

Exploring carbon allocation with a multi-scale model: the case of apple

1 - Introduction

- Tree growth models represent the plant at a given, single scale of representation (e.g. branches, metamers). However, the effects of choosing this scale on the simulated carbon allocation and growth are poorly explored.
- The application of mechanistic models to complex plants is often impossible due to the exponential increase in computation time.
- This study presents 'MuSCA': a model to simulate carbon allocation at multiple user-defined scales in plants.

2 - Model description

- The allocation process takes into account the distances between sources and sinks, the sink strength and the availability of carbohydrates from photosynthesis, following the equation of the SIMWAL model [1].

$$F_{ij} = \frac{Demand_j * dist^{-h}_{ij} * Supply_i}{\sum_{k=1}^n Demand_k * dist^{-h}_{ik}}$$

- The use of Multi-scaleTree Graph (MTG) [2] allows the user to define new spatial scales of plant representation based by topological rules.
- Up- and Down- scaling functions compute properties from fine scale (metamer) to the selected scale and vice-versa.

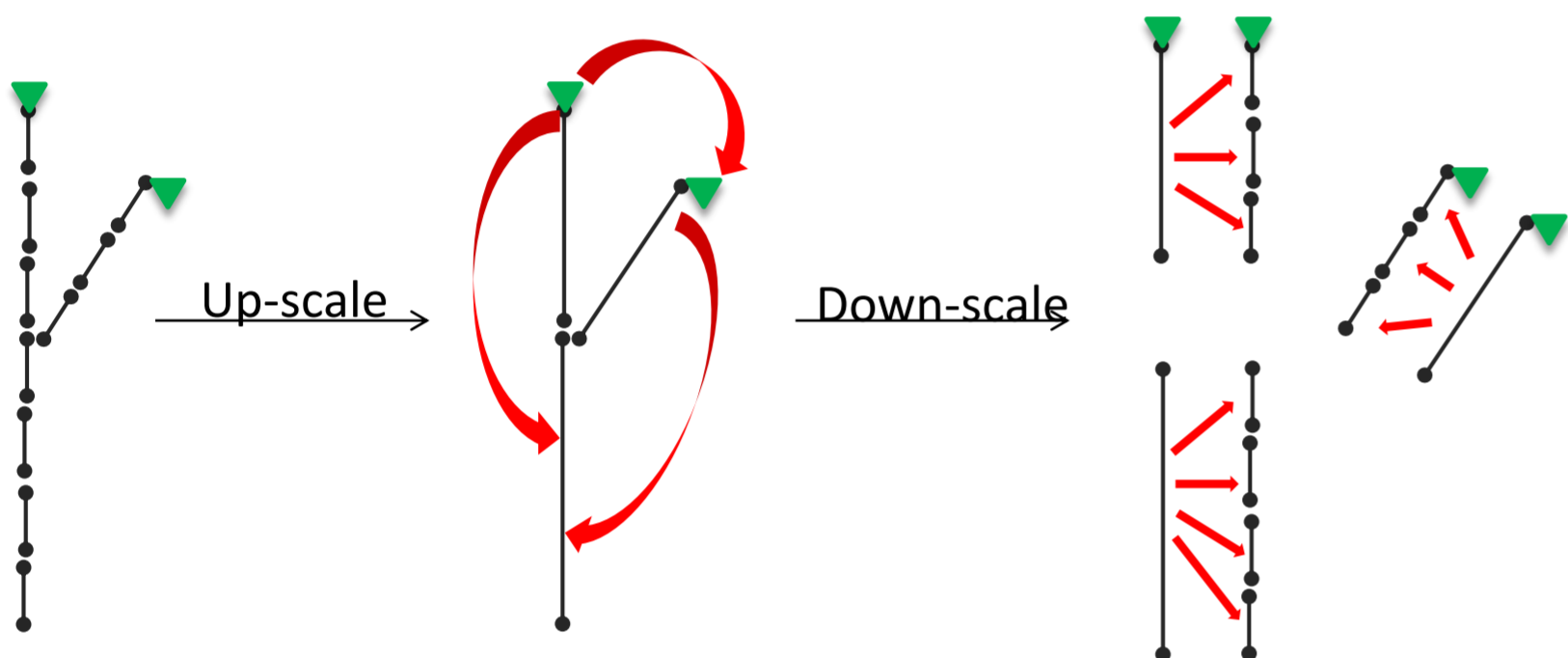


Figure 1: Up- and down- scaling occur in MuSCA before and after computing carbon allocation at any coarse scale of plant representation.

- The modularity of the implementation allows to re-use functions independent of the scale at which the plant is represented.
- The model is implemented in the OpenAlea environment [3], which allows couplings with already available models.

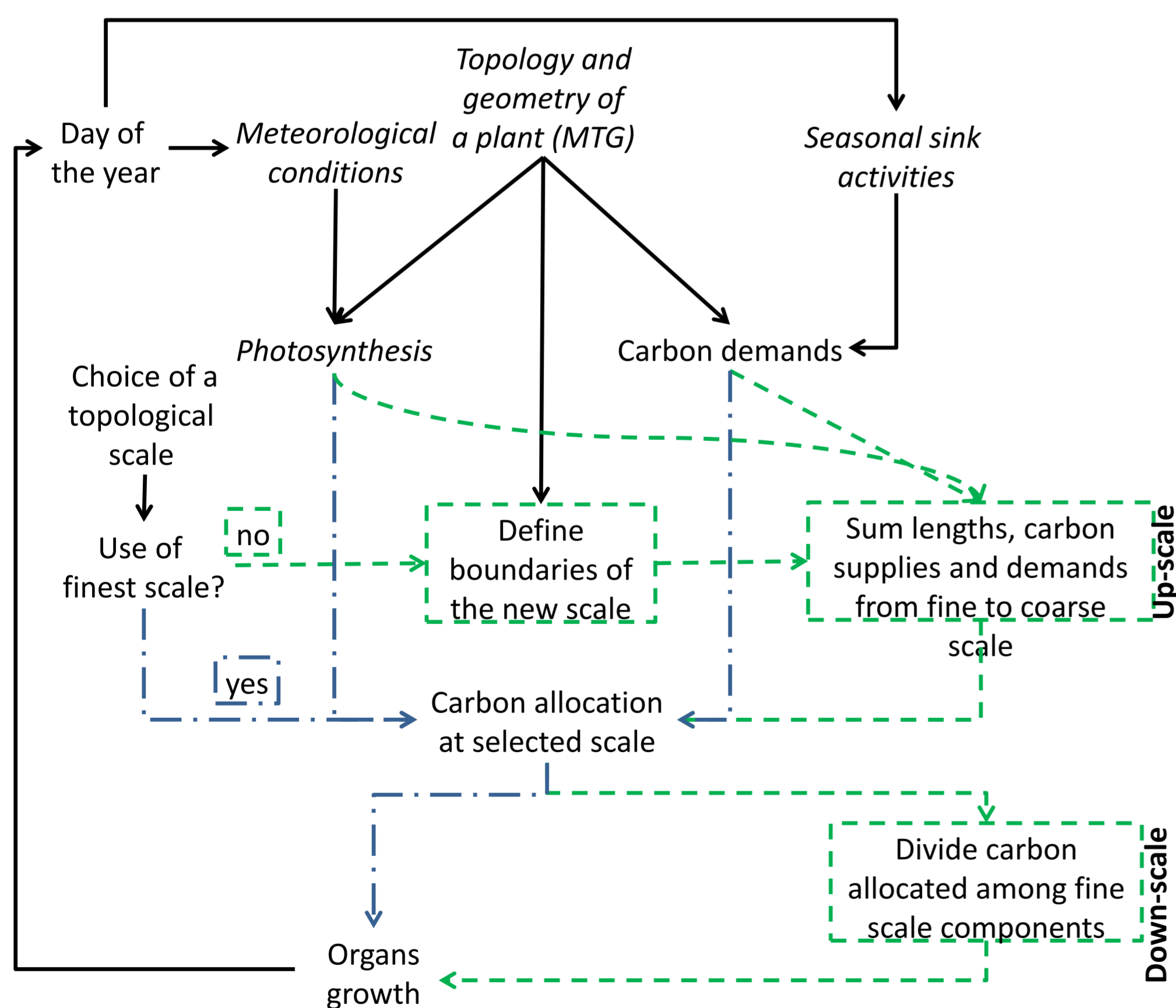


Figure 2: Simplified scheme of the model workflow. Dot-dashed, blue lines indicate the specific path when simulating at finest scale, dashed, green lines are followed when simulating at a coarser scale.

3 - Application to the apple tree

- Carbon demands are calibrated according to the organ specific maximum potential relative growth rates (sink activities) of the apple tree [4].
- The model is adapted to use MTGs of simulated apple trees from the architectural model [5] as inputs.
- A radiative model (RATP [6]) is linked to the carbon allocation model, providing individual leaf photosynthesis.

4 - Preliminary results

- The model showed its ability to represent the main drivers of carbon allocation, such as source-sink distances and competition among sinks, when applied to simulated apple tree structures at metamer scale.
- Model benchmarking showed a sharp increase in computation time when using coarser scales of representation of the plant.

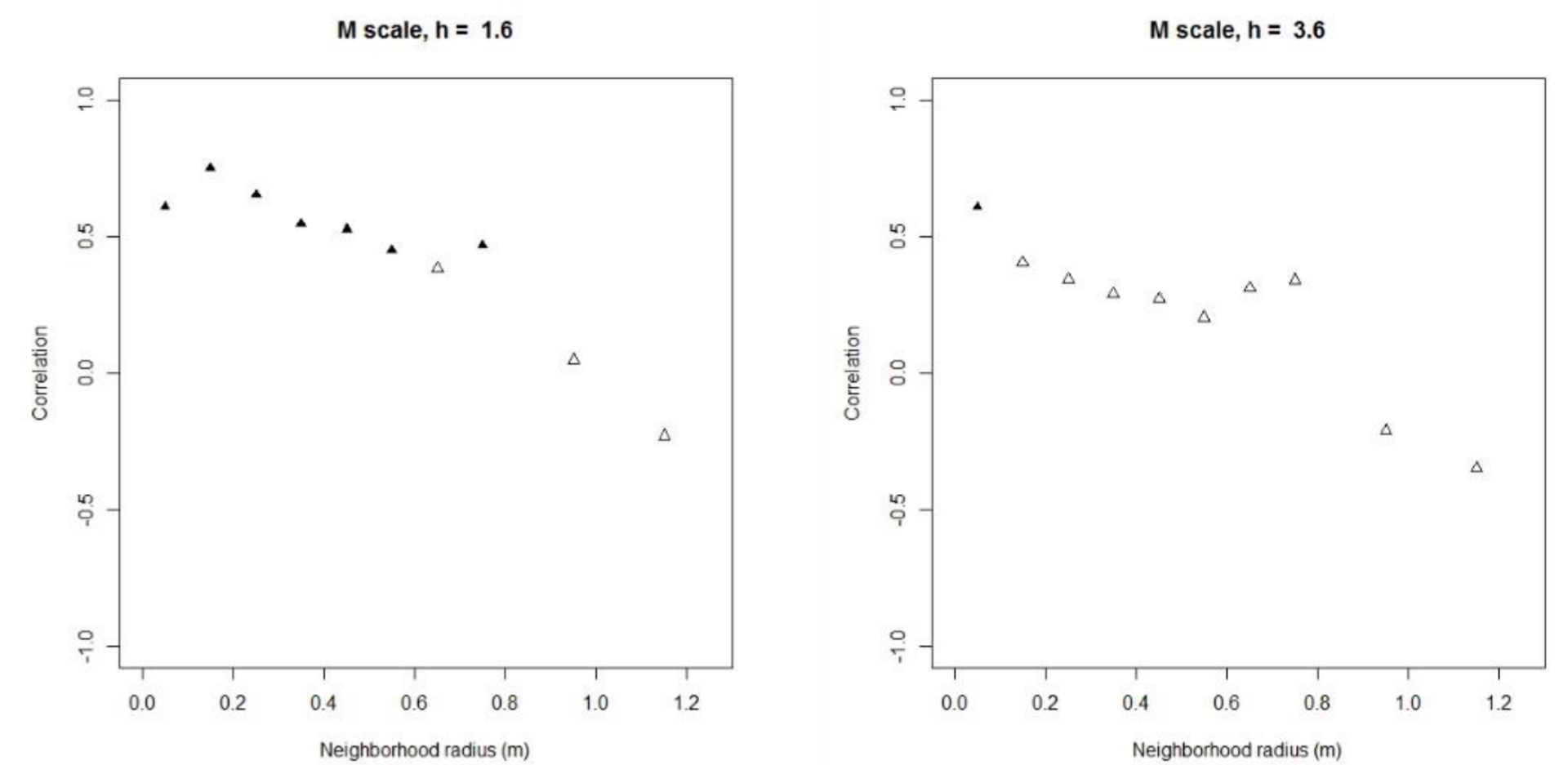


Figure 3: Sensitivity of the model to the driver of carbon allocation (supplies, sinks and distances) for different friction parameter (h).

Neighborhoods of different radius are defined around individual fruits. The accumulated photosynthesis simulated for a period of 30 days, the number of other fruits and the growth of individual fruit are evaluated in these neighborhoods. The ratio C-supplies/Number of fruits is calculated for each neighborhood: the higher the ratio the lower the competition for C-supplies. Pearson correlation is calculated between fruit growth and the calculated ratio. Full triangles indicate significant relationships.

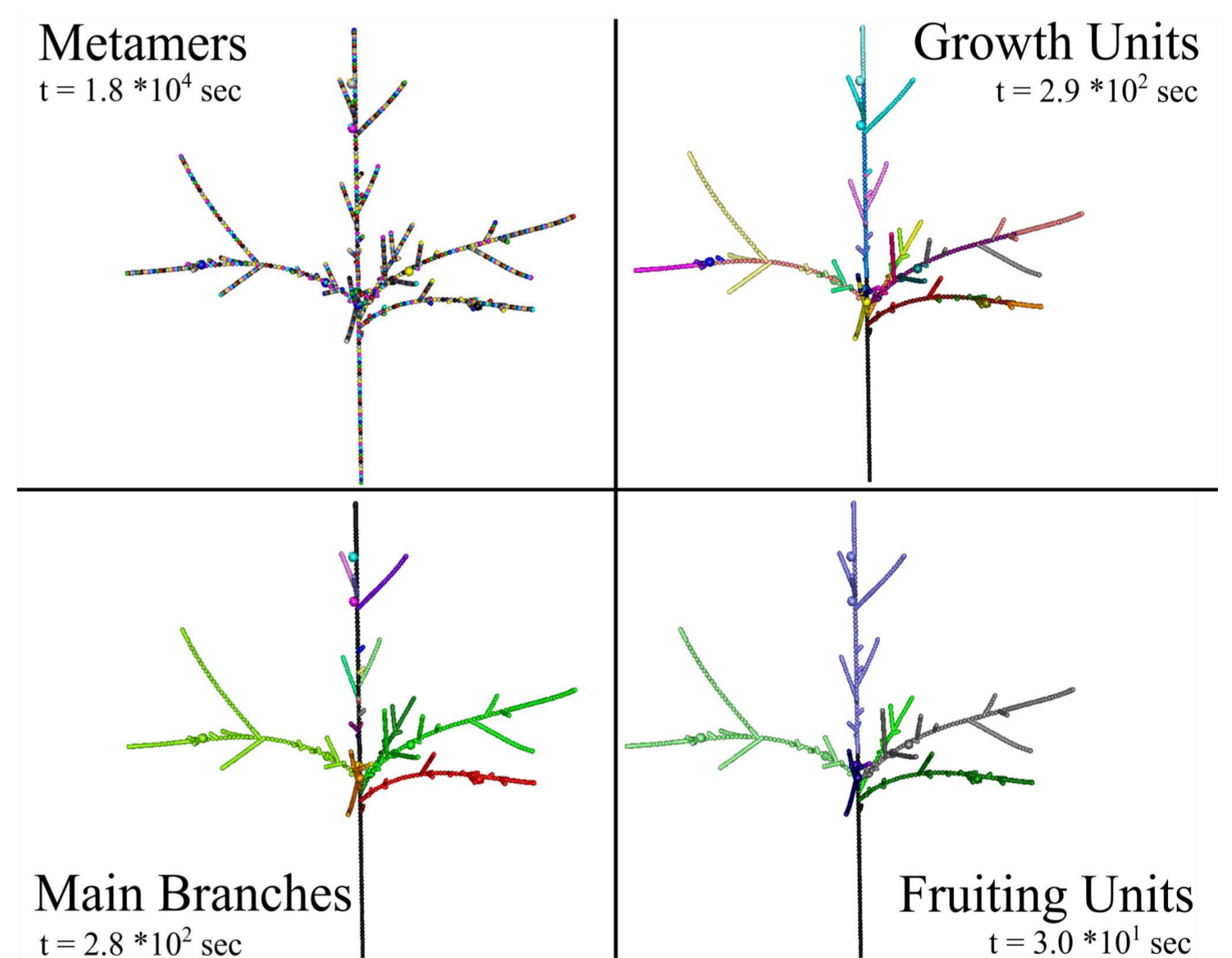


Figure 4: Computation time to simulate carbon allocation on a 3 years old apple tree, for 30 days at different spatial scales.

5 - Conclusions and future developments

- The model provides a framework to re-interpret the plant topology in order to test the influence of the scale of representation on the simulated carbon allocation processes.
- It allows investigating the trade-offs between the detail at which a plant is described, and the accuracy and computational efficiency in predicting carbon allocation.
- A model validation is foreseen in order to test the accuracy in predicting fruit growth.

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