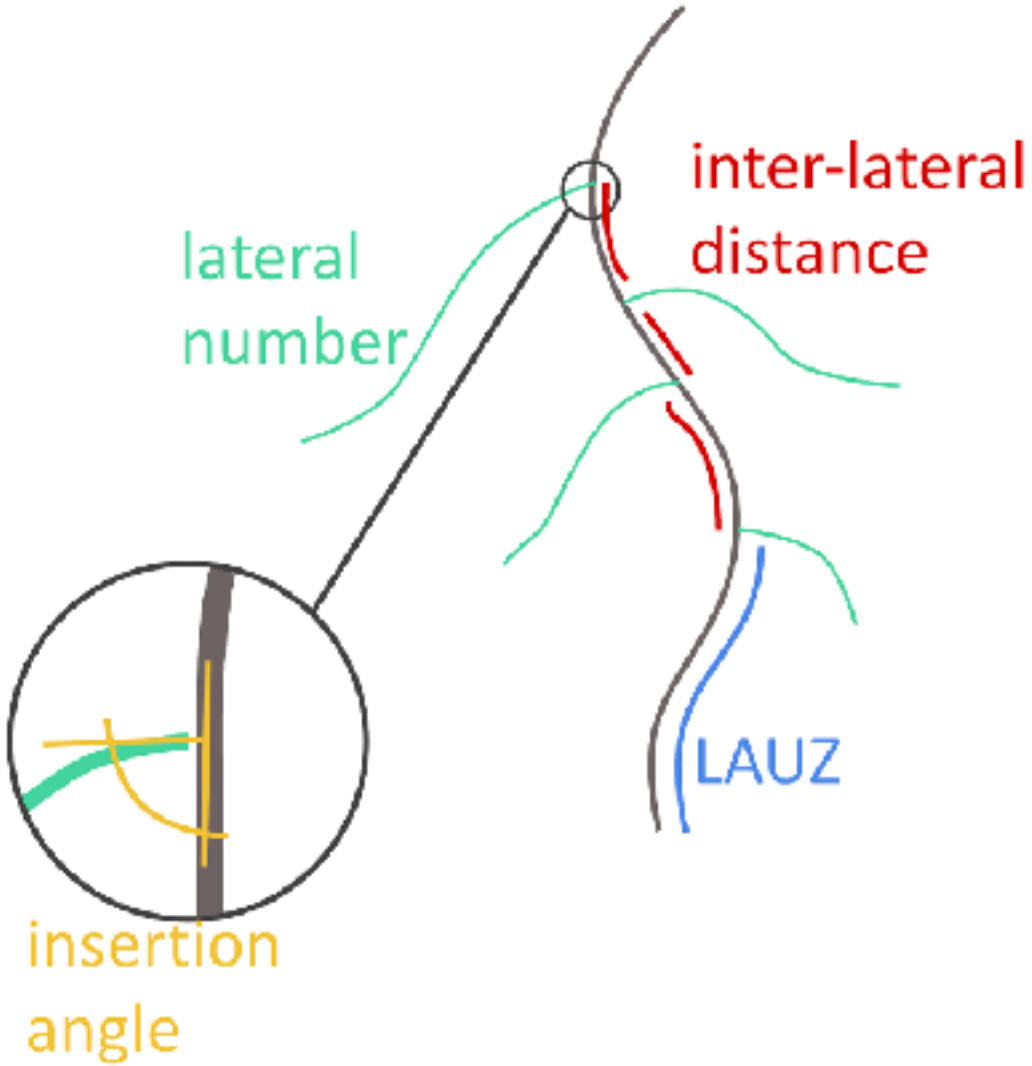


MANY WAYS TO DESCRIBE ROOT SYSTEMS, OFTEN PARTIAL

# Dynamic information

**What you need**

Time series images

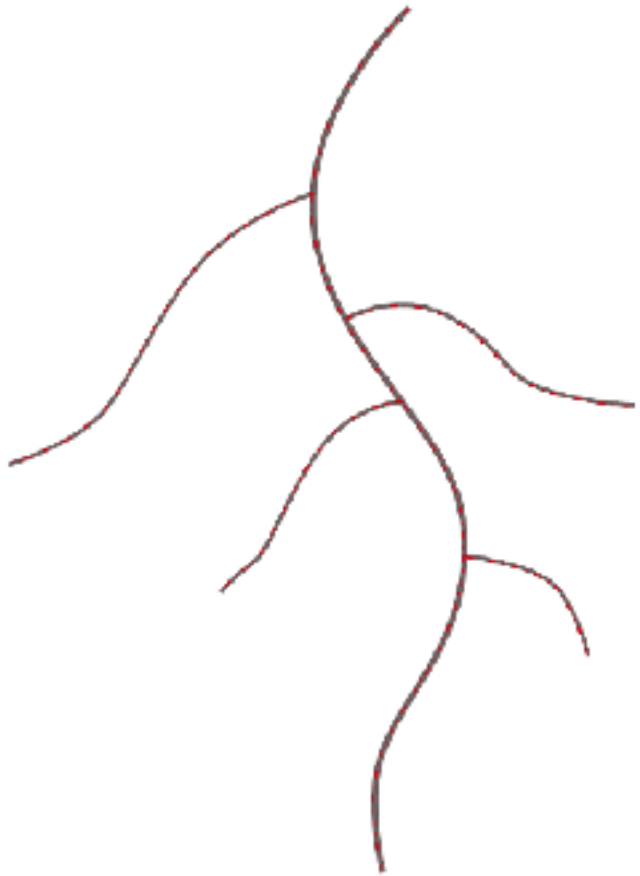
Follow the roots individually

**What you get**

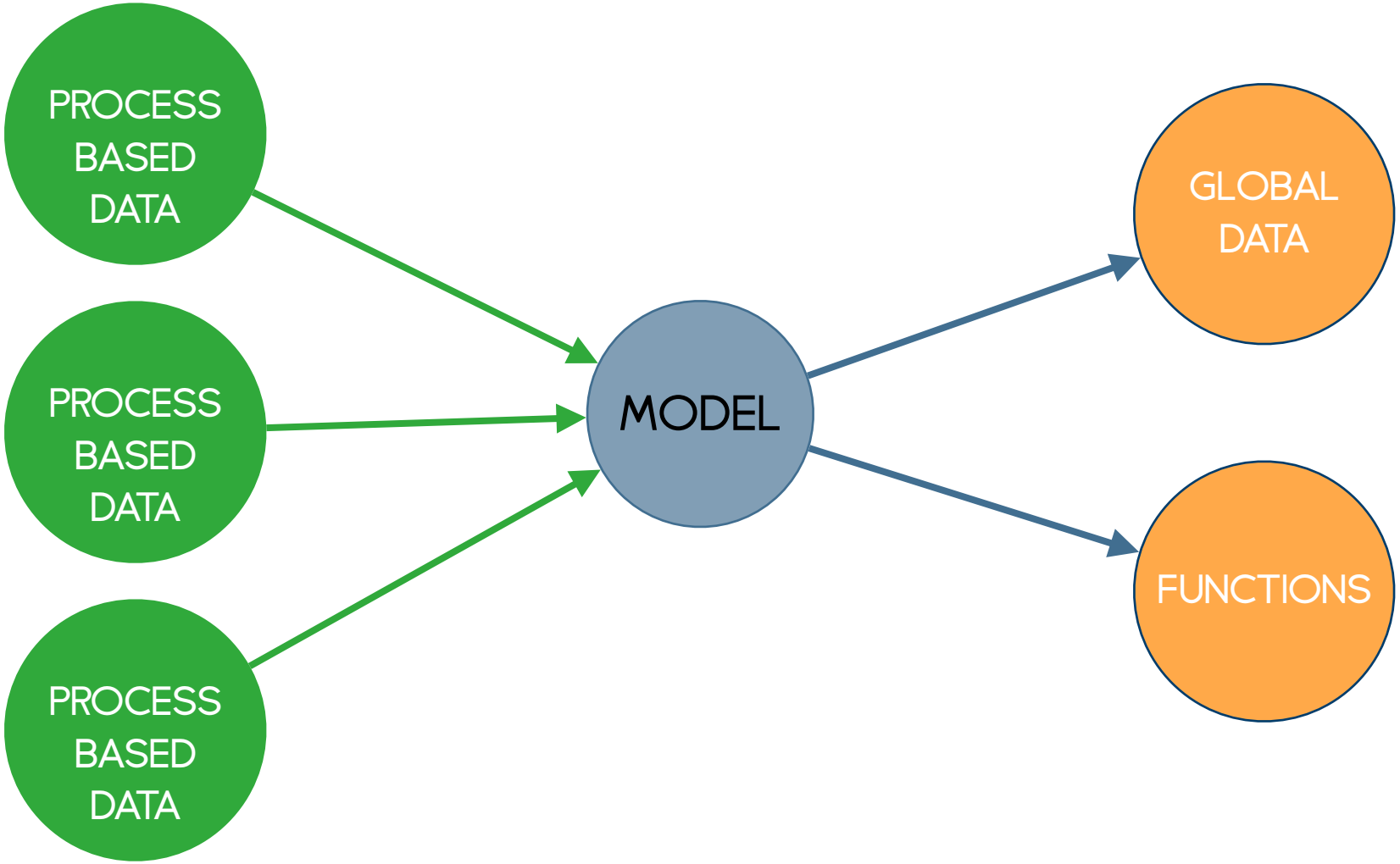
Growth rates

Root emergence rates

…



# USE MODELS TO EXTEND YOUR DATASET

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# 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**

Anagallis femina

**The algorithmic beauty of plant roots: an L-System model for dynamic root growth simulation**

Leitner D, Klepsch S, Knieps A, Schnepf A
Mathematical and Computer Modelling of Dynamical Systems, 16, 575-587, 2010
View paper

## 2. Update parameters

**2. Select root type**

primaryroot

**Select parameter to change**

Length of basal zone [cm]

**Parameter mean:**

0 1 2

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2

**Parameter deviation [%]:**

0 50

35 40 45 50

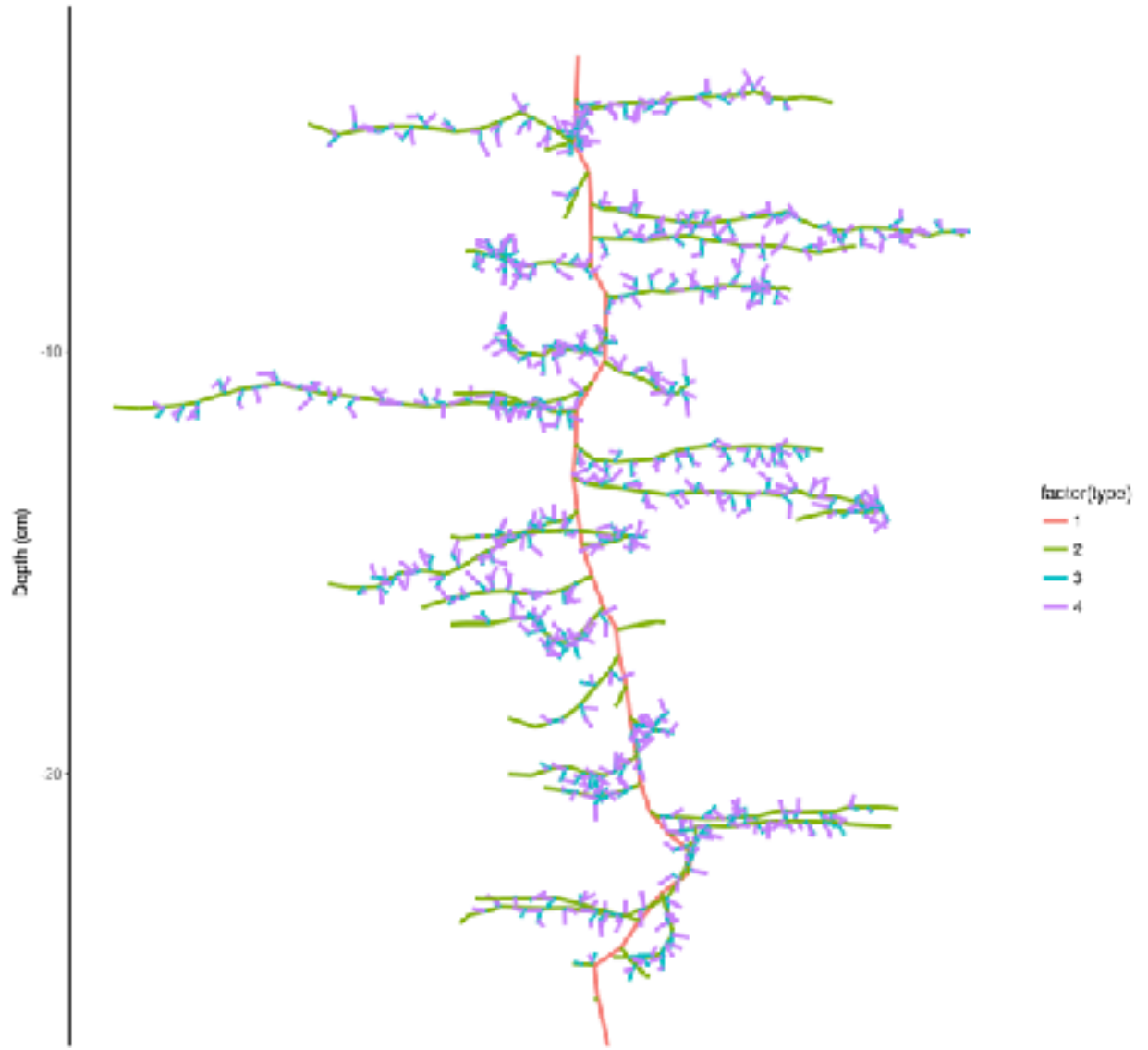
l zone of the

change

8

4.2 4.8 5.4 6

Root system representation | Root length profile | About CRootBox




– CROOTBOX –

Open Source

bit.ly/crootbox

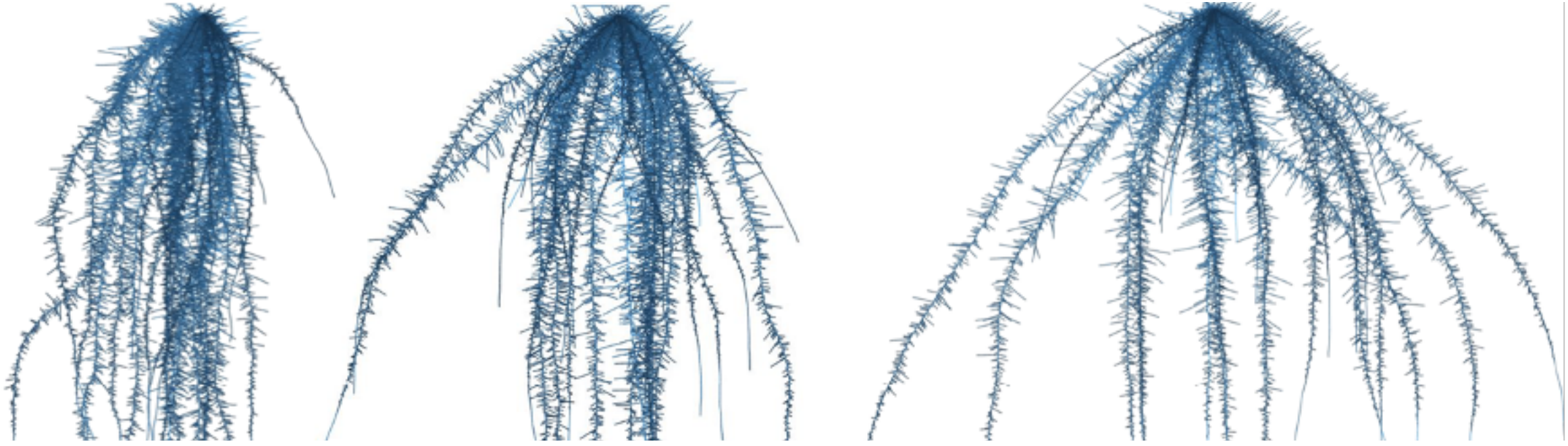
Schnepf et al, 2018
Annals of Botany

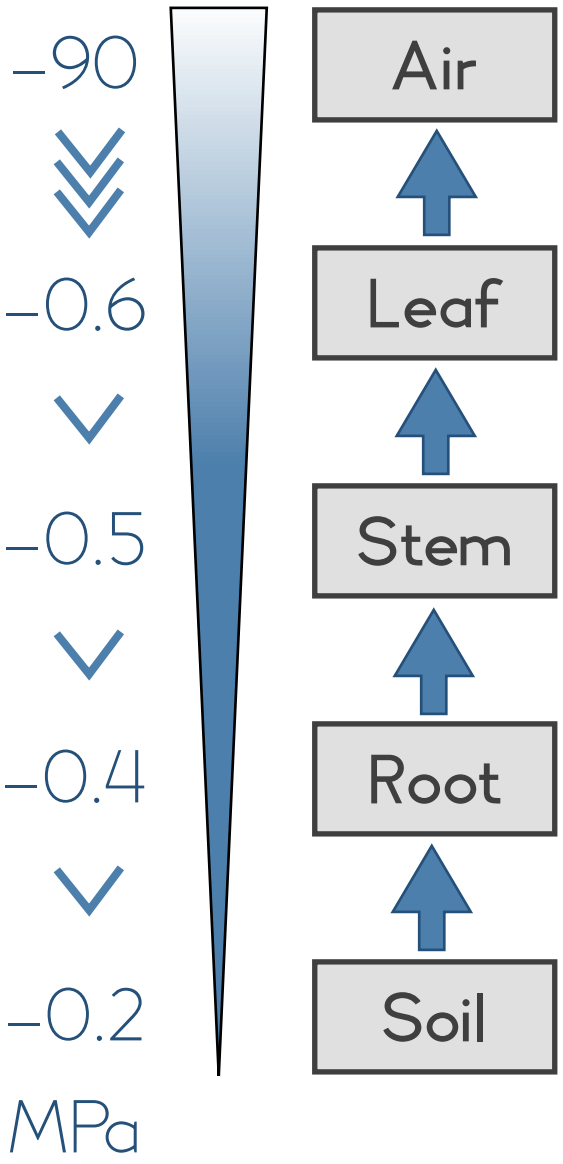
# WHAT IS THE EFFECT OF A CHANGE IN ROOT GROWTH RATE ?

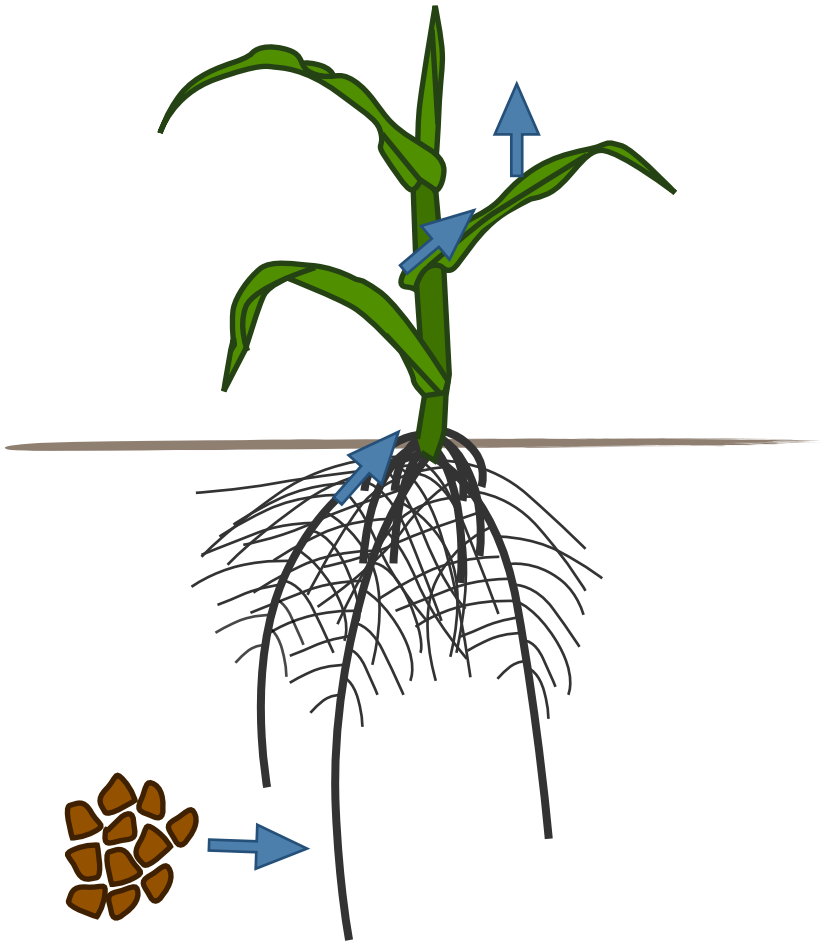
- FOR THE PRIMARY ROOT ?
- FOR THE 1ST ORDER LATERAL ROOTS ?
- IS IT THE SAME FOR DIFFERENT SPECIES ?

# 2. FROM STRUCTURES TO FUNCTIONS

## ARCHITECTURES





# WATER FLOW IN THE SOIL–PLANT–ATMOSPHERE IS A PASSIVE PROCESS

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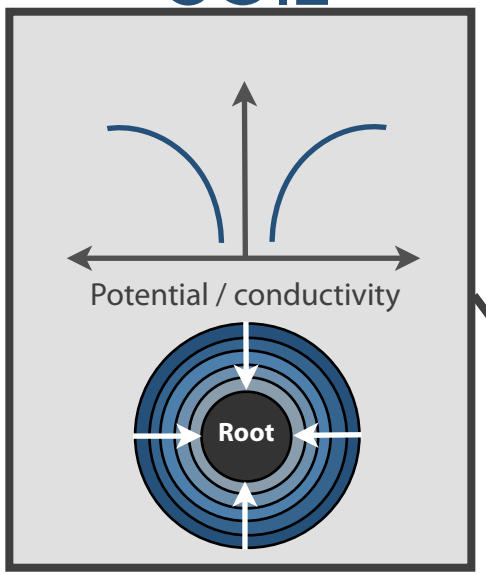
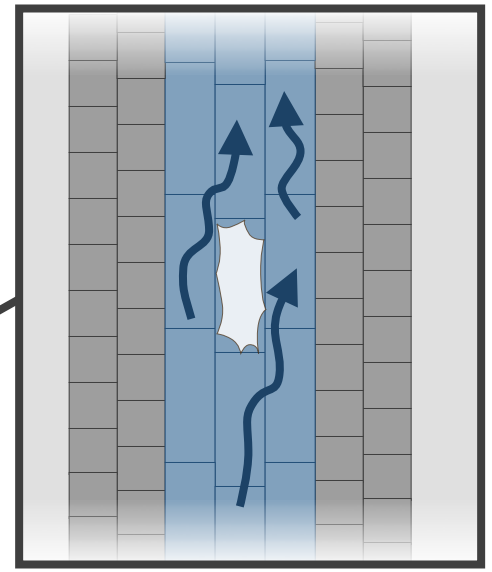
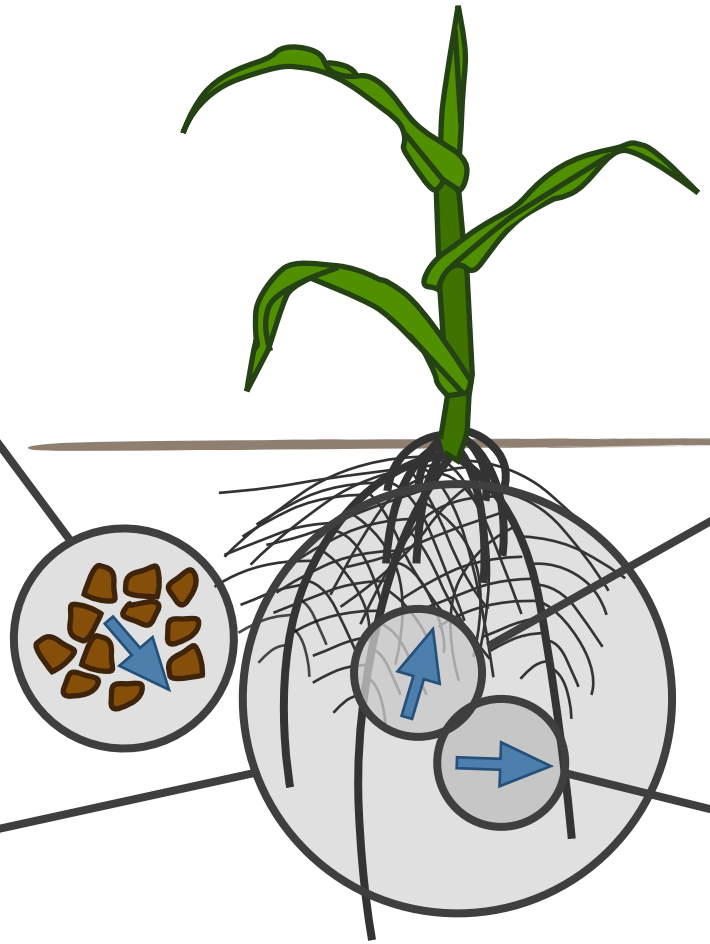
# CONDUCTIVITIES CAN BE REGULATED

## SOIL

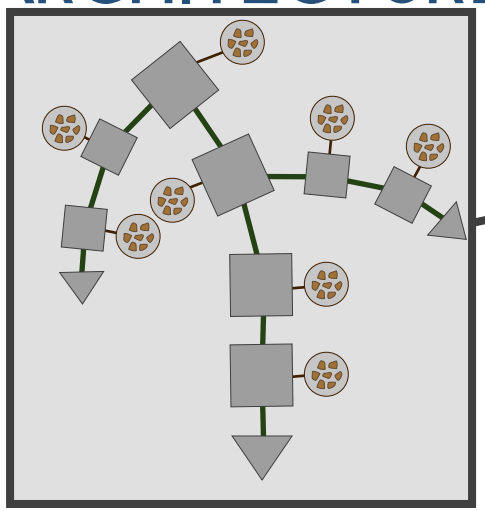



## AXIAL CONDUCTIVITY

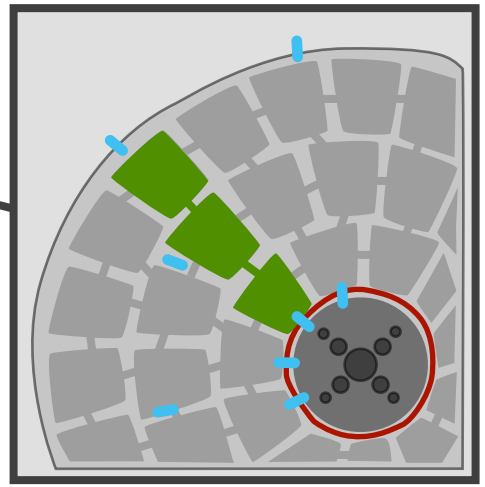




## ARCHITECTURE



## RADIAL CONDUCTIVITY



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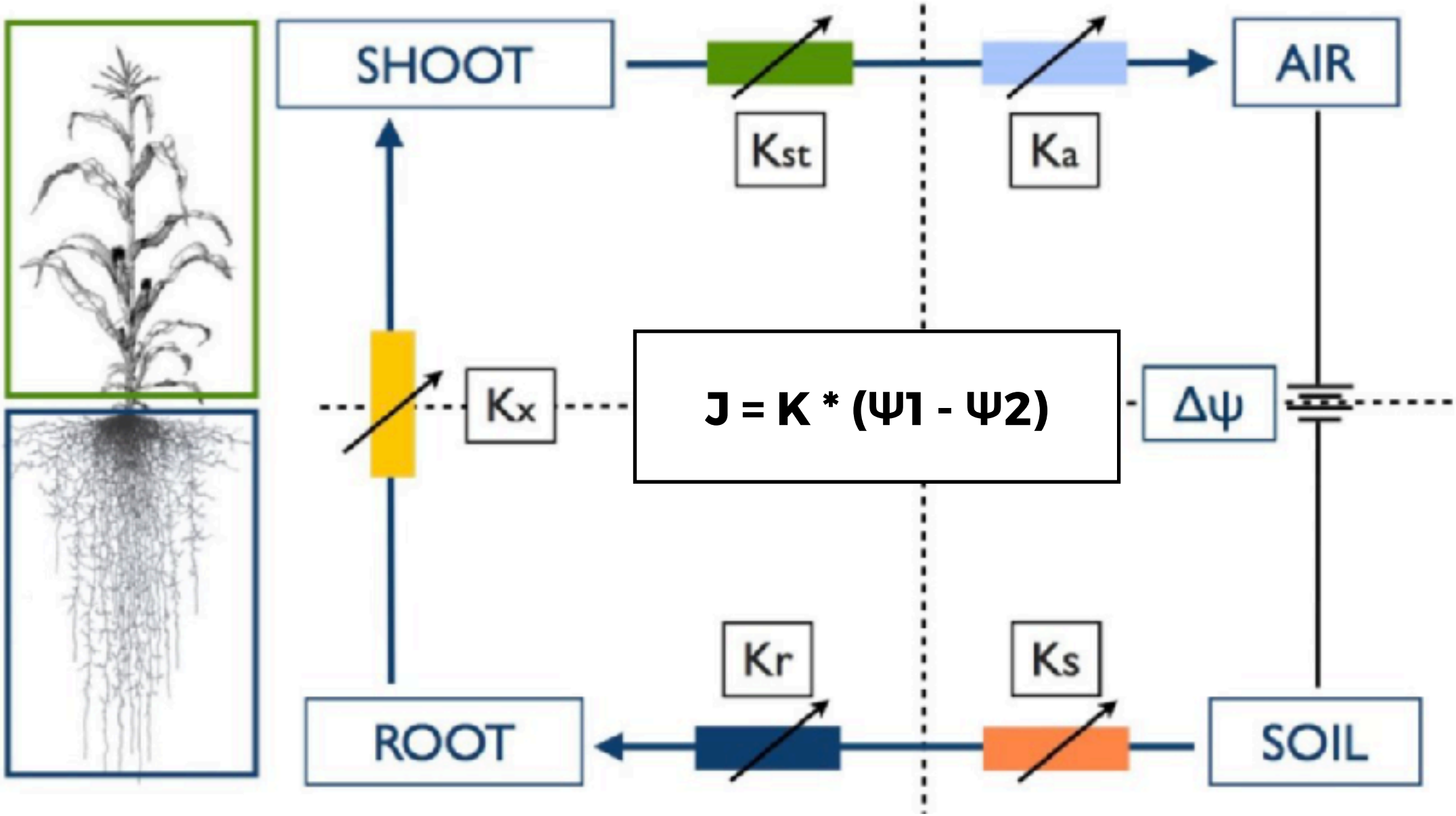
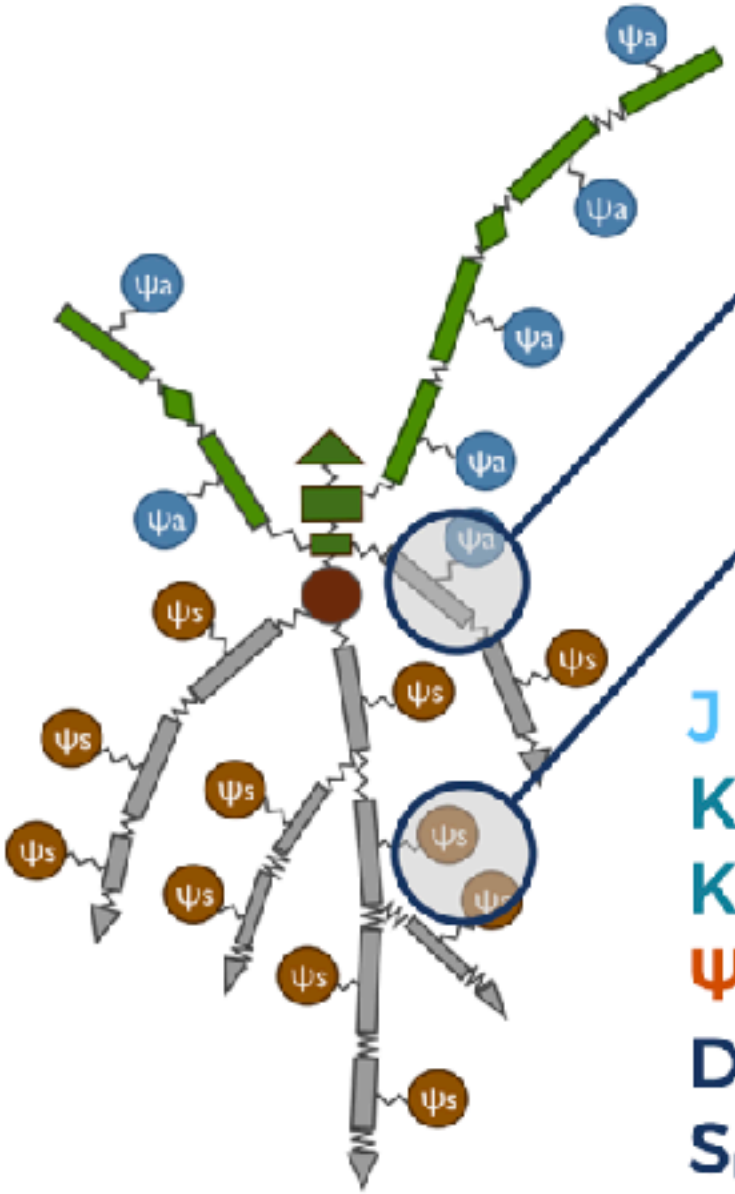
# ELECTRICAL ANALOGY FOR WATER FLOW



# ELECTRICAL ANALOGY FOR WATER FLOW




**Axial flux**

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

**Radial flux**

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

**ROOT SYSTEM CONDUCTIVITY** [Krs]

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

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

**$K_x$ = radial conductivity** [$m.s^{-1}.MPa^{-1}$]

**Ψ = water potential** [MPa]

**$D_{r2\text{-}r1}$ = distance between nodes** [m]

**$S_{r1}$ = surface** [$m^2$]

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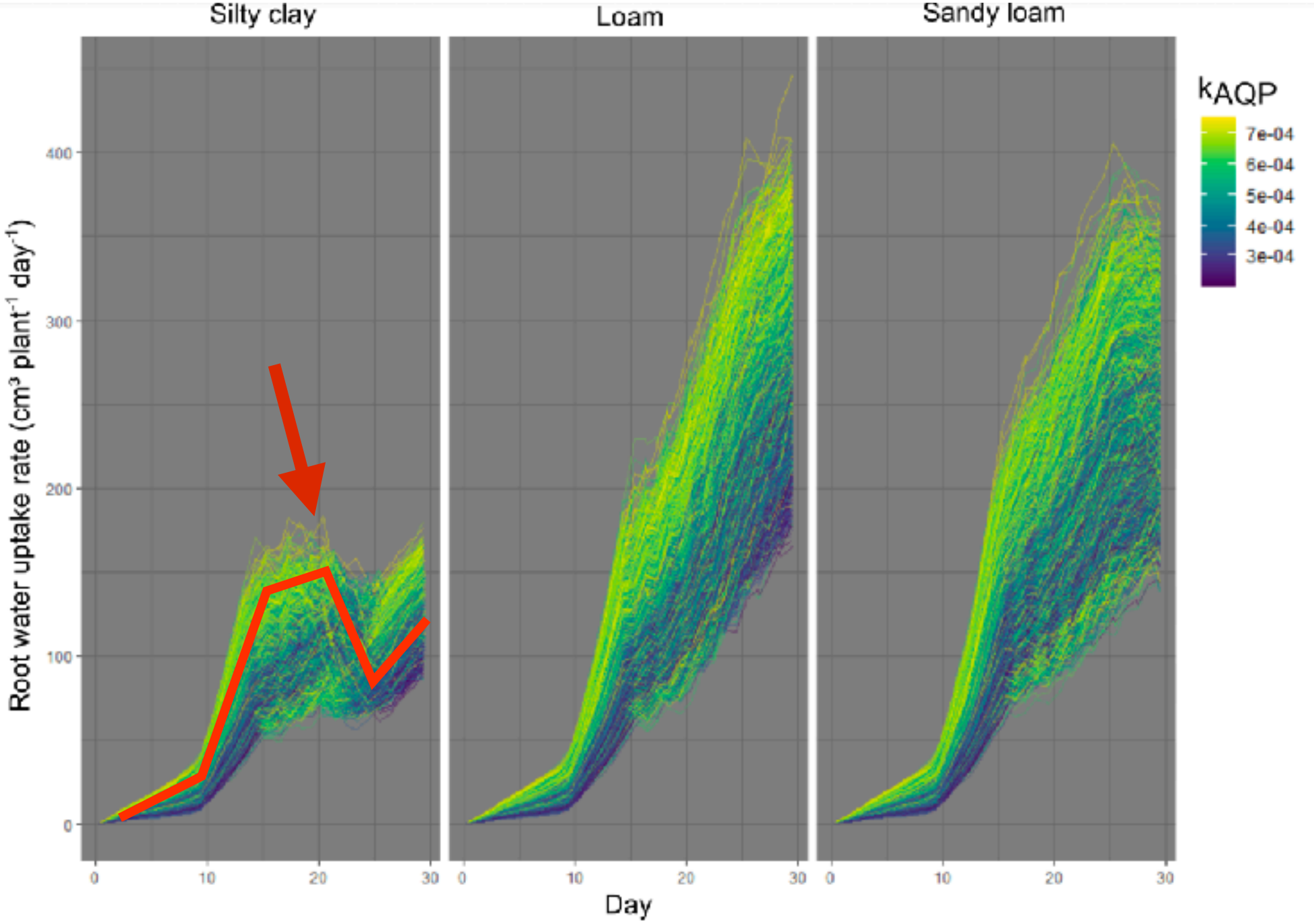
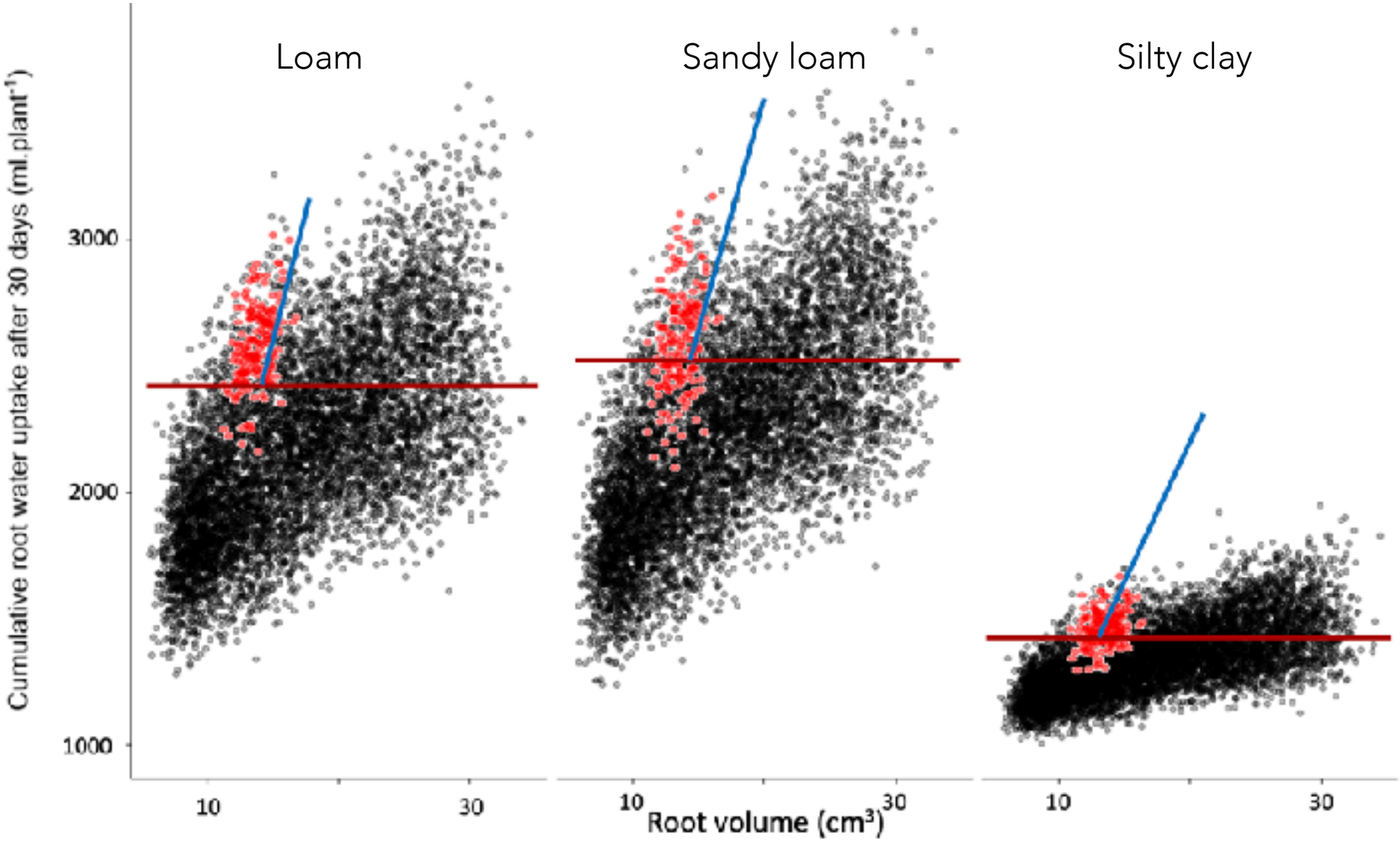
1

# SOIL SPECIFIC **DYNAMICS**



# ROOT TRAIT COMBINAISON TO **MAXIMISE WATER UPTAKE EFFICIENCY IN SPECIFIC ENVIRONMENT**

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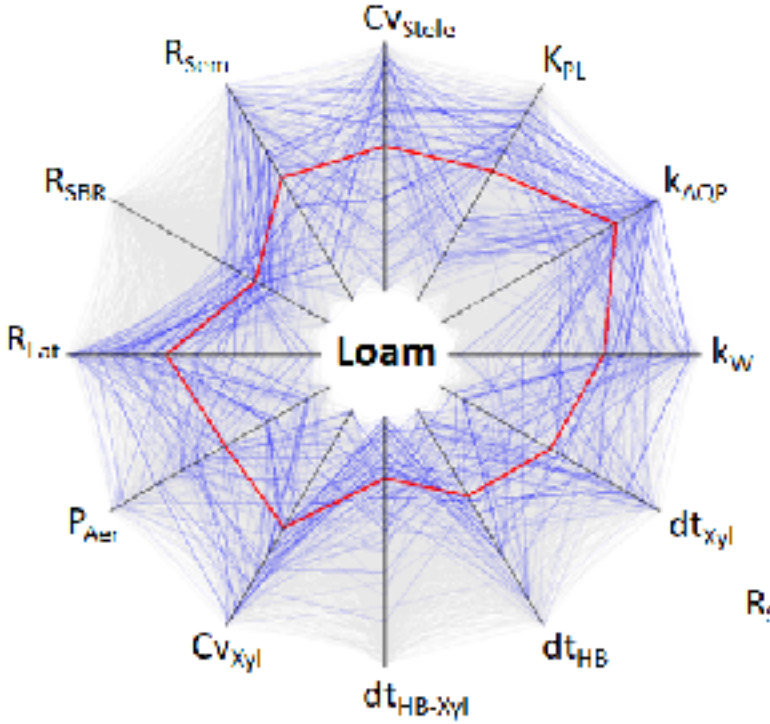
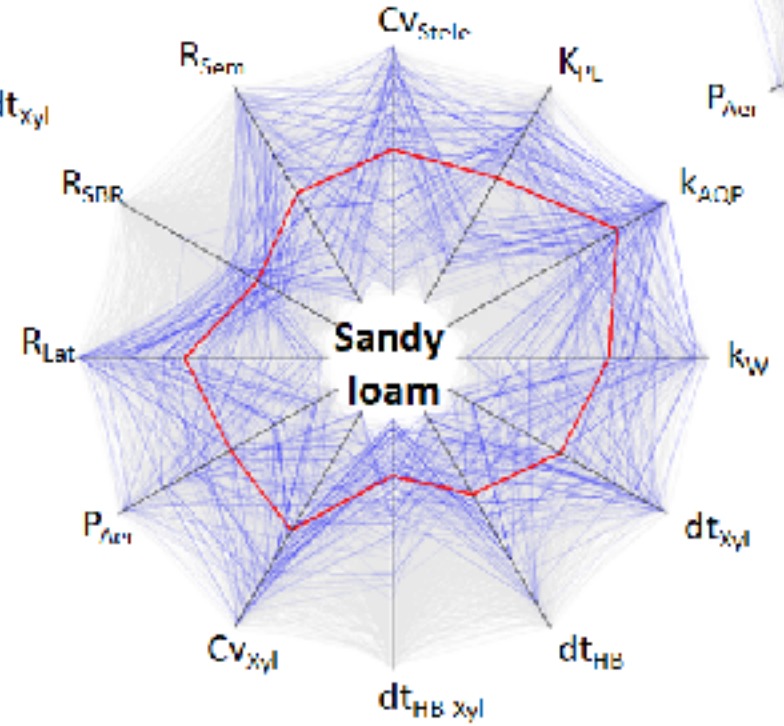
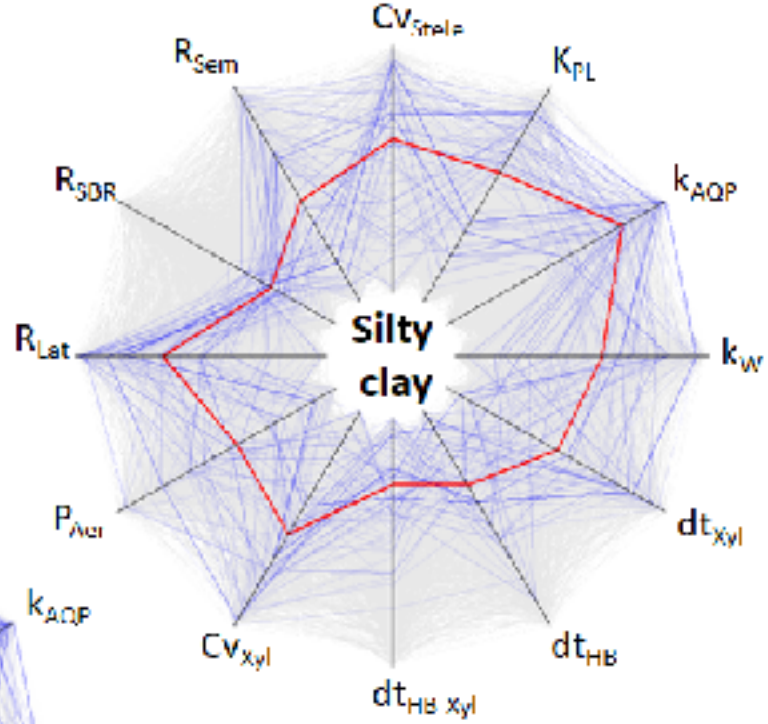
# ROOT TRAIT COMBINAISON TO **MAXIMISE WATER UPTAKE EFFICIENCY IN SPECIFIC ENVIRONMENT**

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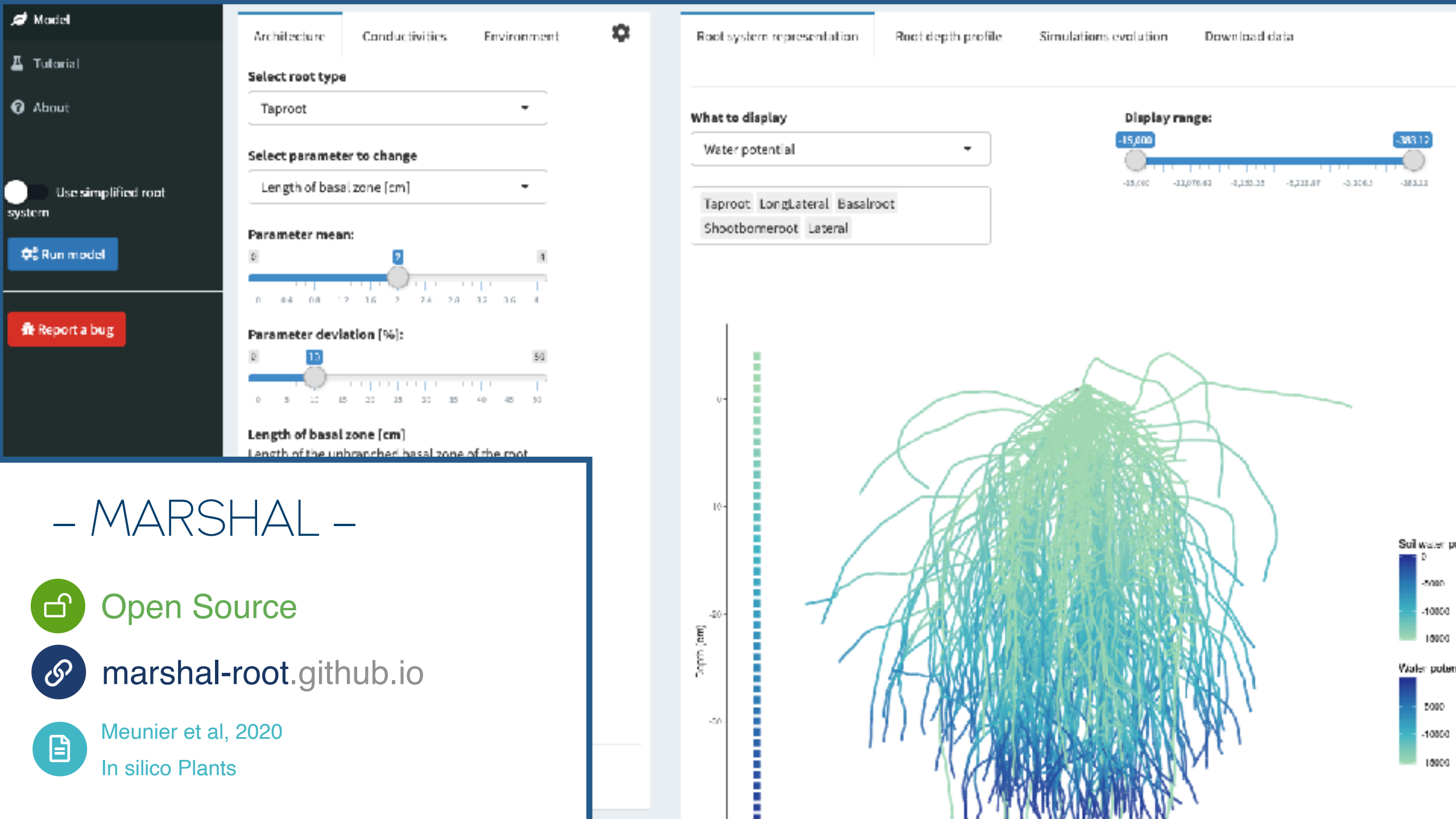
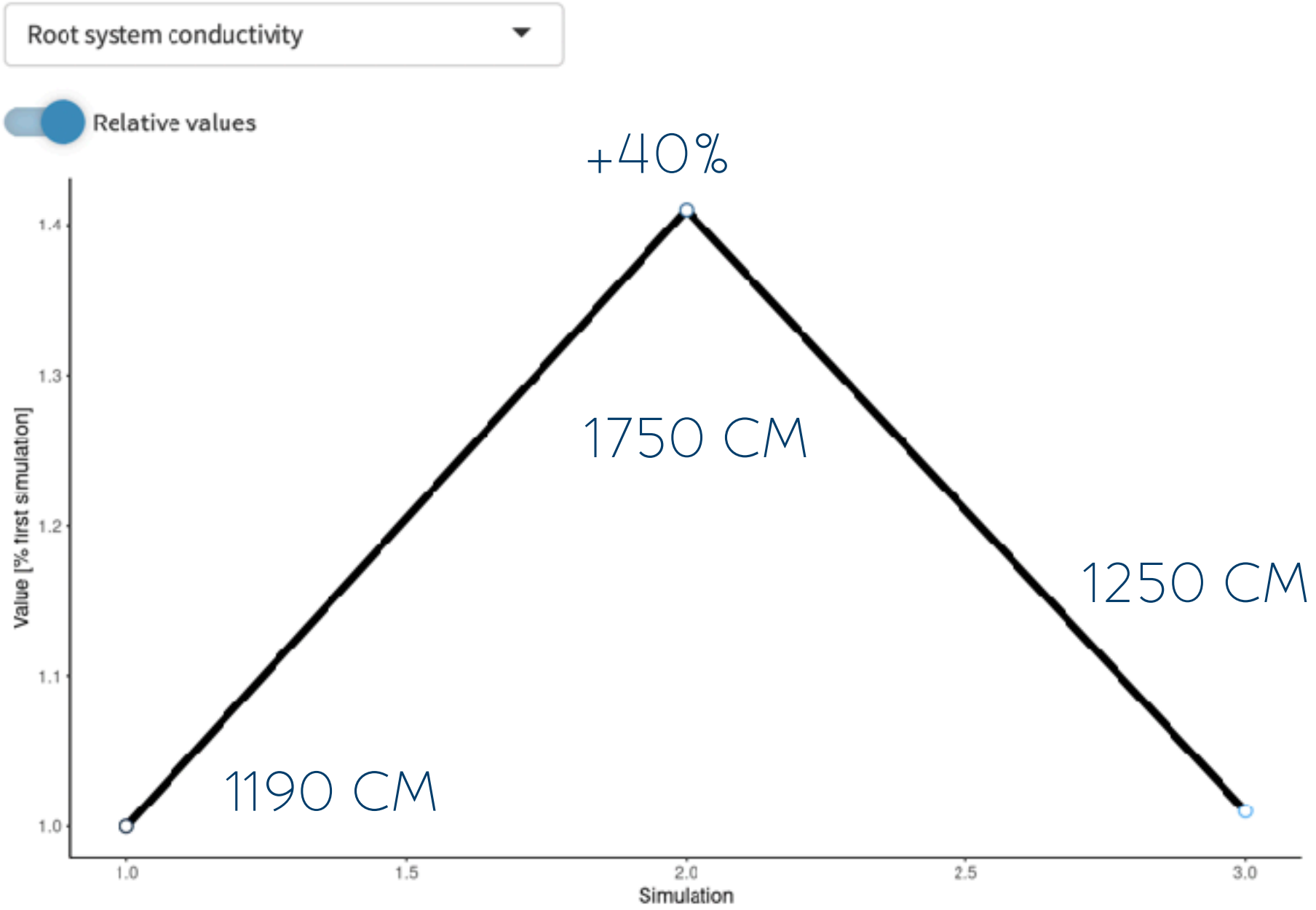

Model
Tutorial
About
Use simplified root system
Run model
Report a bug
Architecture
Conductivities
Environment
Select root type
Taproot
Select parameter to change
Length of basal zone [cm]
Parameter mean:
Parameter deviation [%]:
Length of basal zone [cm]
Root system representation
Root depth profile
Simulations evaluation
Download data
What to display
Water potential
Display range:
Taproot
LongLateral
Basalroot
Shootborneroot
Lateral
– MARSHAL –
Open Source
marshal-root.github.io
Meunier et al, 2020
In silico Plants

# WHAT IS THE EFFECT OF A CHANGE IN LATERAL ROOT DENSITIES?

- FOR THE PRIMARY ROOT ?
- FOR THE 1ST ORDER LATERAL ROOTS ?

# COMPENSATORY CHANGES IN THE ROOT SYSTEMS

- INCREASE THE **PRIMARY ROOT GROWTH RATE BY 50%**
- OBSERVE THE EFFECT ON THE KRS
- INCREASE THE **PRIMARY ROOT INTER LATERAL DISTANCE BY 50%**
- OBSERVE THE EFFECT ON THE KRS




This plot show the value of Krs or Tact for the different simulation

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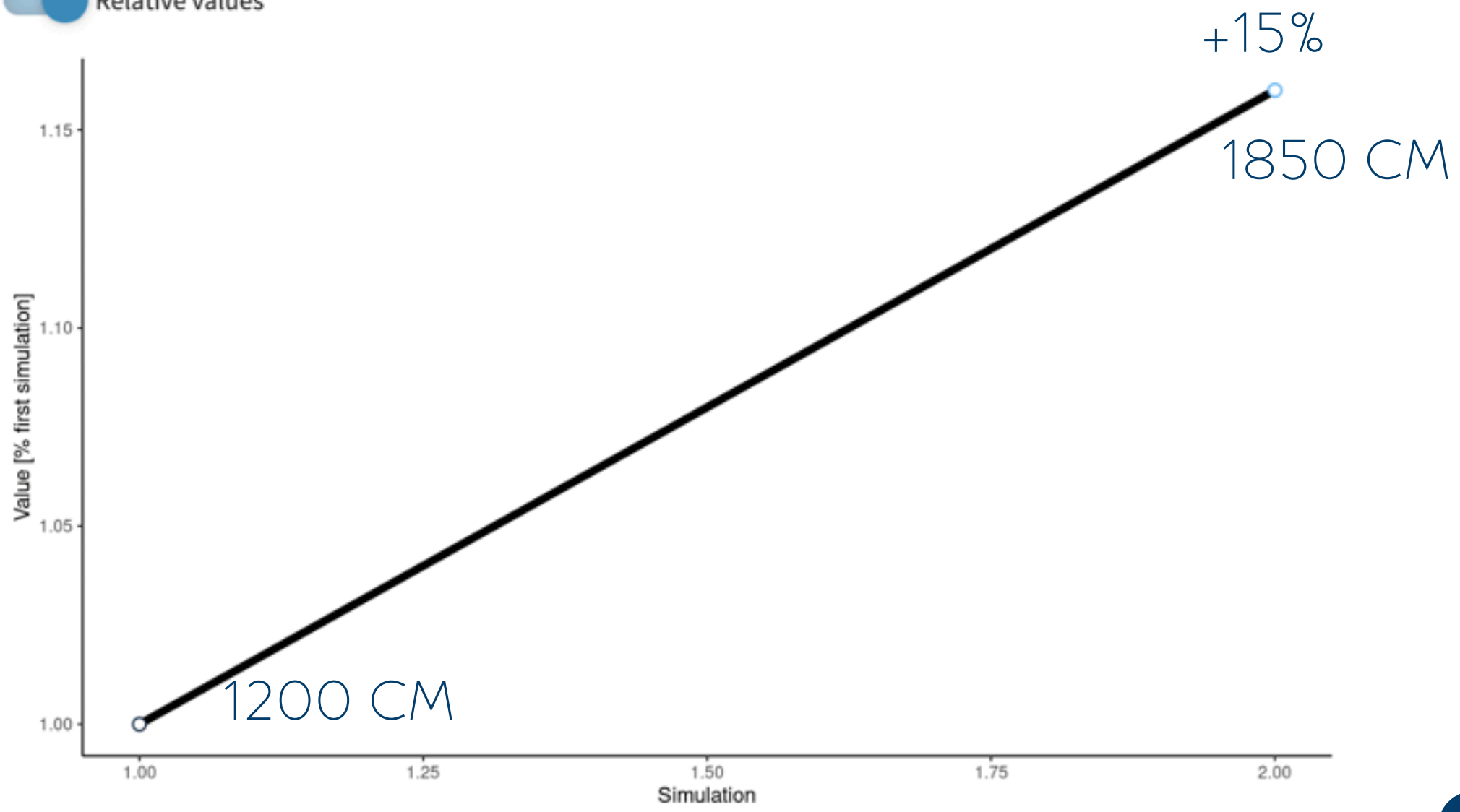
Forschungszentrum

# COMPENSATORY CHANGES IN THE ROOT SYSTEMS

- INCREASE THE **LATERAL ROOT MAX LENGTH BY 100%**
- OBSERVE THE EFFECT ON THE KRS

Root system conductivity

Relative values




This plot show the value of Krs or Tact for the different simulation

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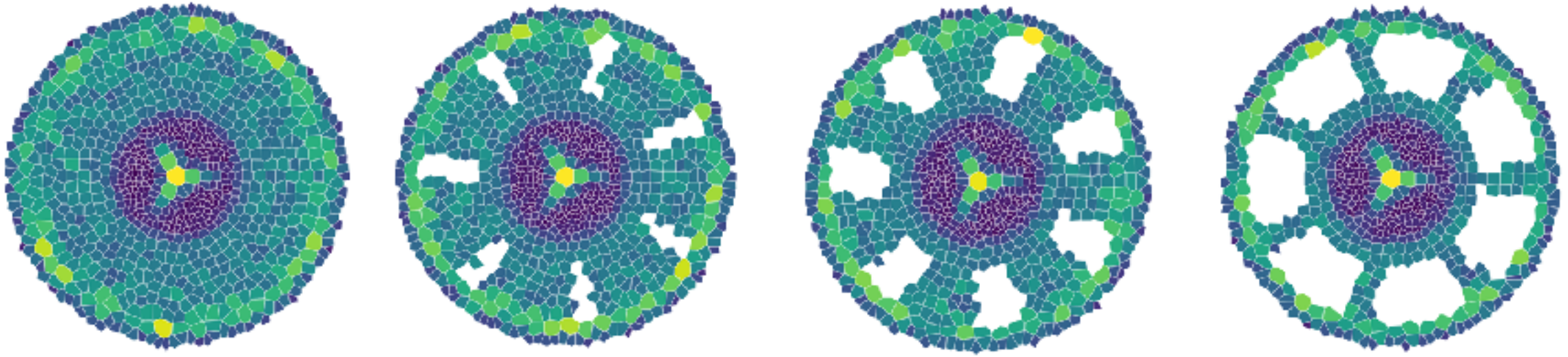
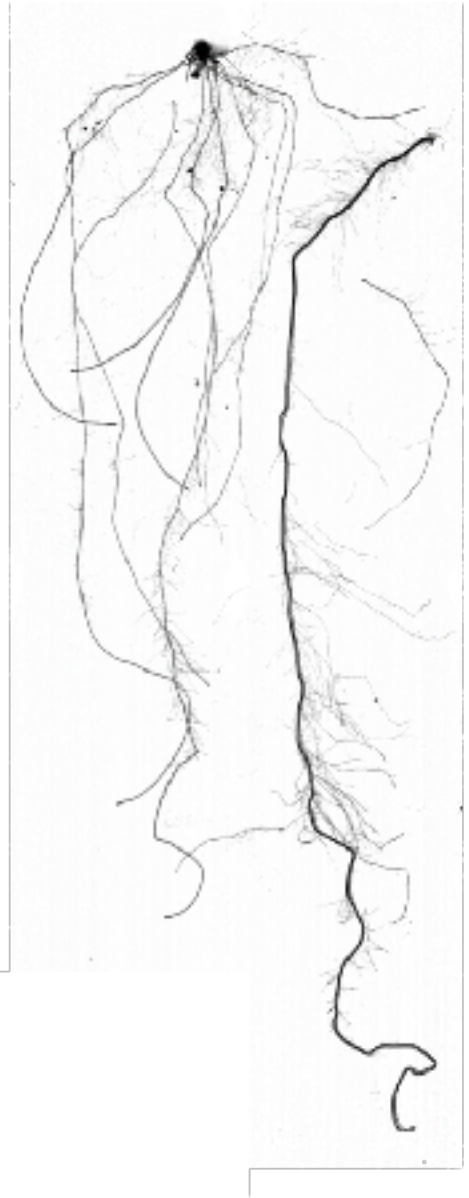
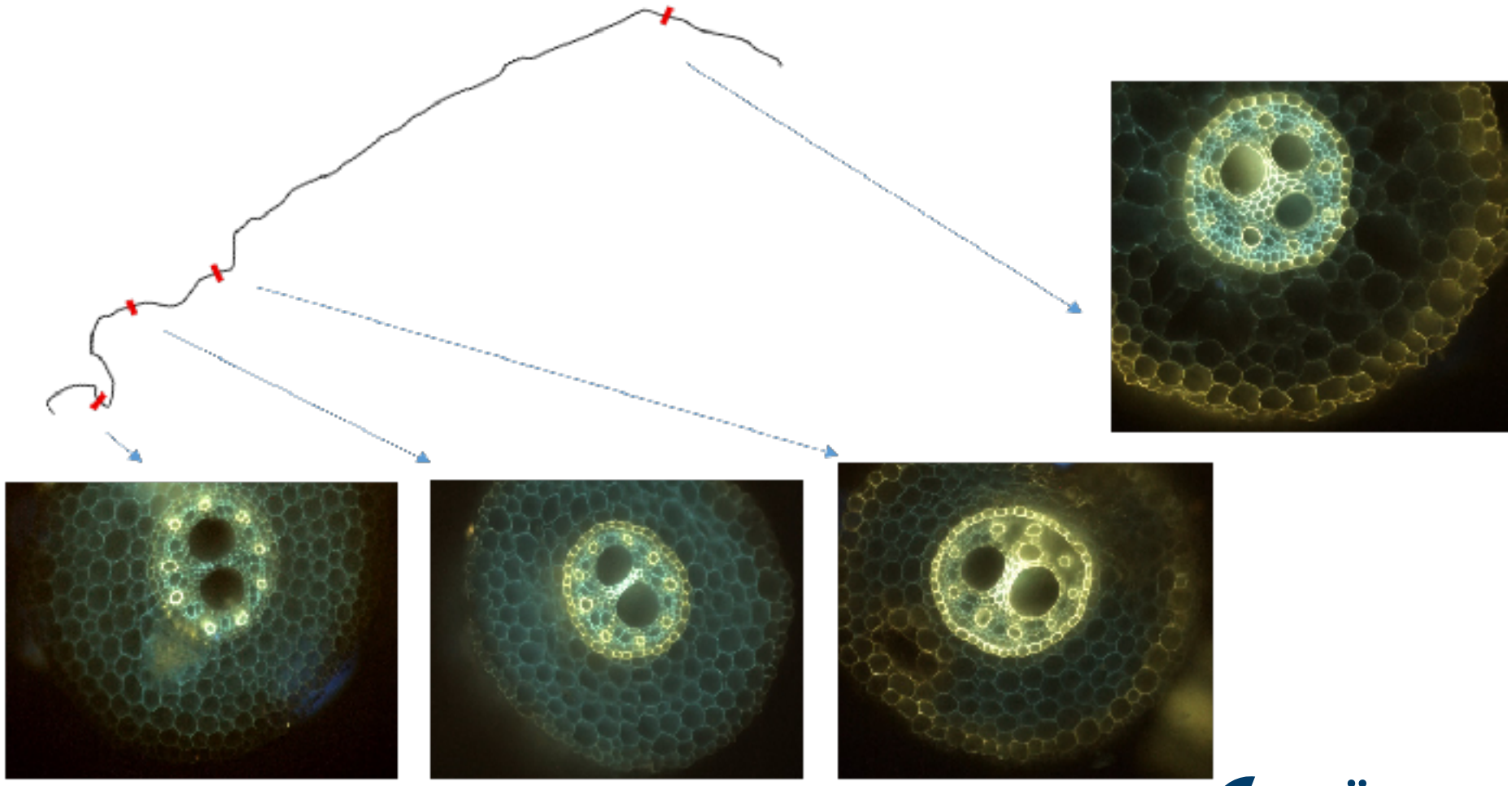
# FROM STRUCTURES TO FUNCTIONS

## 1 – ANATOMIES

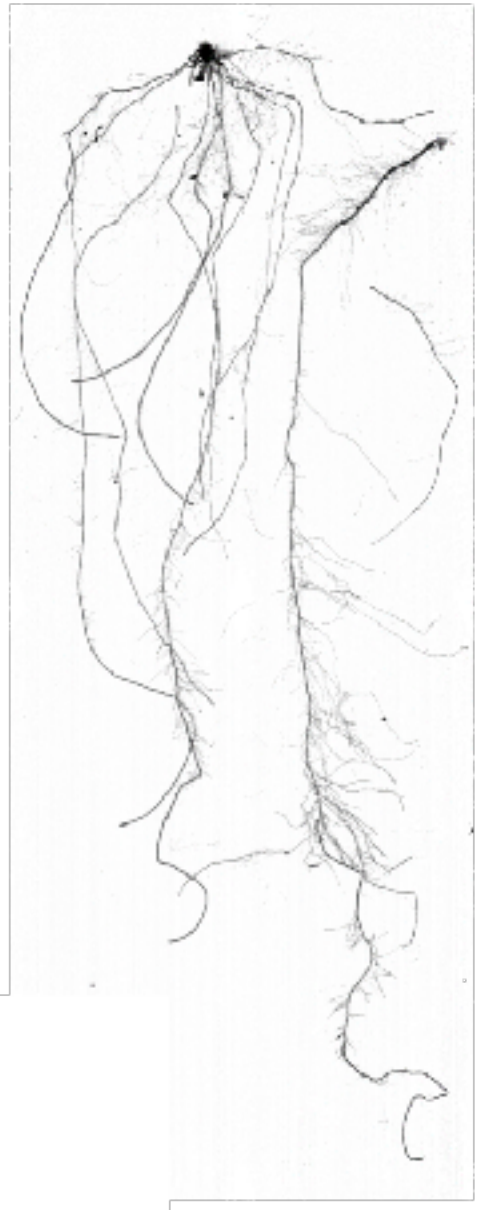


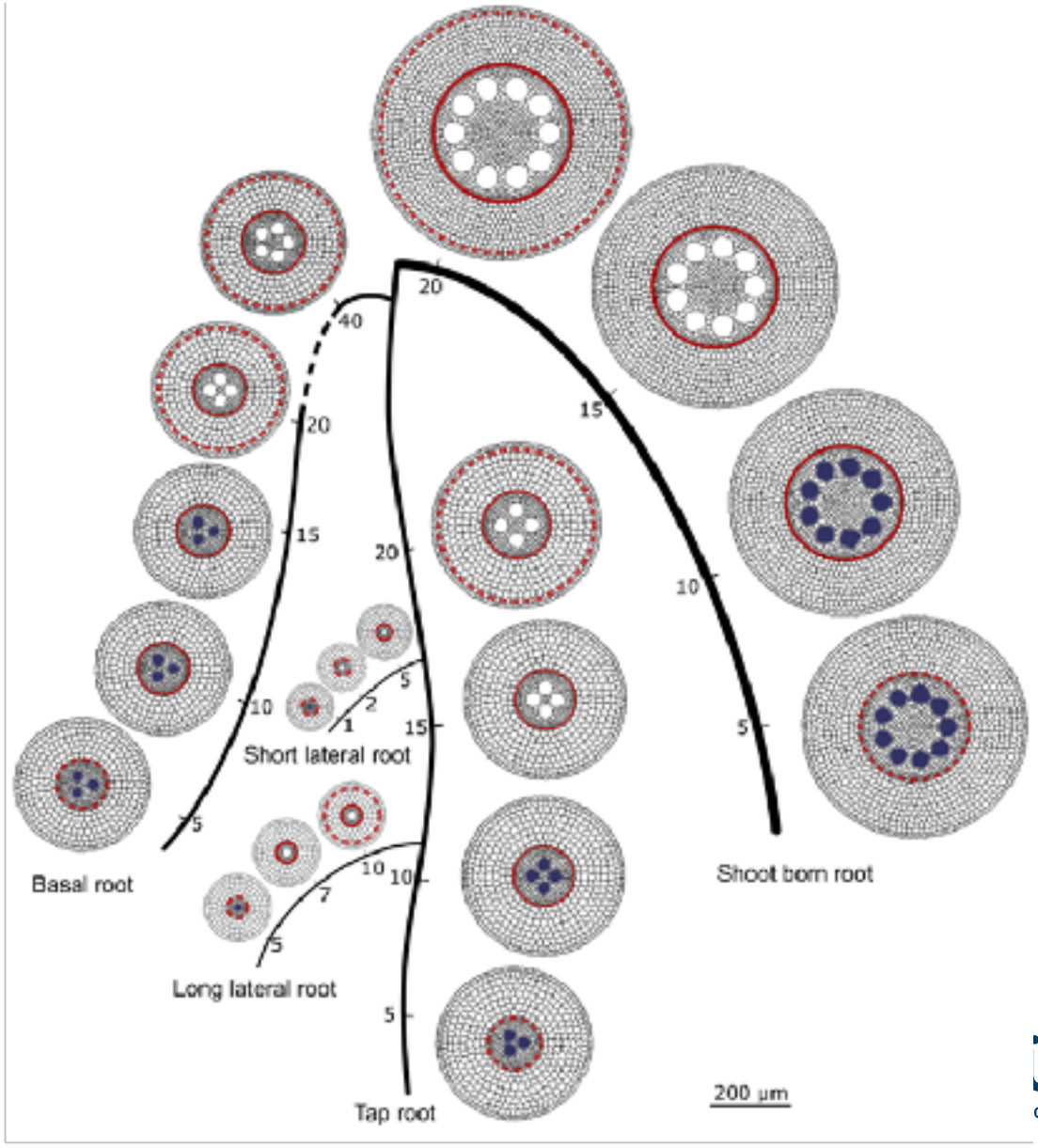
# FROM STRUCTURE TO FUNCTION : ROOT ANATOMY



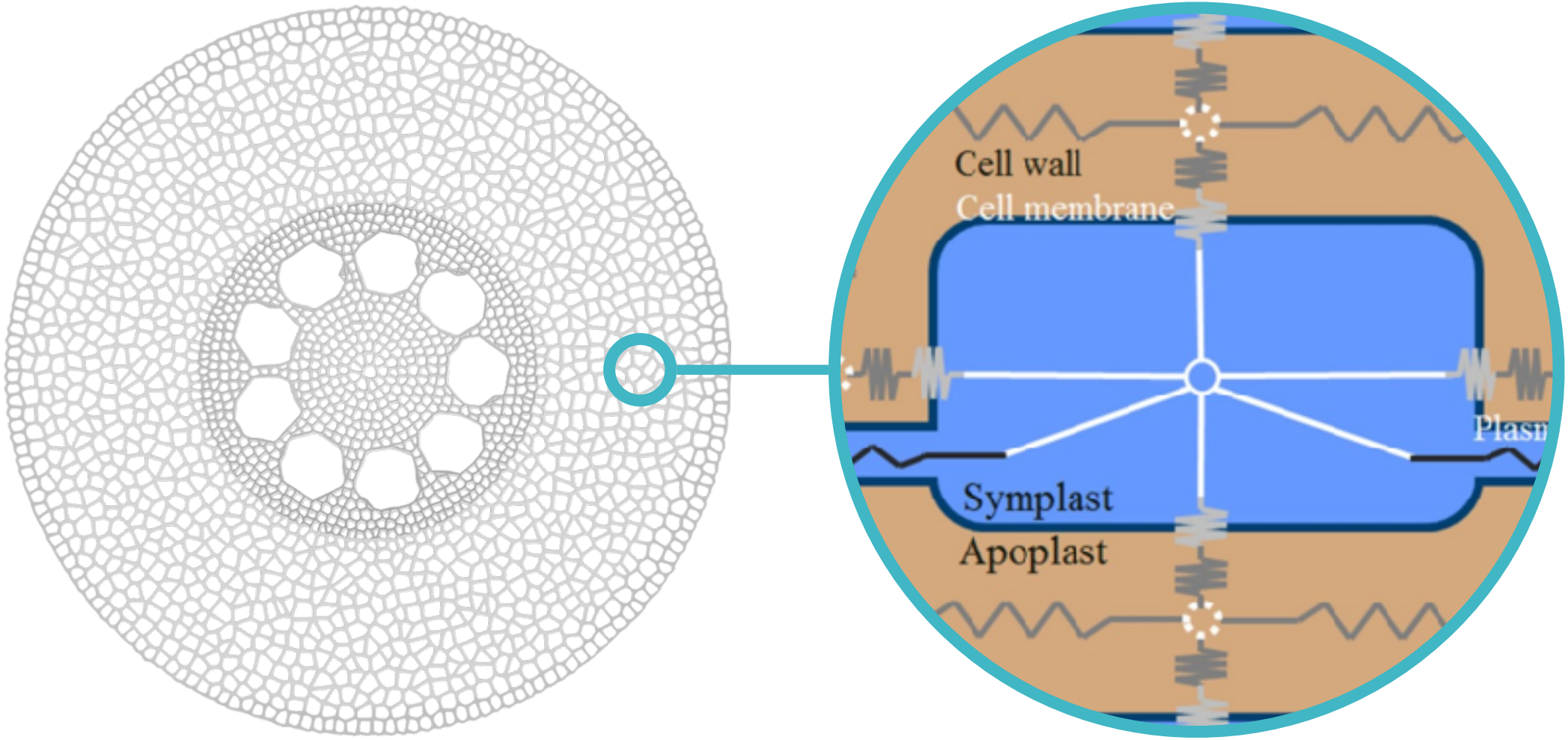


# MAIZE ROOT ANATOMICAL ATLAS





# MECHA + GRANAR TO EXPLORE THE LINK BETWEEN ANATOMY AND FUNCTION




Heymans et al, 2020

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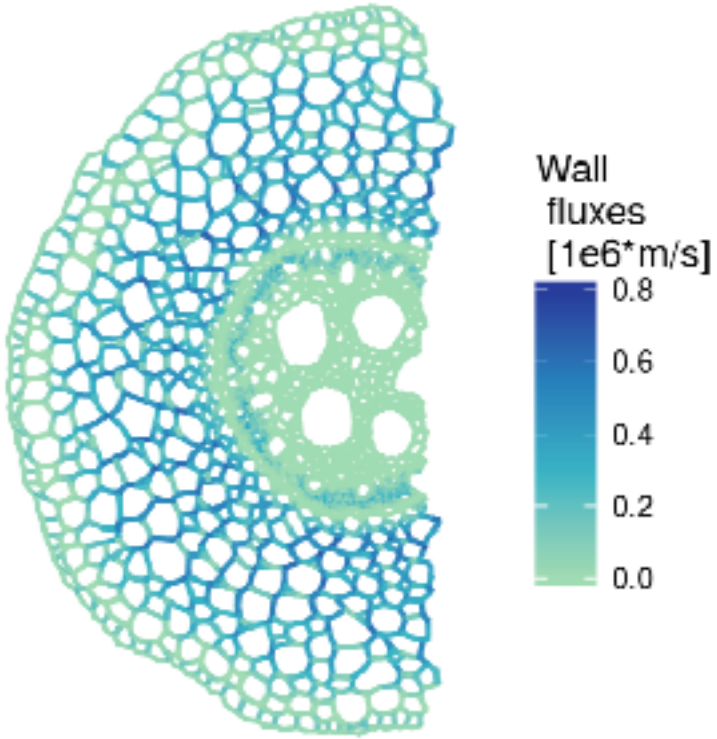
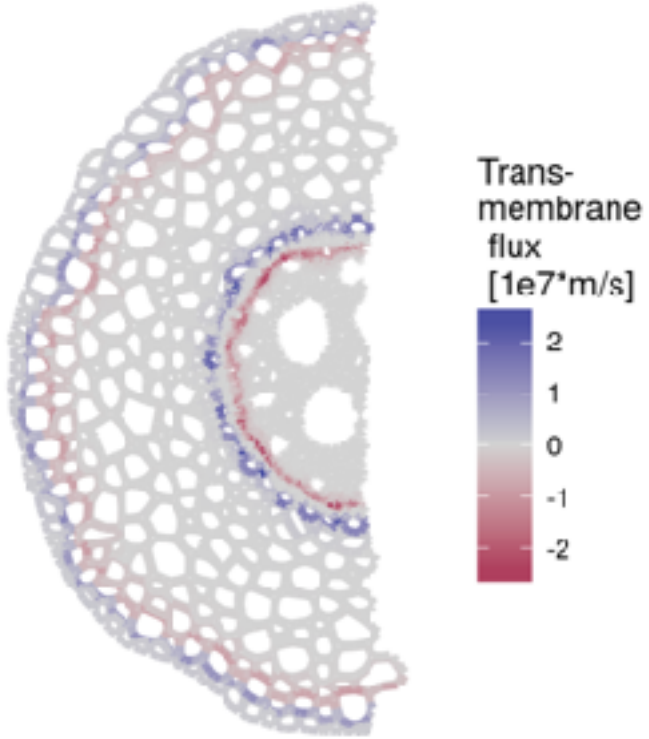
# MODELLING WATER FLOW AT THE ORGAN SCALE

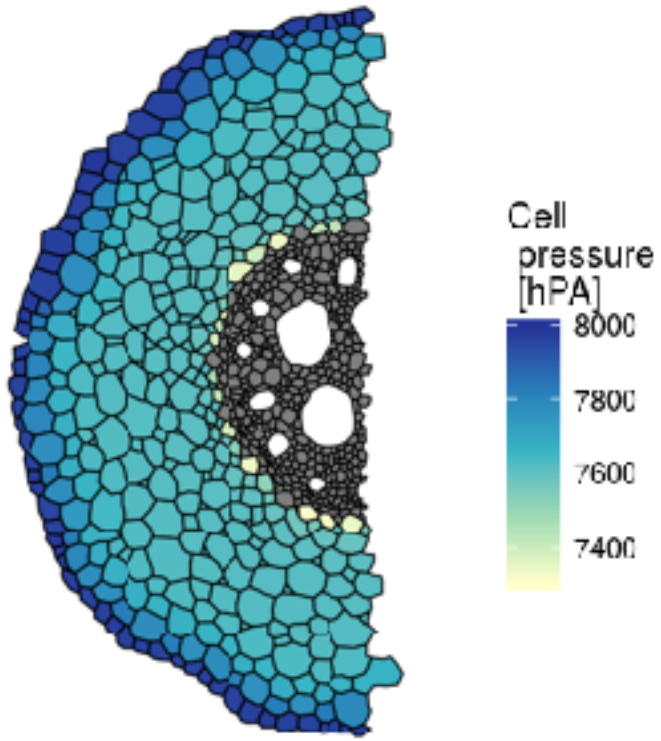
# – MECHA –




FLUXES IN
CELL WALLS




FLUXES IN
CELL MEMBRANES

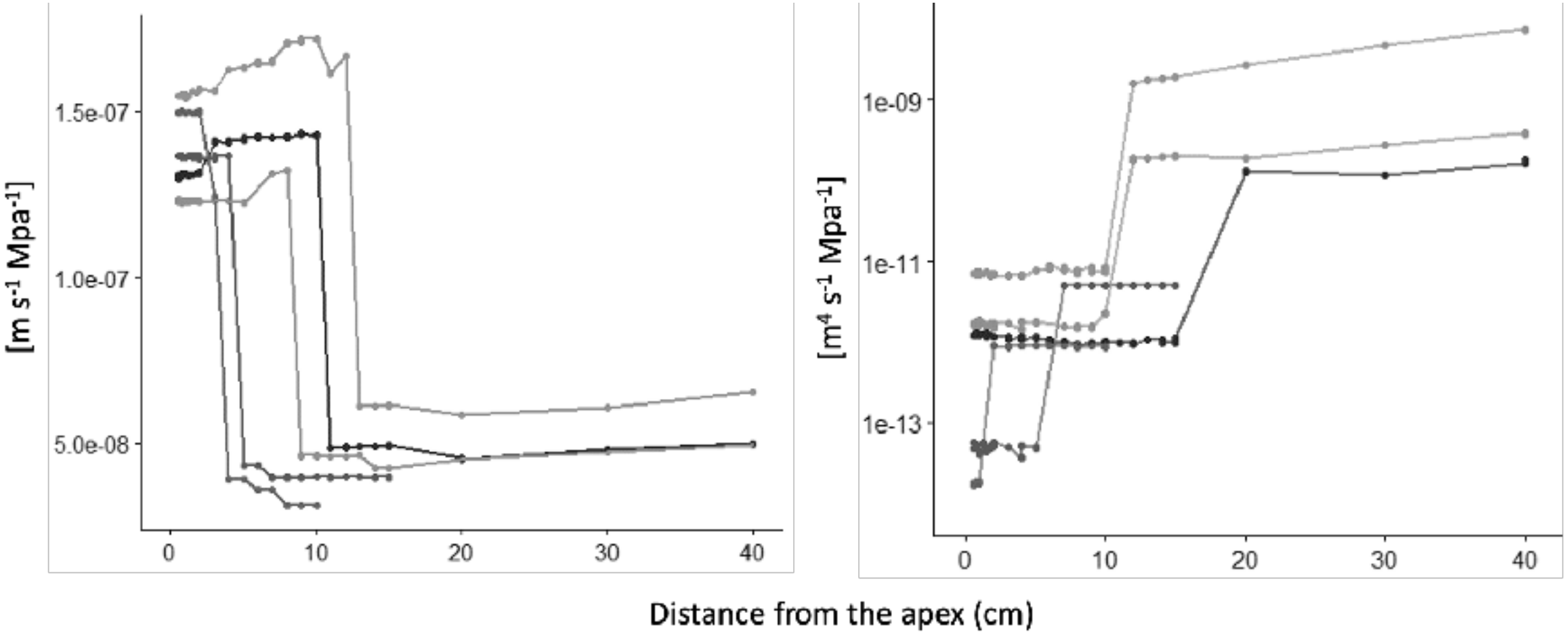



PRESSURES IN
CELLS

RADIAL CONDUCTIVITY

AXIAL CONDUCTIVITY

# ROOT HYDRAULIC PROPERTIES VARY WITH DEVELOPMENT

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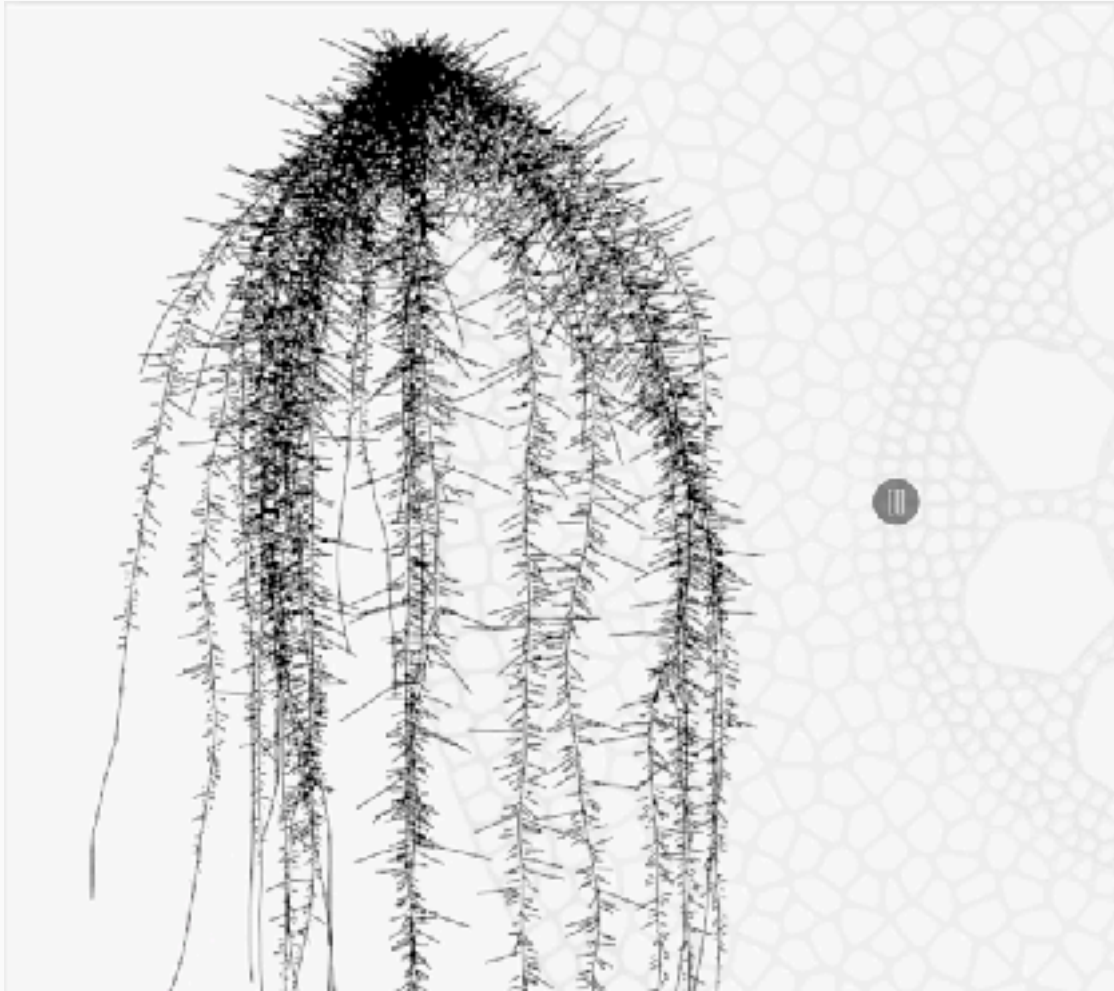
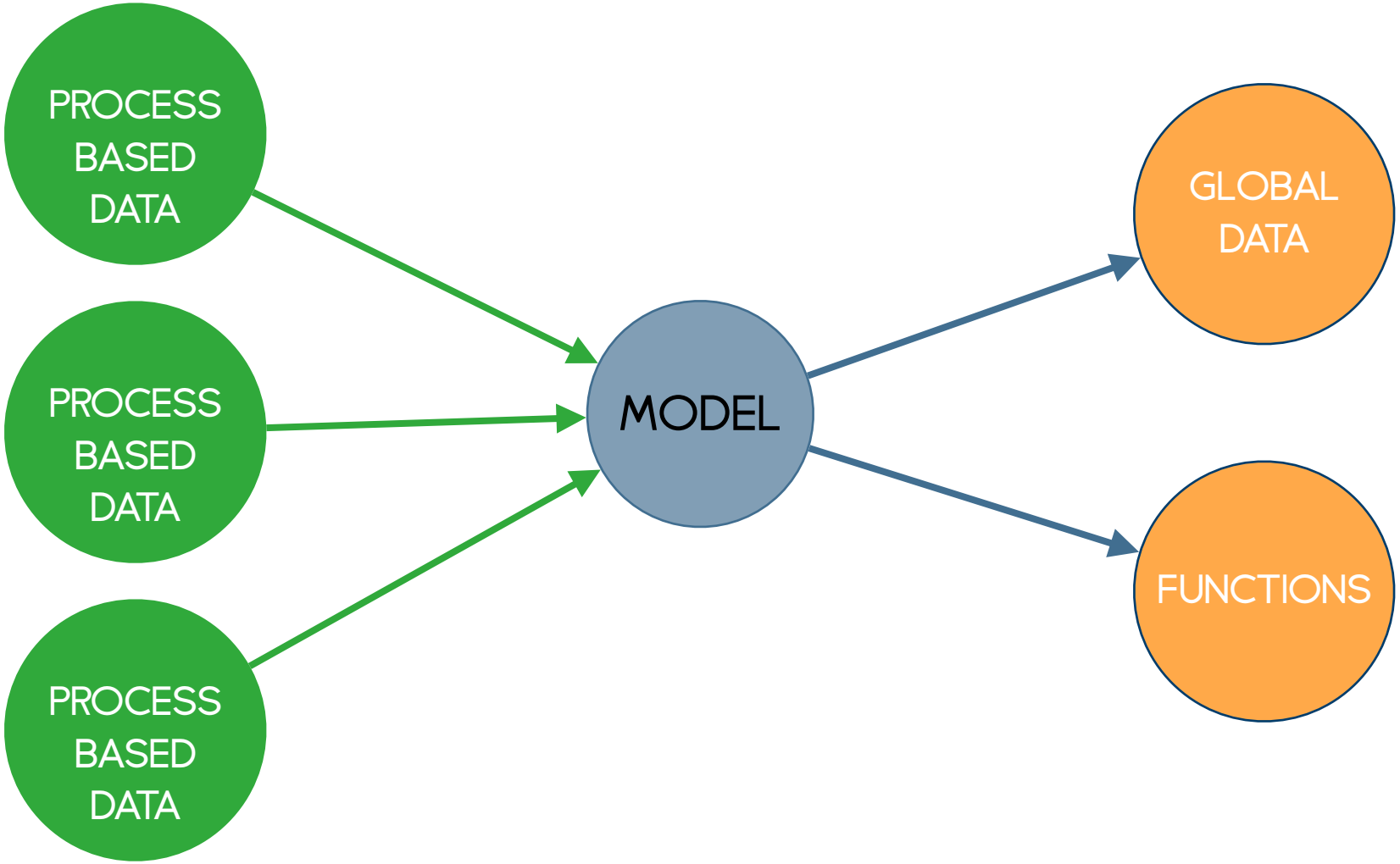
# FROM DATA TO MODELS



# KNOW THE MODEL YOU ARE PLANNING TO USE!

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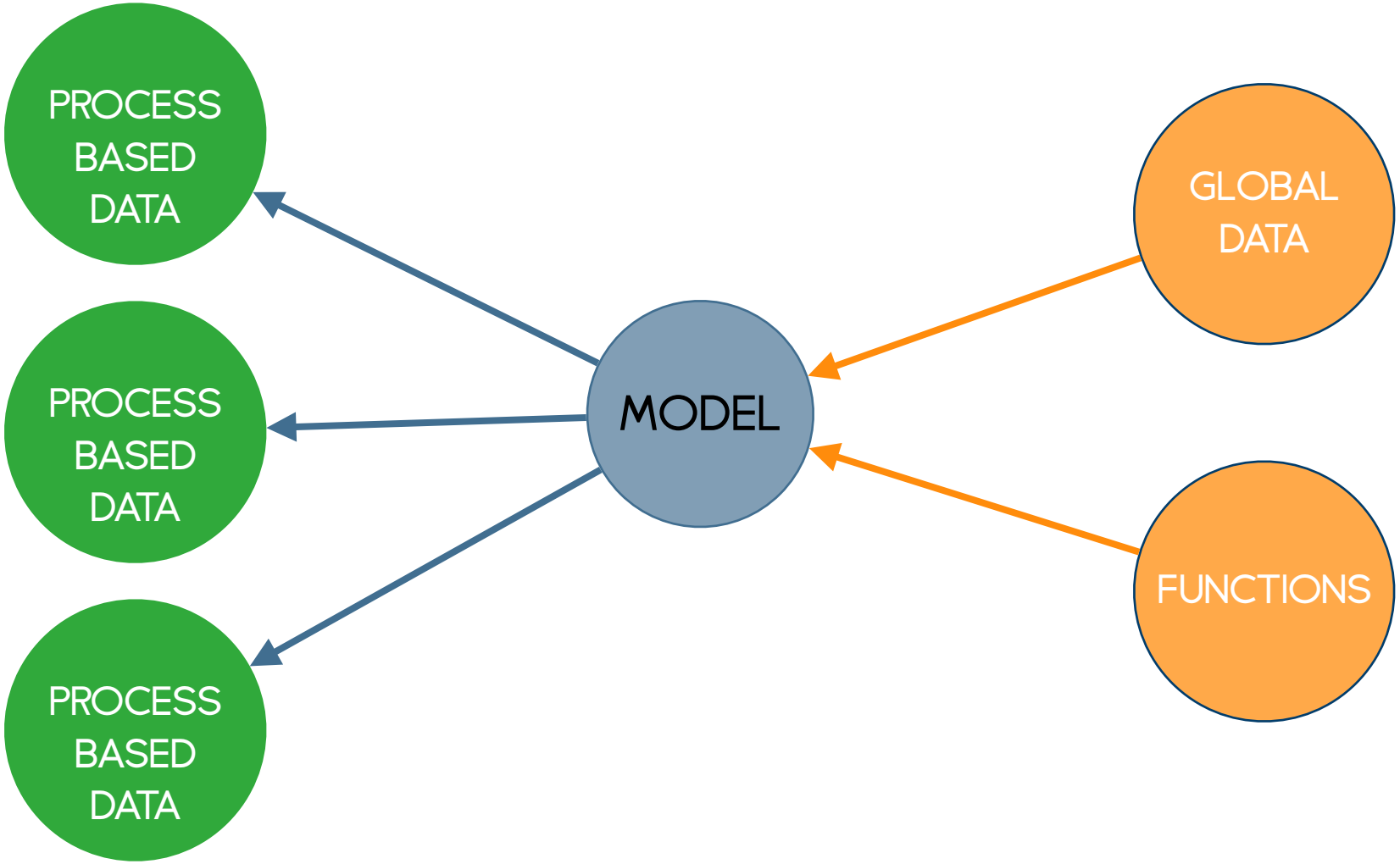
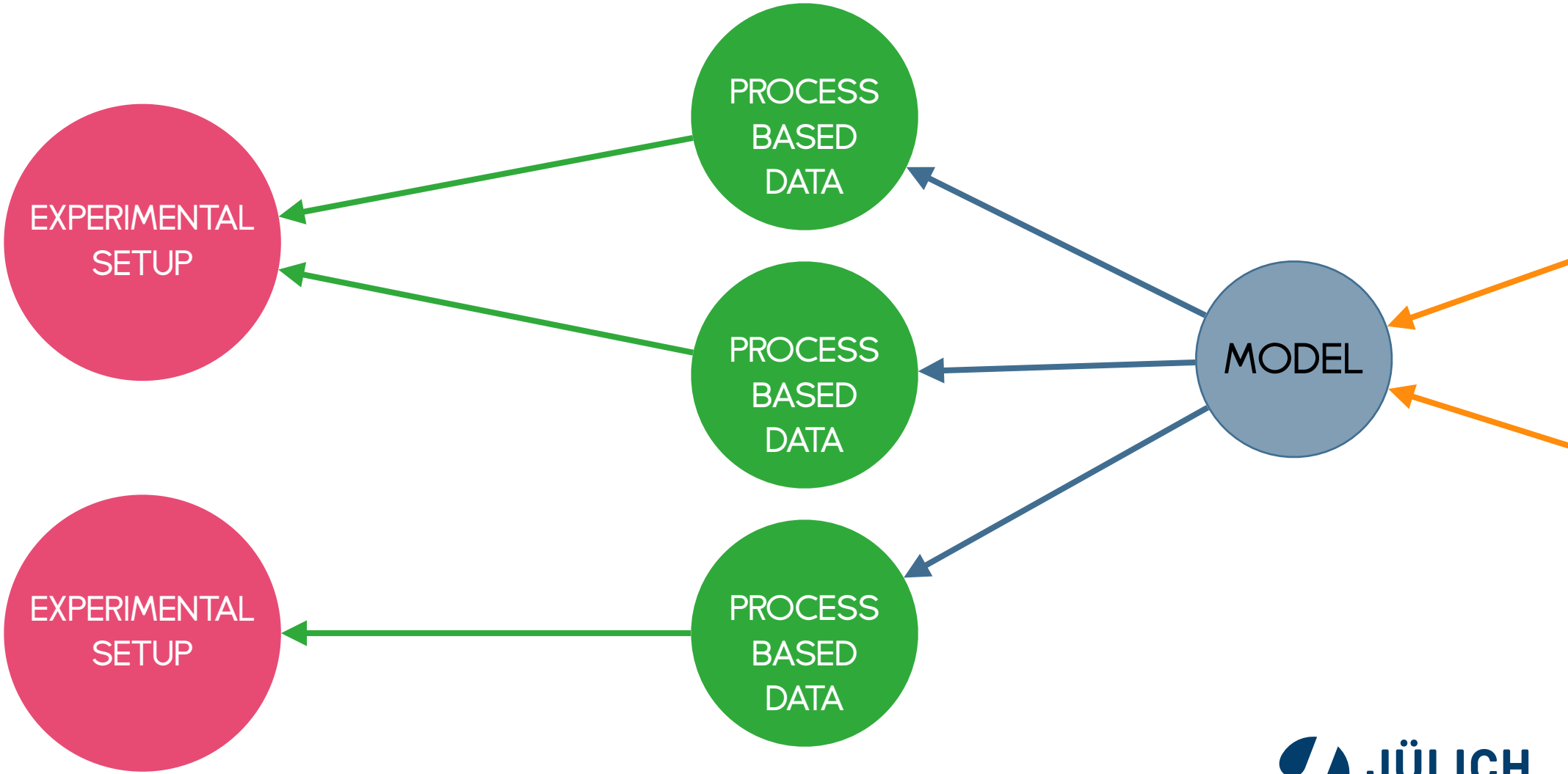


# THEN DESIGN YOUR EXPERIMENT

> https://plantmodelling.shinyapps.io/drw_database/

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# EXEMPLE WITH SMARTROOT