What are the impacts of tree shade on the absorption of light by grapevine in alley-cropped vineyards?

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2. CESBIO, Toulouse, France
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20-22 May 2019
Le Corum Conference Centre
Montpellier, France

Introduction

Modern forms of agroforestry vineyards

a.

Vitiforest ?

b.

J. Grimaldi

c.

D. Vinet

d.

J. Grimaldi

e.

J. Grimaldi

Modern forms of agroforestry vineyards

Vitiforest

a.

b.

J. Grimaldi

c.

D. Vinet

What are the microclimatic impacts from trees?

d.

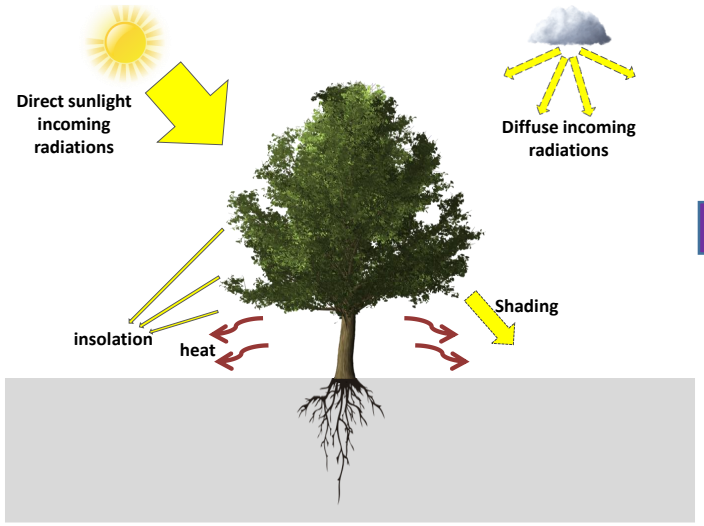
J. Grimaldi

e.

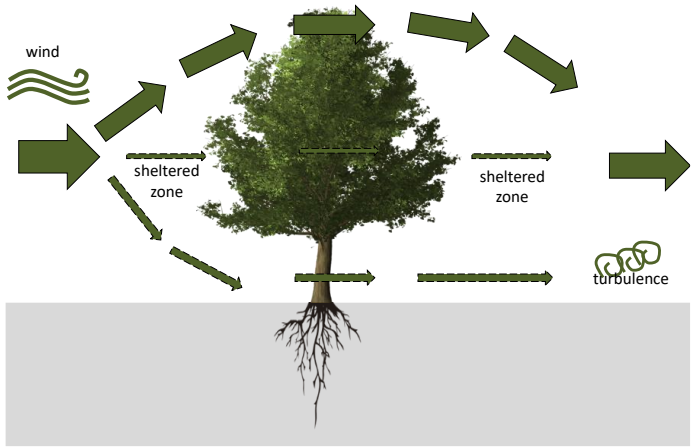
J. Grimaldi

Main mechanisms at stakes

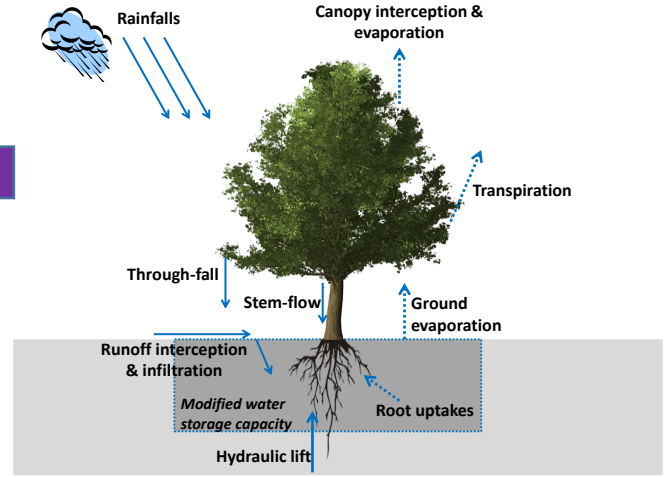
Shading



Sheltering



Water budget modifications



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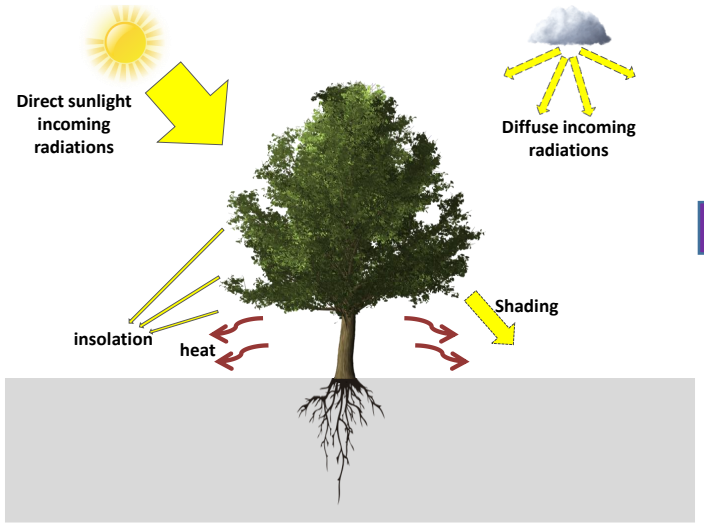

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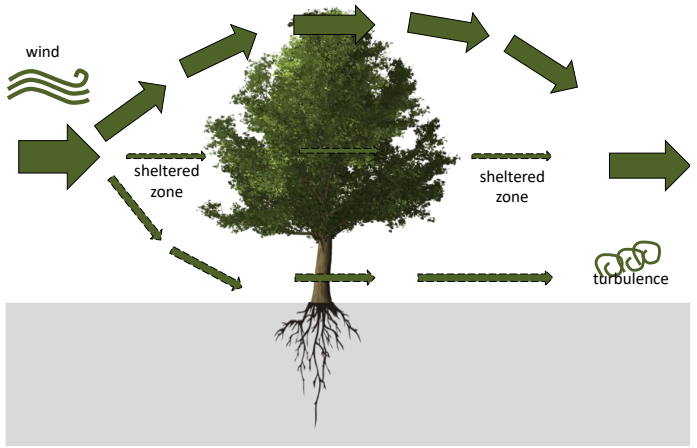

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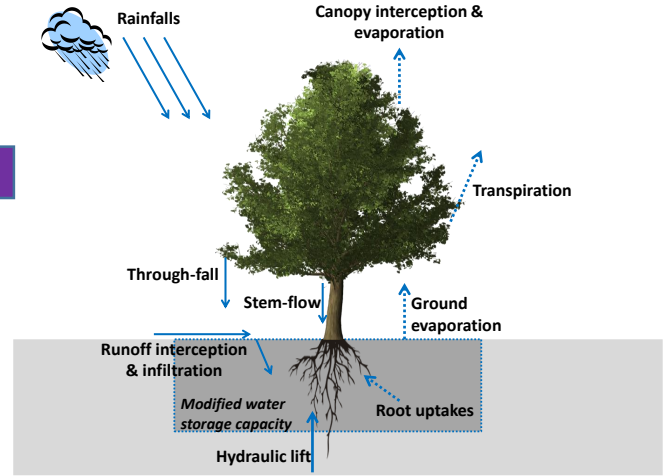
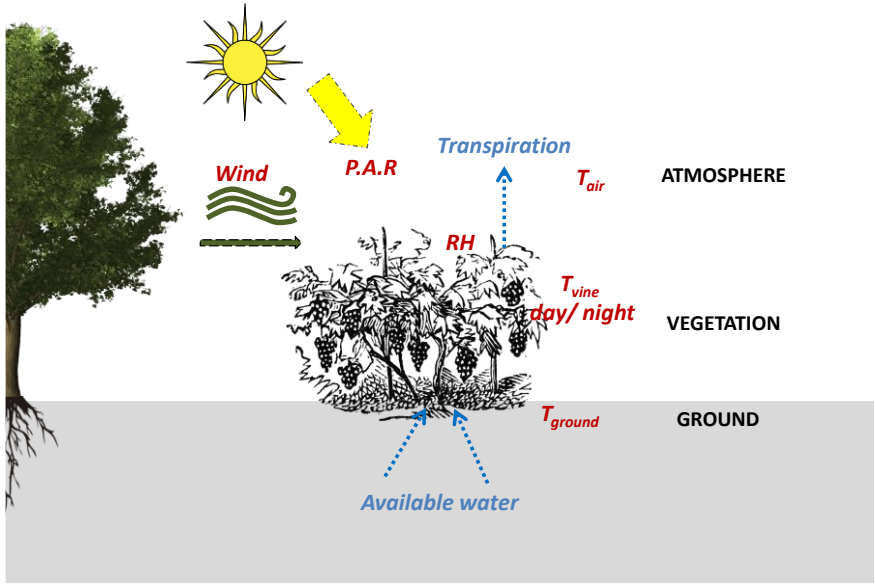


Impacts on grapevine energy and water budgets



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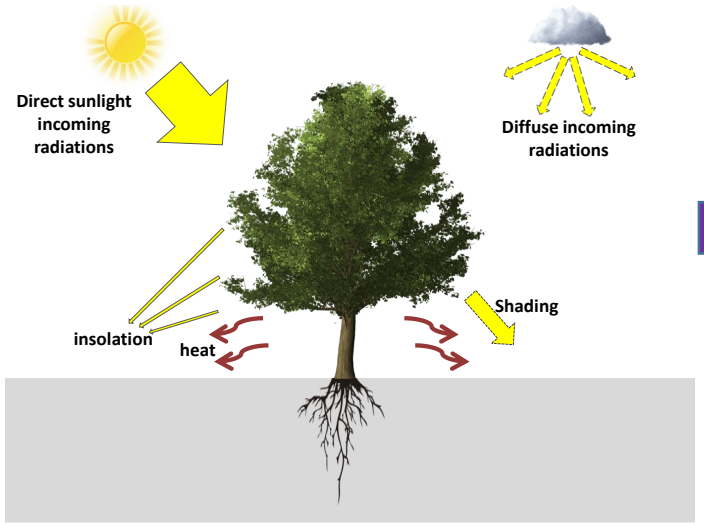

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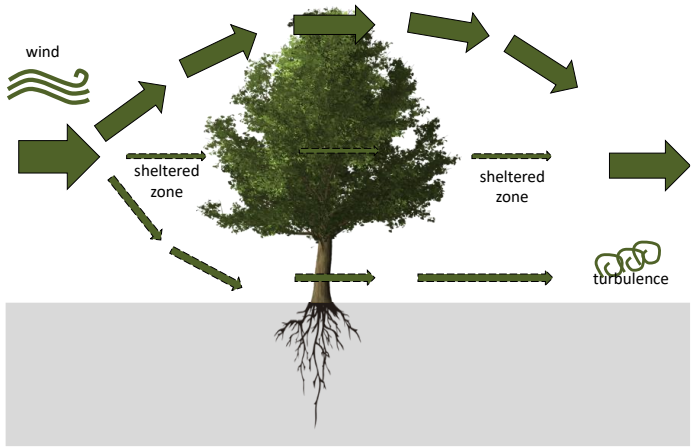

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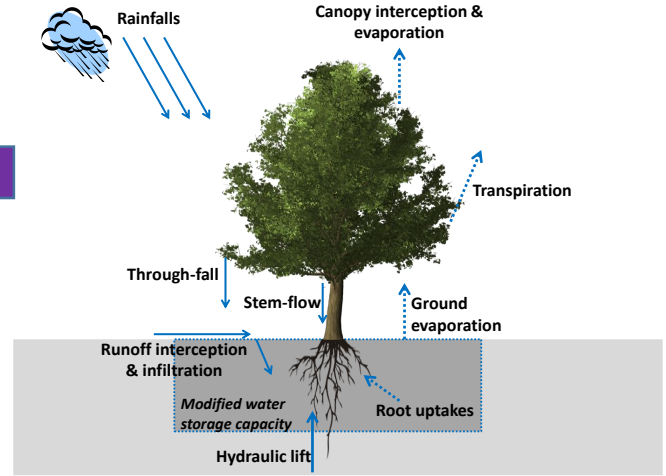

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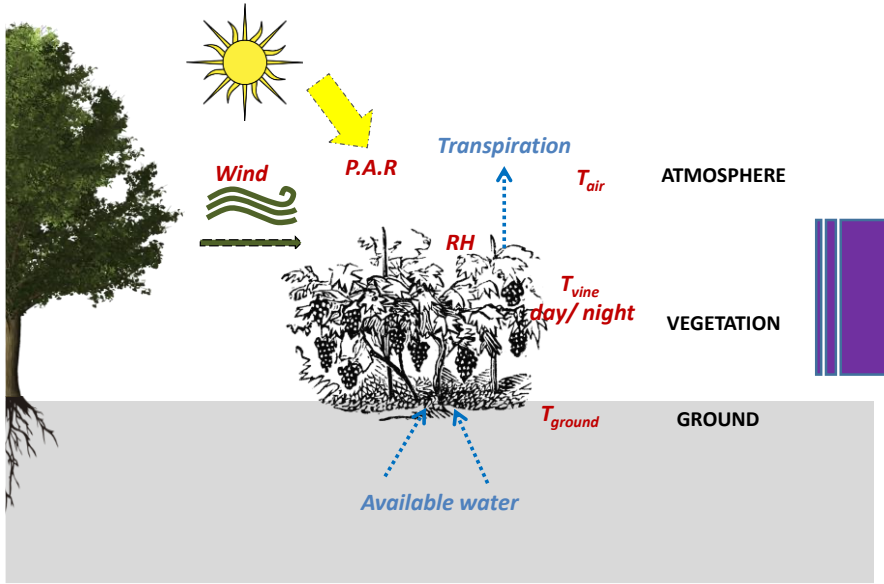
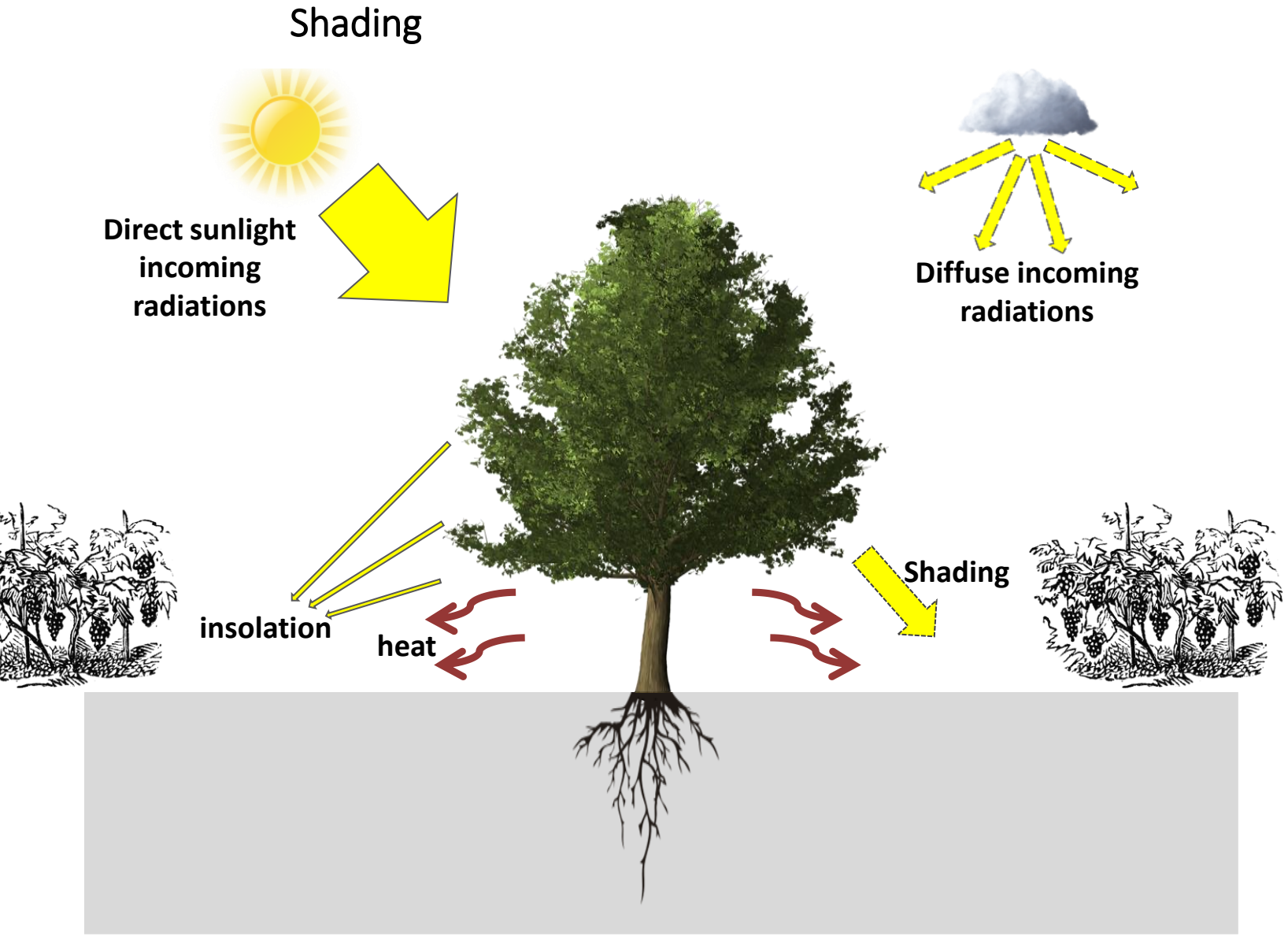


Yield
Berry quality for wine making

Research questions



→ Impacts of trees on grapevine light absorption?

→ Variability according to vegetation structure?

→ Variability according to meteorological context?

Material and methods

Models of light propagation used for studying light distribution in agroforestry systems

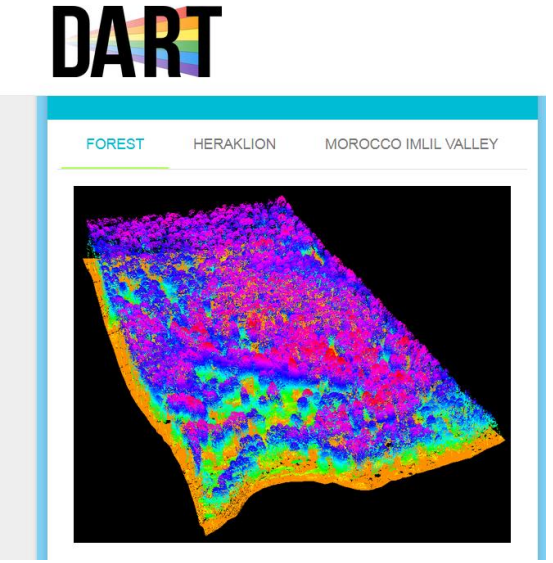
Model	Vegetation modeling	Light modeling, scattering and light extinction (LE) computation	Model outputs
Light partitioning method from Wallace (1995) (Annex A)	Canopies: 1D medium filled with mixed canopies. It is characterized by the LAI_i of each canopy component	LE: Beer's Law	Fraction of light available at the top of each canopy component
The simple model of light interception by discontinuous canopies of Jackson and Palmer (1979)	Trees: cone / ball / parallelepiped canopies Crop: none	Light: Global incoming radiation LE: Beer's law	Fraction of the incoming light available at ground level over a given period of time (1D time integrated budget)
Gap Light Analyzer GLA (Frazer et al. 1999)	Trees: Hemispherical images of tree canopies	Light: Global radiation including a diffuse fraction LE: Empirical equation of intercepted PAR according to the gap fraction in the canopy images, the global incident radiation and the cloudiness factor	1/ amount of above-and below-canopy (transmitted) direct, diffuse, and total solar radiation incident on a horizontal or arbitrarily inclined surface 2/sunfleck-frequency distribution and daily duration
Light module in WaNuLCAS agroforestry model (Van Noordwjik and Lusiana 1998; Noordwijk et al. 2004)	Landscape: Horizontal layers subdivided in 3D cells Canopies: All the cells in a given layer are defined by a AD for each type of canopy components (tree leaves, crop leaves, woody parts)	Light: Direct light only LE: Beer's law applied in each cell of vegetation	Absorbed PAR per horizontal layer of vegetation and per vegetation type (tree/crop)
Hybrid model which was actually used for the first time in 'gap models' FORSKA model (Prentice and Leemans 1990)	Landscape: 3D array of cells. Trees: ellipsoid turbid medium Crop: homogeneous understory turbid layer. Discontinuities in the crop canopy (i.e. sparse canopies) are managed considering the individual plant shade area (m^2), the individual plant leaf area (m^2) and the plant density (plants m^{-2})	Light: Global radiation from a standard overcast sky model Scattering: One order of scattering from the canopy external envelop (albedo) LE: modified Beer's law adapted to crop sparse canopies	Absorbed PAR in each 3D cell of tree canopy or crop. (pseudo 3D instantaneous budget)
RATP model (Radiation, Absorption, Transpiration and Photosynthesis) of Sinoquet et al. (2001), initially developed by Sinoquet and Bonhomme (1992) and modified by Meloni and Sinoquet (1997) to consider three-dimensional heterogeneous canopies	Landscape: 3D array of cells. Canopies: Each cell can contain several canopy components (various types of leaves, woody parts, fruits), and is characterized by the AD of every component in the cell	Light: discrete beams from direct and diffuse sources Flux tracking: radiosities method LE: Equation of radiative transfer applied in each cell.	Intercepted PAR flux for each plant component type in each voxel (3D instantaneous budget)
DART (Discrete Anisotropic Radiative Transfer) (Gastellu-Etchegorry et al. 1996, 2012)	Landscape: 3D array of cells including atmosphere layers Canopies: same as RATP and/or ensemble or accurate planar 3D objects with optical properties	Light: discrete beams from direct and diffuse sources Flux tracking: N flux method LE: Equation of radiative transfer applied in each cell	Intercepted PAR flux for each plant component type in each voxel (3D instantaneous budget)

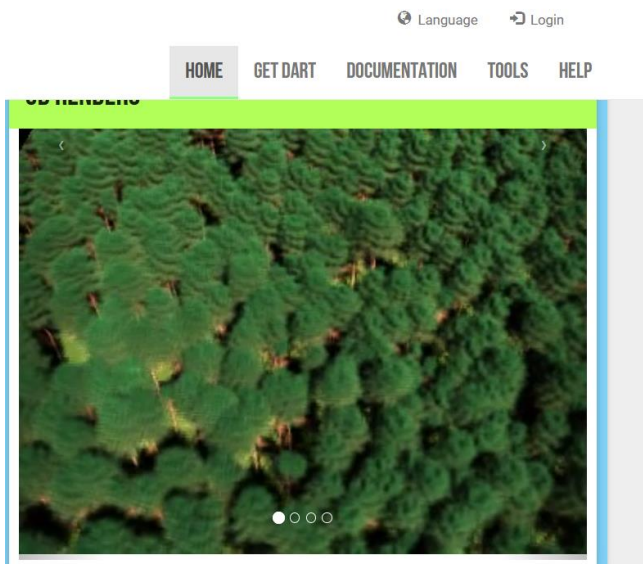
DART: The Discrete Anisotropic Radiative Transfert model

- Developed at CESBIO since 1996
- Physical based model
  - → radiative budget
  - → remotely sensed images
- 3D modeling of heterogeneous and complex landscapes
- Free academic licences:

  http://www.cesbio.ups-tlse.fr/dart/#/

  http://www.cesbio.ups-tlse.fr/us/dart.html
- Graphical interface (*GUI*) and python scripts

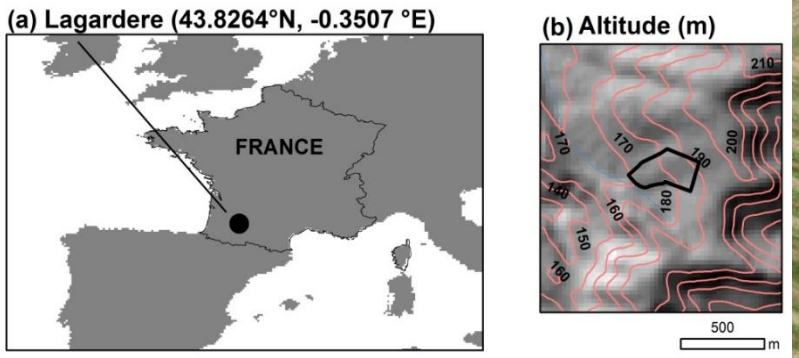




Université de Toulouse

CESBIO

Study site: an agroforestry vineyard in south-western France



Lagardere, France, 07/2016

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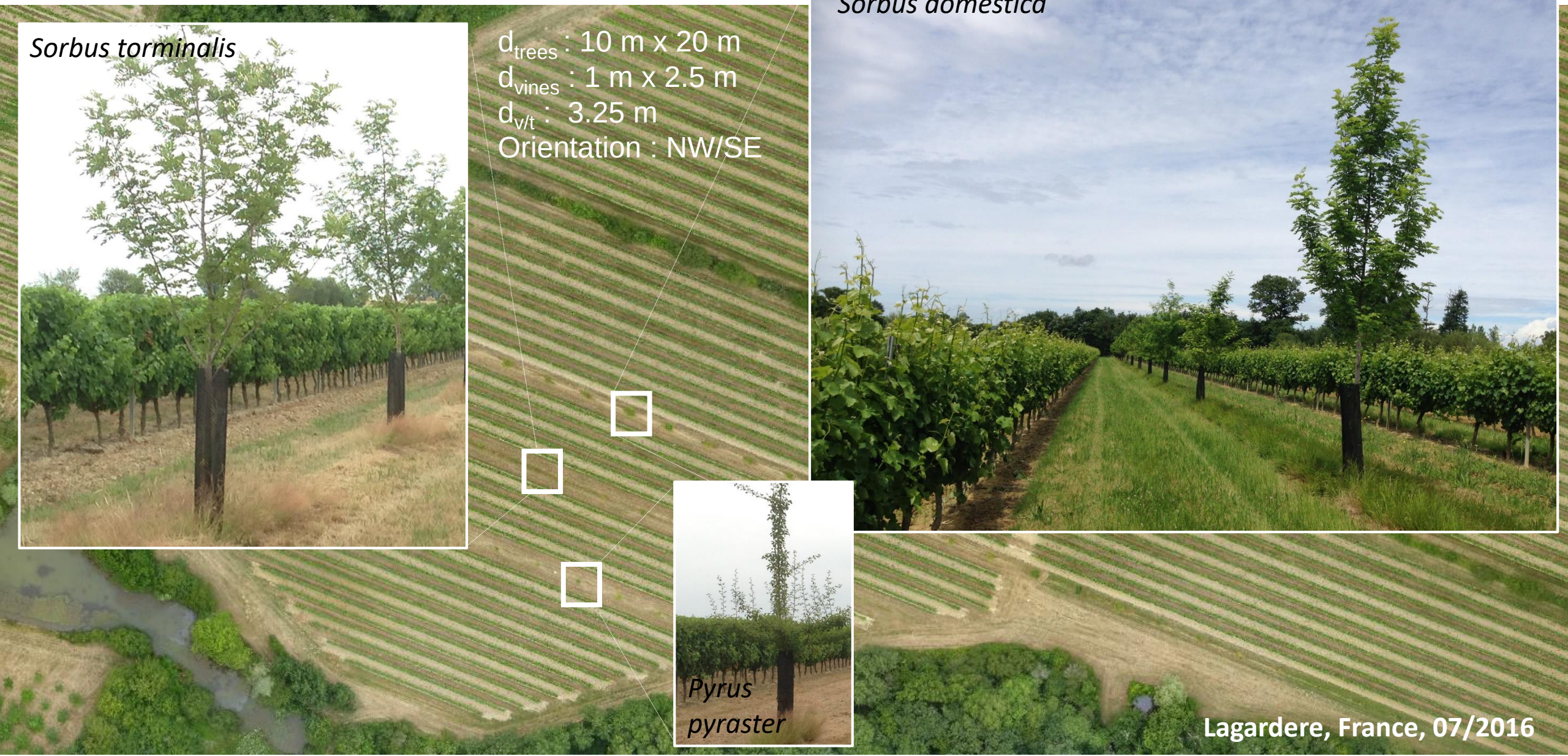
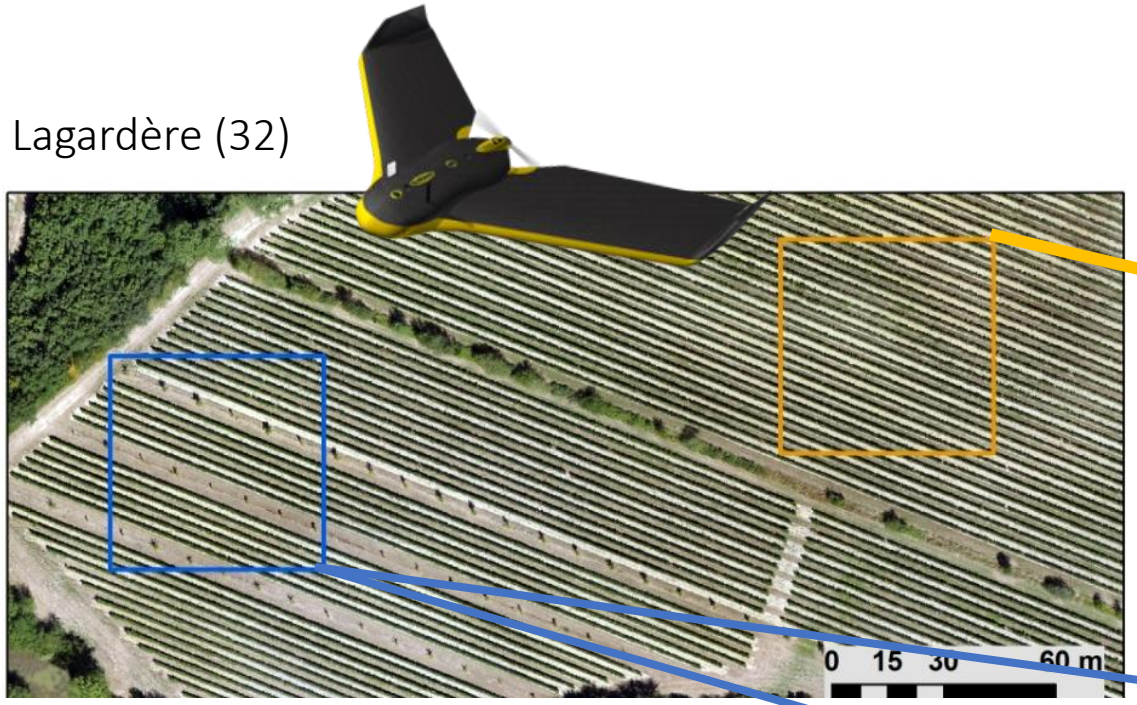


Building 3D landscape mock-ups including realistic vegetation cover and topography

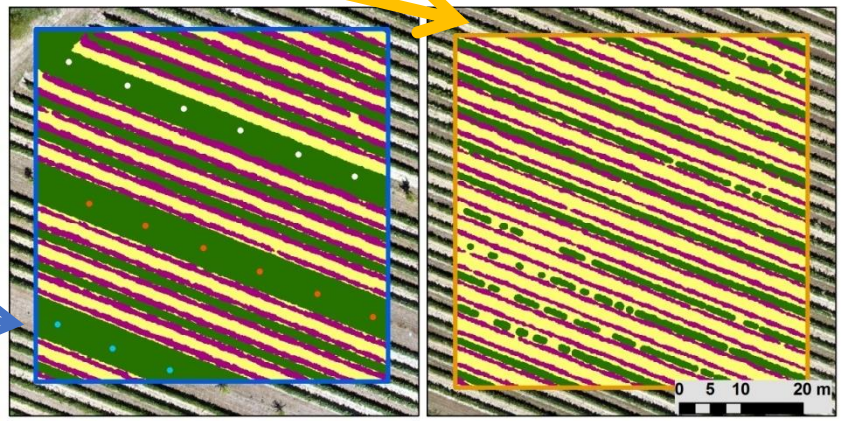
Lagardère (32)



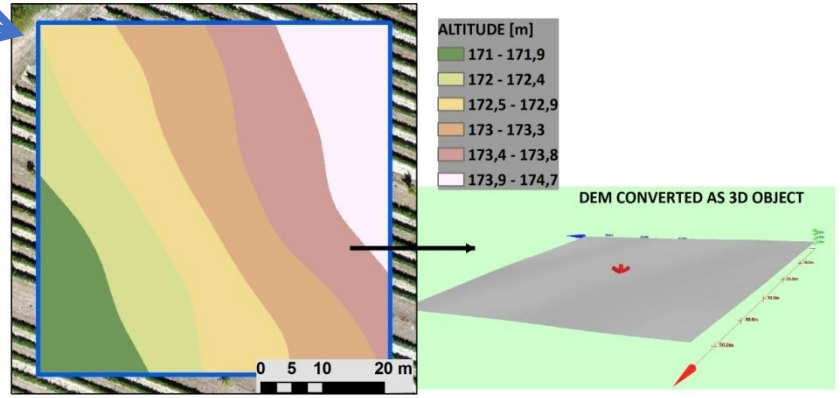
monocropped zone

zone in agroforestry

Land cover maps



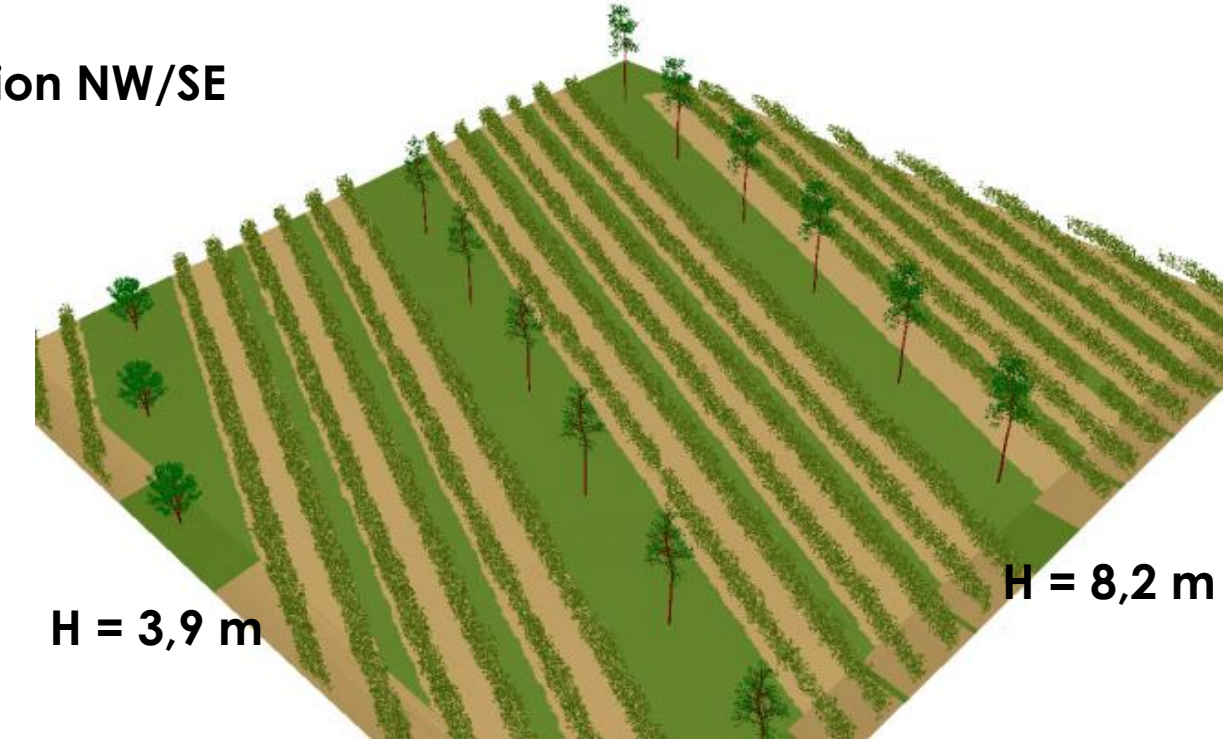
Terrain model

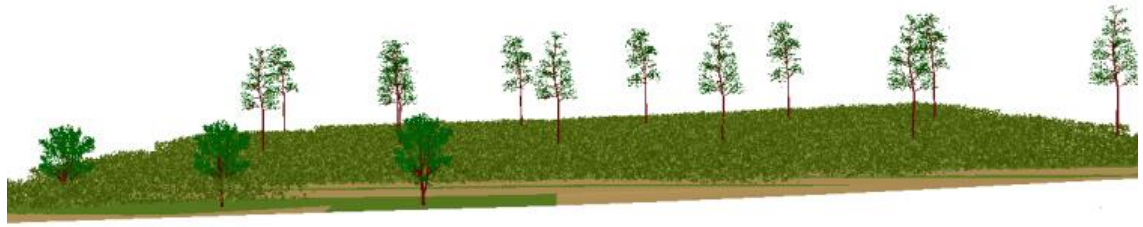


Five arrangements of vegetation

Lagardère (current)

- **Orientation NW/SE**

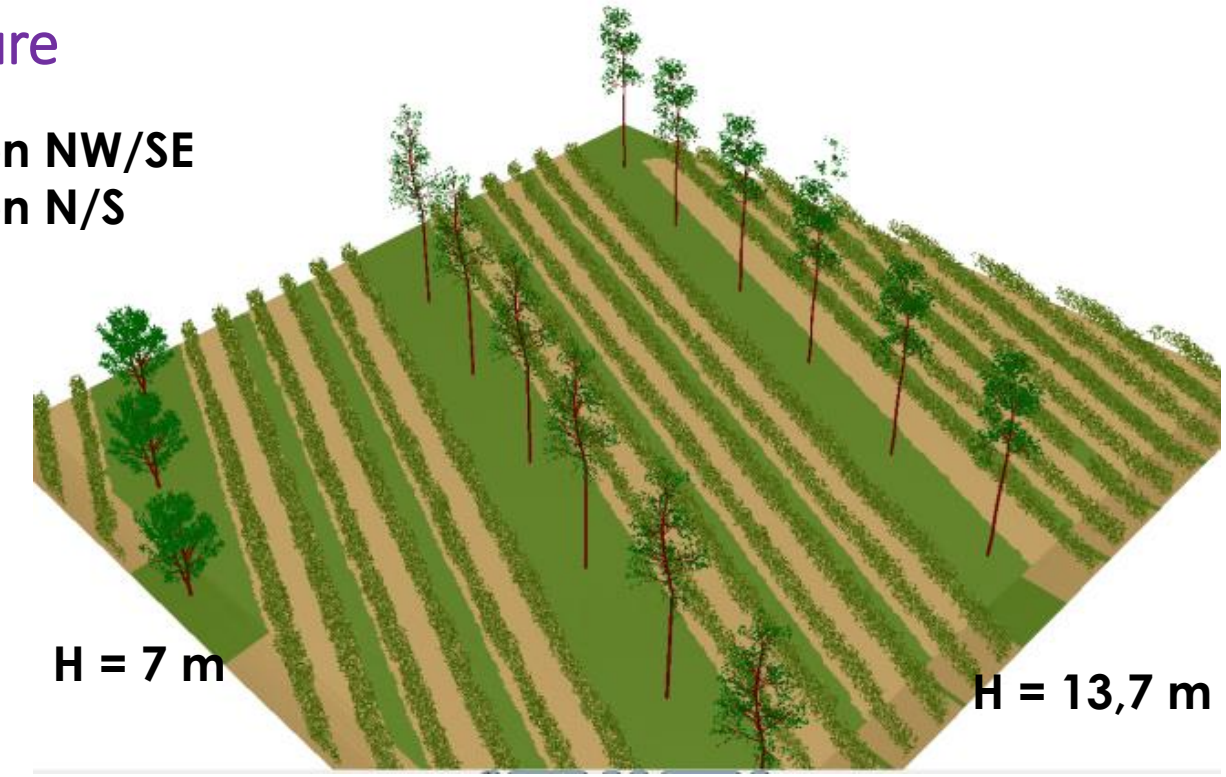


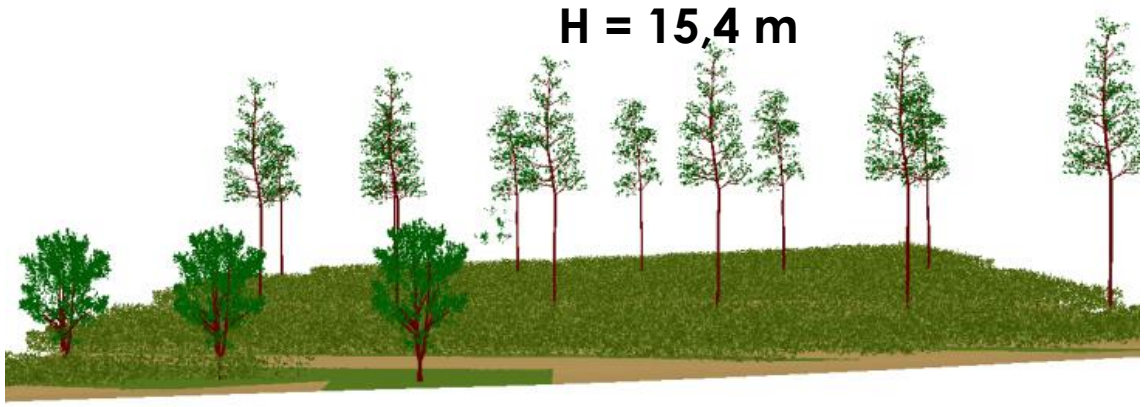


Five arrangements of vegetation

Lagardère future

- **Orientation NW/SE**
- **Orientation N/S**

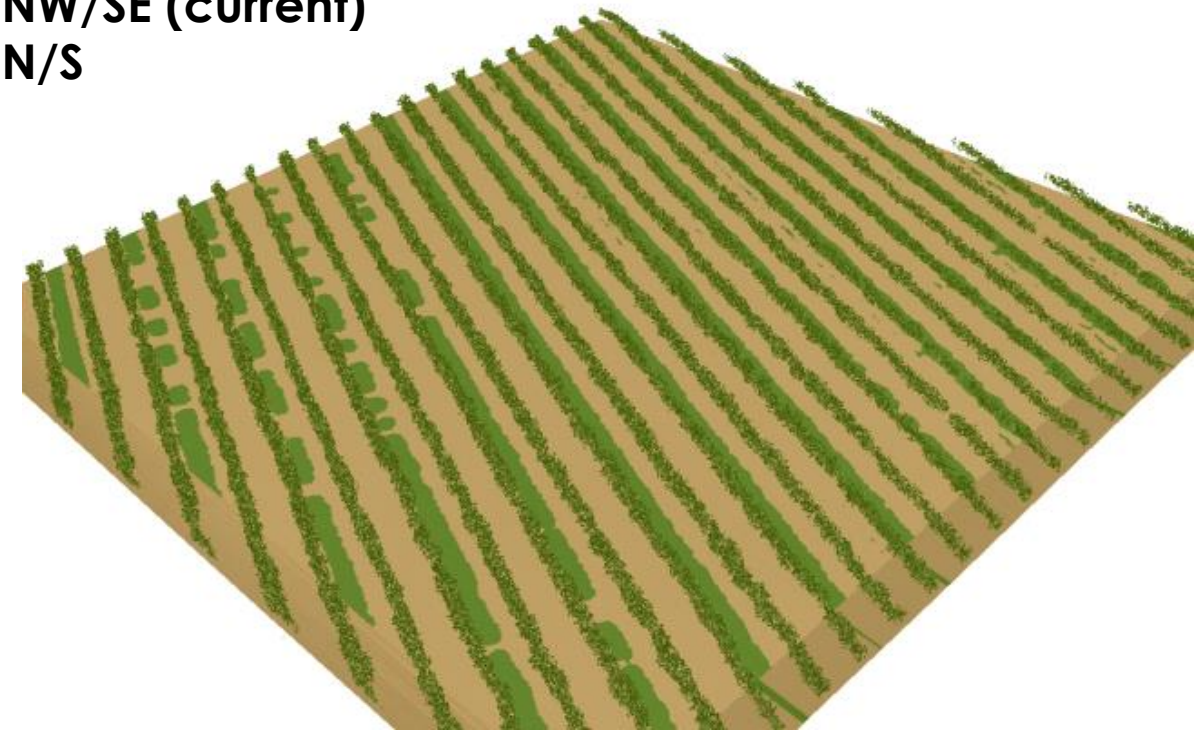




Five arrangements of vegetation

Lagardère without trees

- **Orientation NW/SE (current)**
- **Orientation N/S**



Methodological challenge #1: Properties of tree and vine canopies

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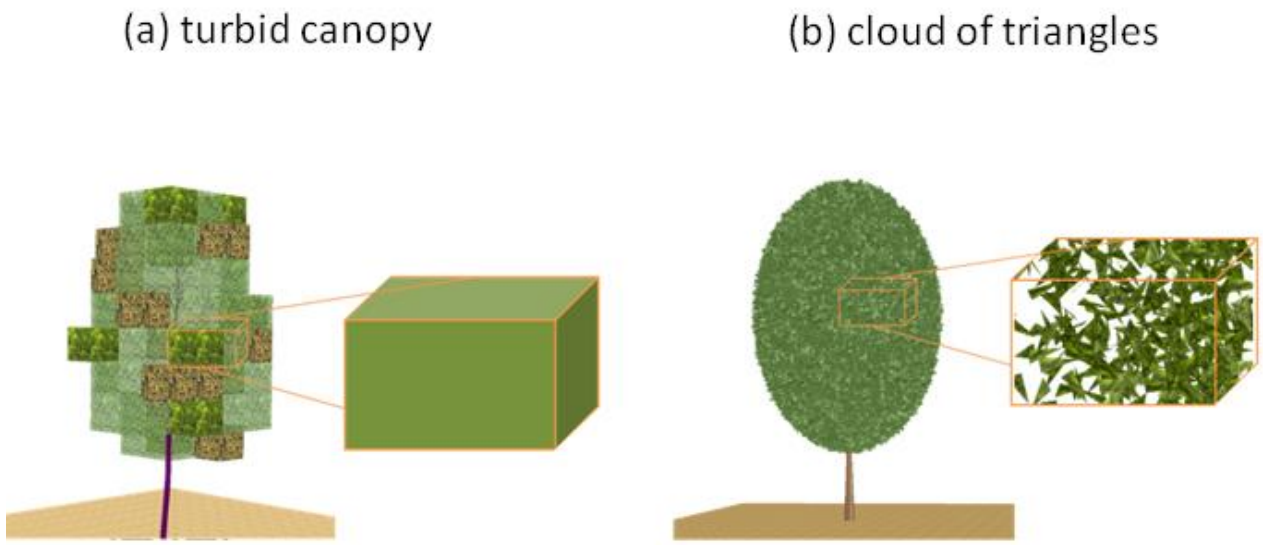
Tree morphology



RAMI4 database - Wildoski J-L, etal. (2011) doi: 10.1029/2010JG001511

Methodological challenge #1: Properties of tree and vine canopies

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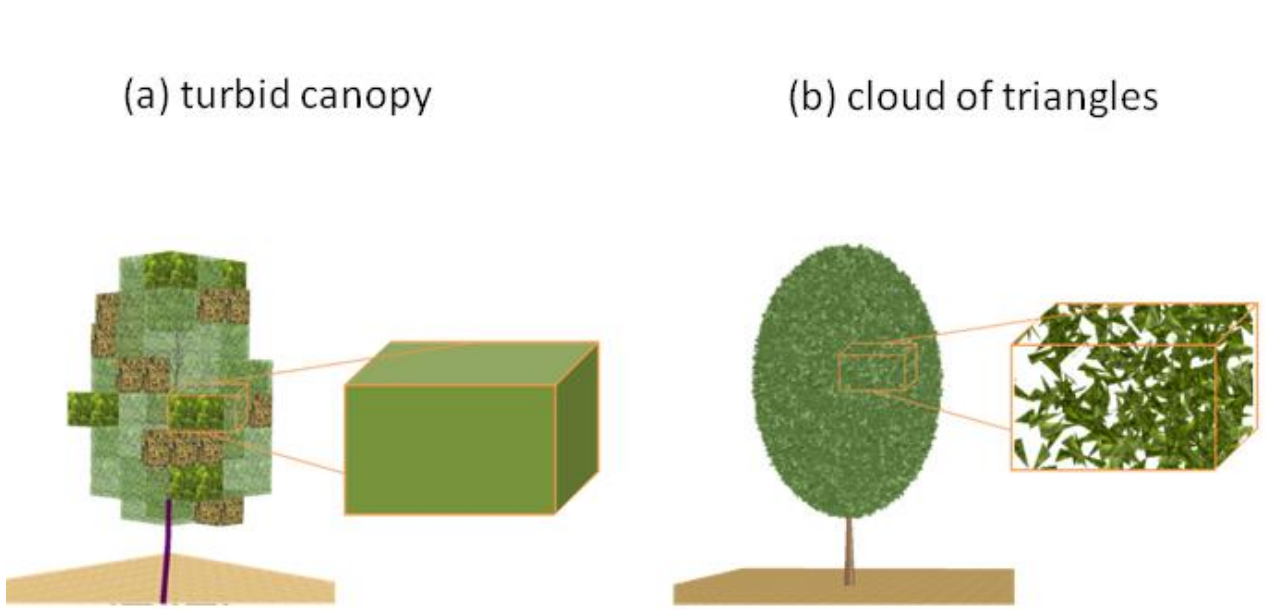

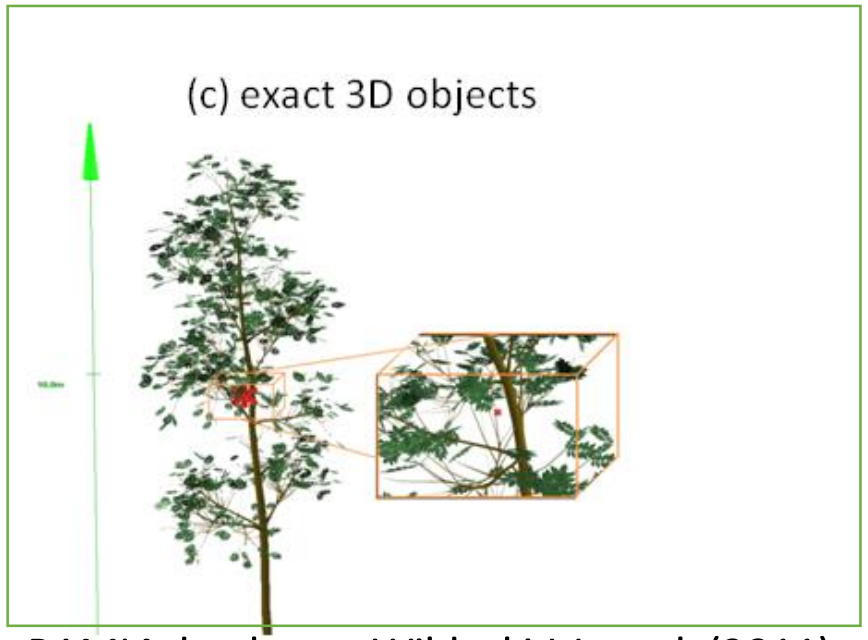

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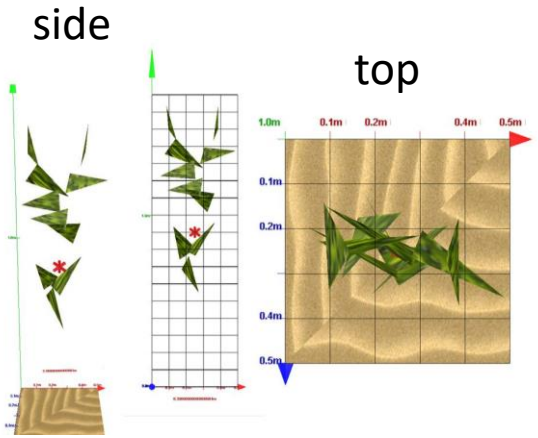
Grapevine morphology

H_{spring} : 0.5 m

H_{summer}: 1 m



Methodological challenge #2:
Simulation of a realistic time serie of cloud cover

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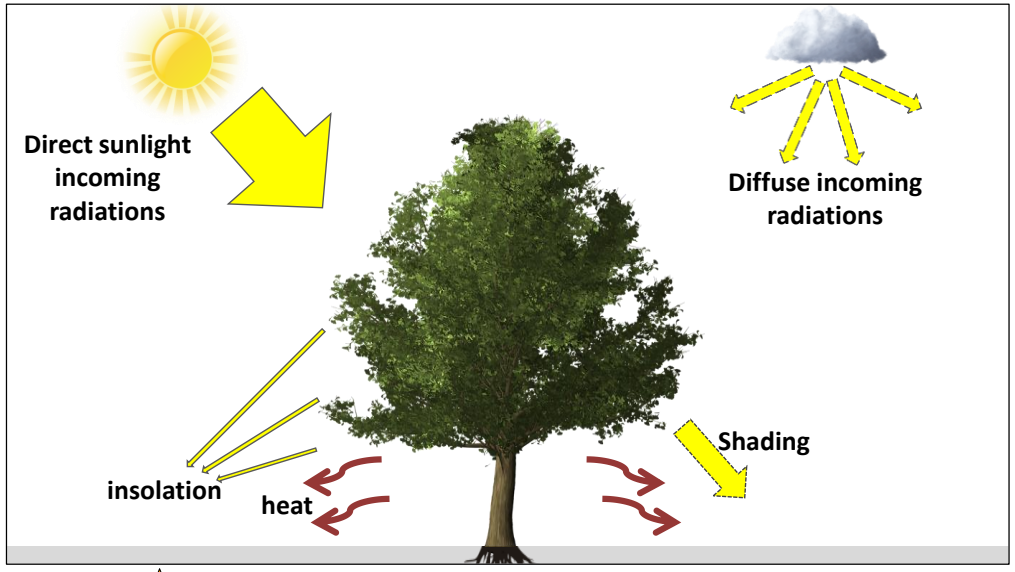

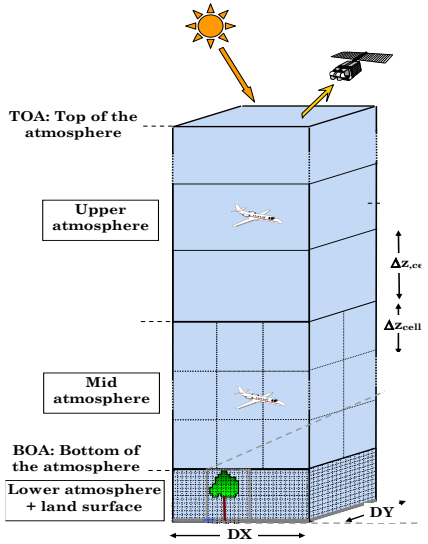

$$SKYL = \frac{E_{BOA}^{diff}}{E_{BOA}^{tot}}$$

$$= \frac{"sky\ (atmosphere)\ irradiance"}{"total\ (sun + sky)\ irradiance"}$$

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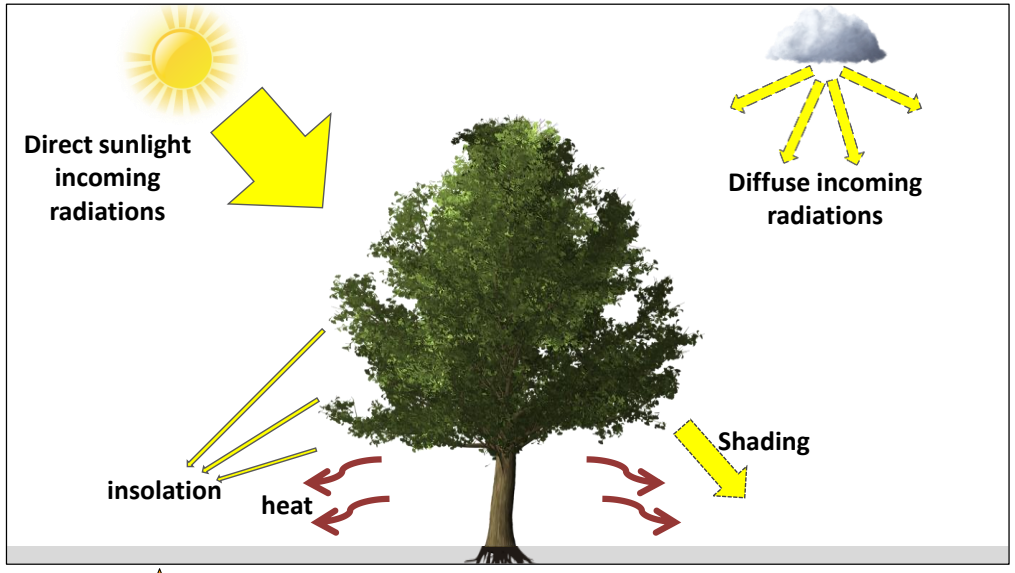

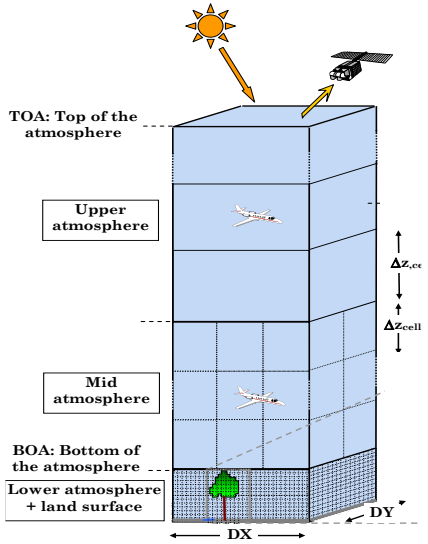

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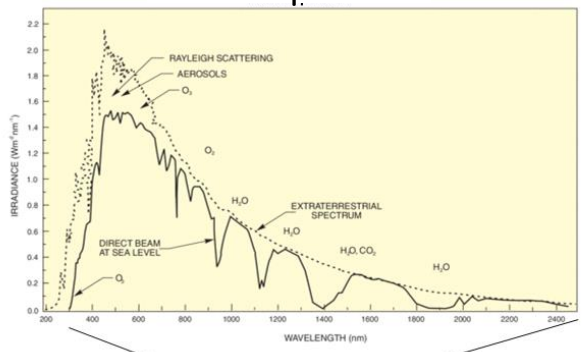
→ Adjustment of aerosols and cloud optical depth using on site measures of total solar irradiance $\epsilon = \left|\frac{E_{simu} - E_{mes}}{E_{mes}}\right| = 3\%$

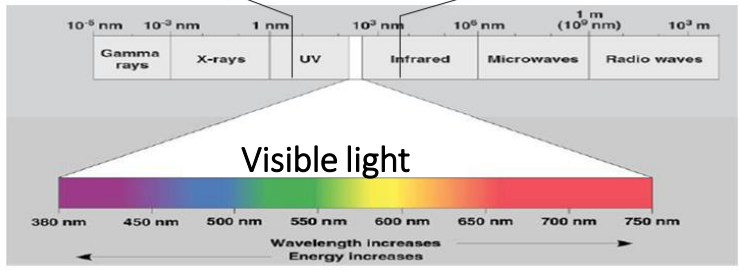
Period	from 1-April. 2016 to 15-sept.2016
Time step	every 5 days * every hour of the day
Spectral bands	

Adjustment simulations

Solar spectra



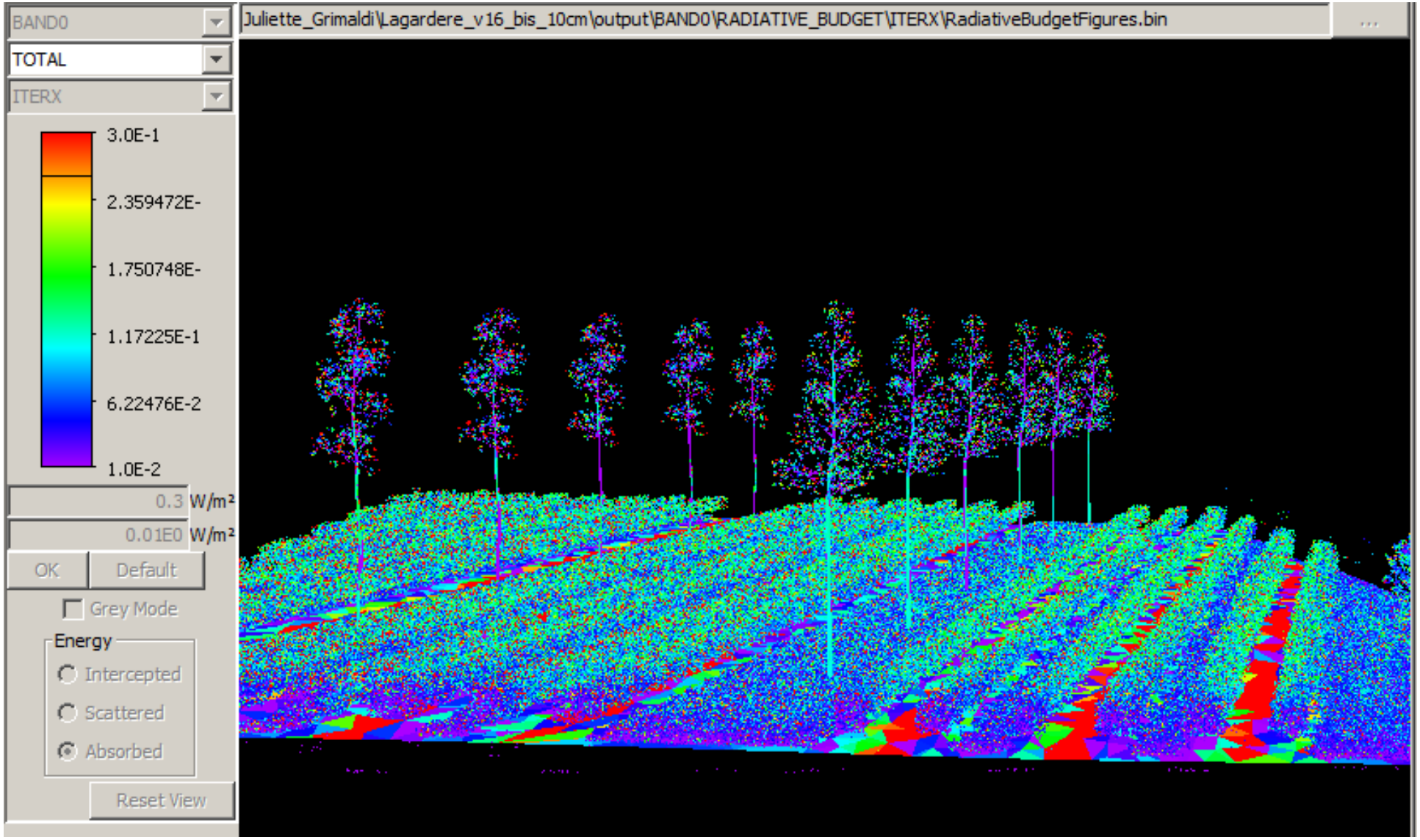
Thematic simulations



Phtotosynthetically Active Radiations

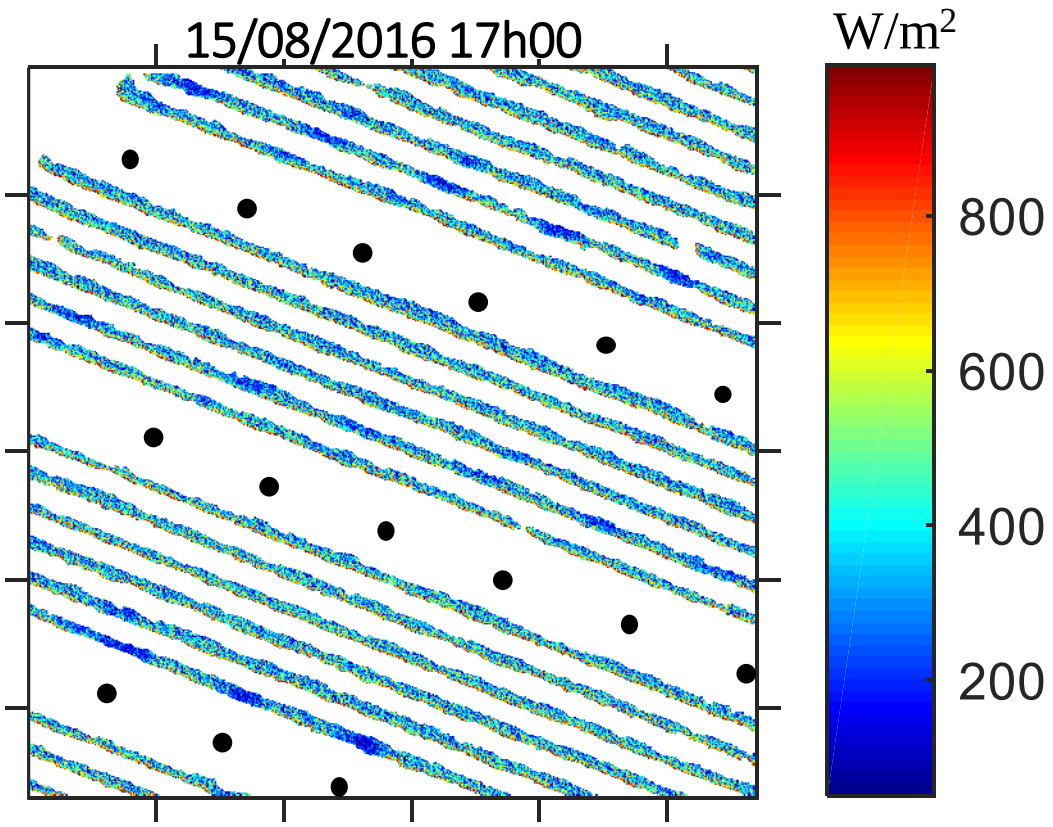
Results

Instantaneous 3D radiative budget in the PAR waveband



Instantaneous energy absorbed by grapevine (2D projection)

Arrangement : BIG TREES orientation W/E



Clear sky

E^{PAR}_{tot} = 300 W/m^2

SKYL = 0.4

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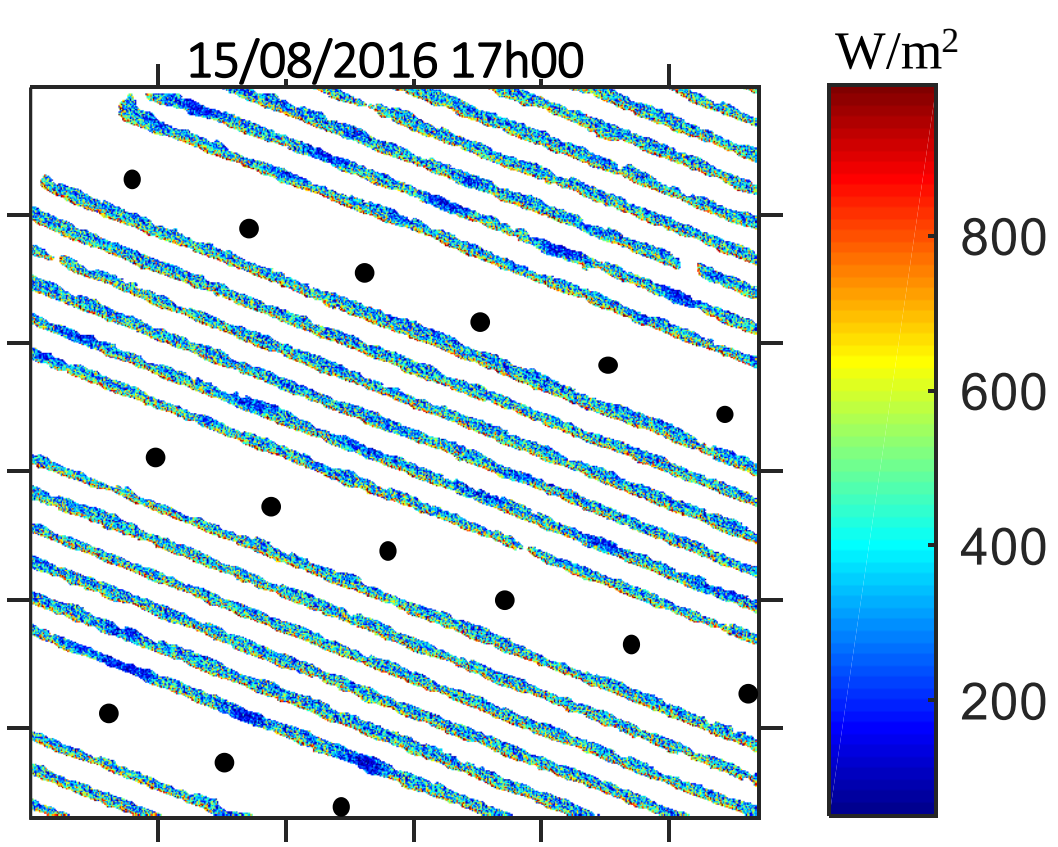

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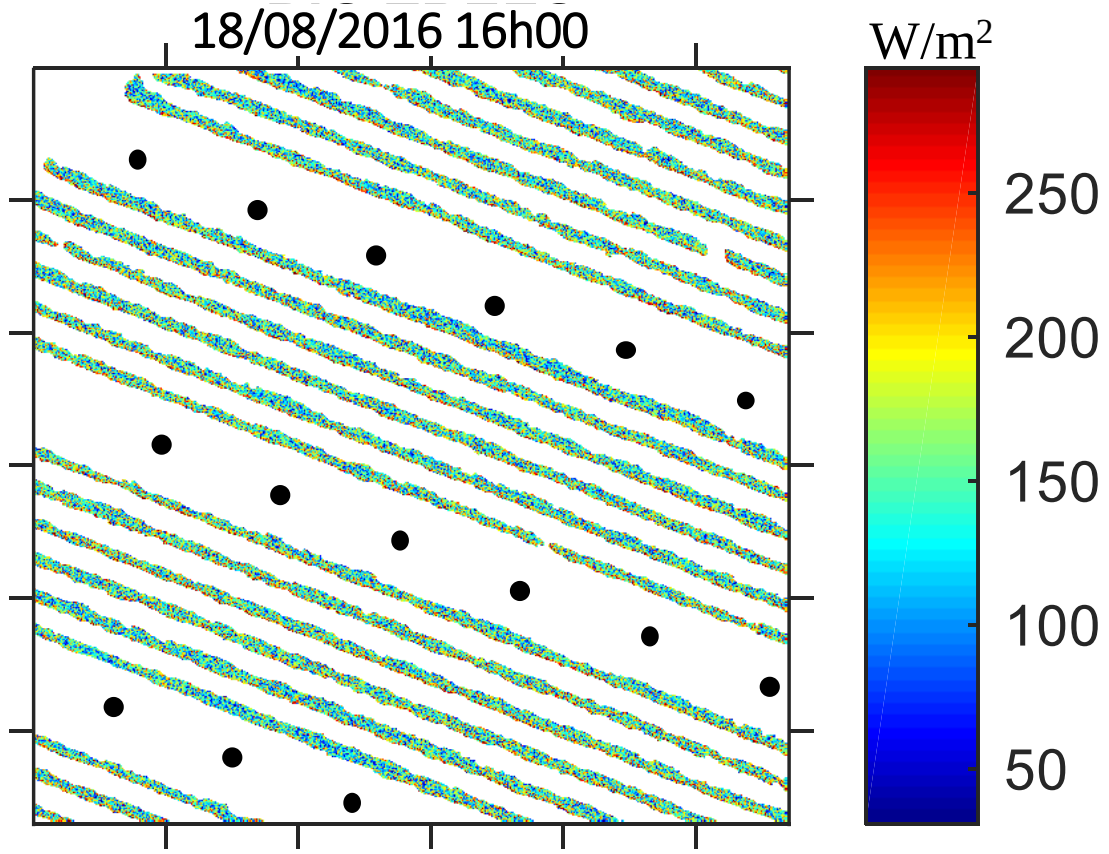


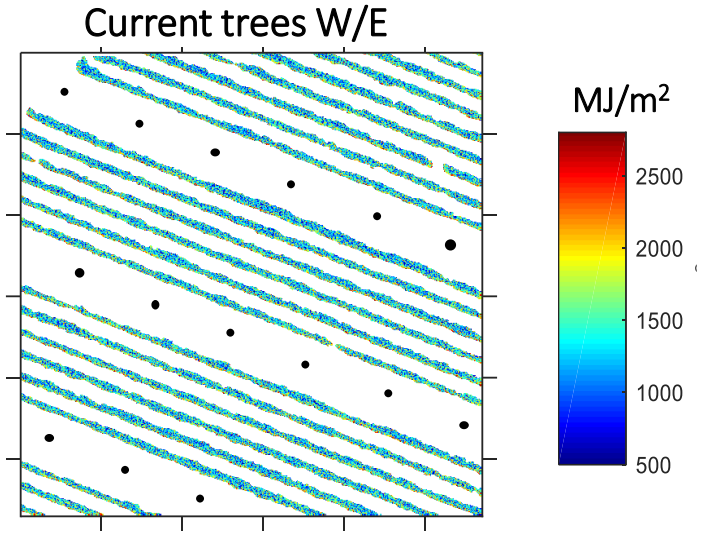
Overcast sky

E^{PAR}_{tot} = 120 W/m²

SKYL = 0.99

Cumulated energy absorbed by grapevine from budburst to harvest, in 2016 (2D projection)

Variability in space



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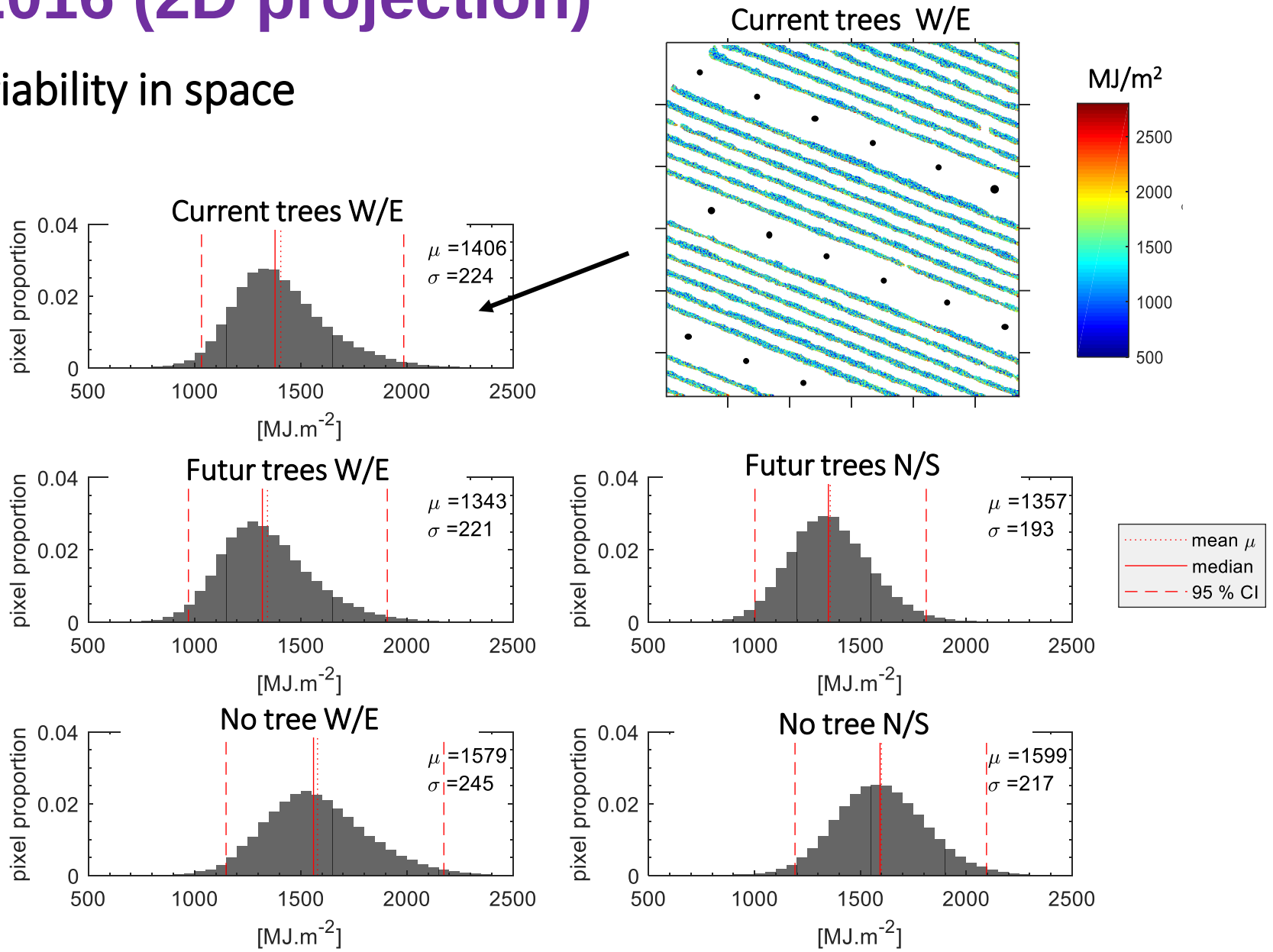
Variability in space



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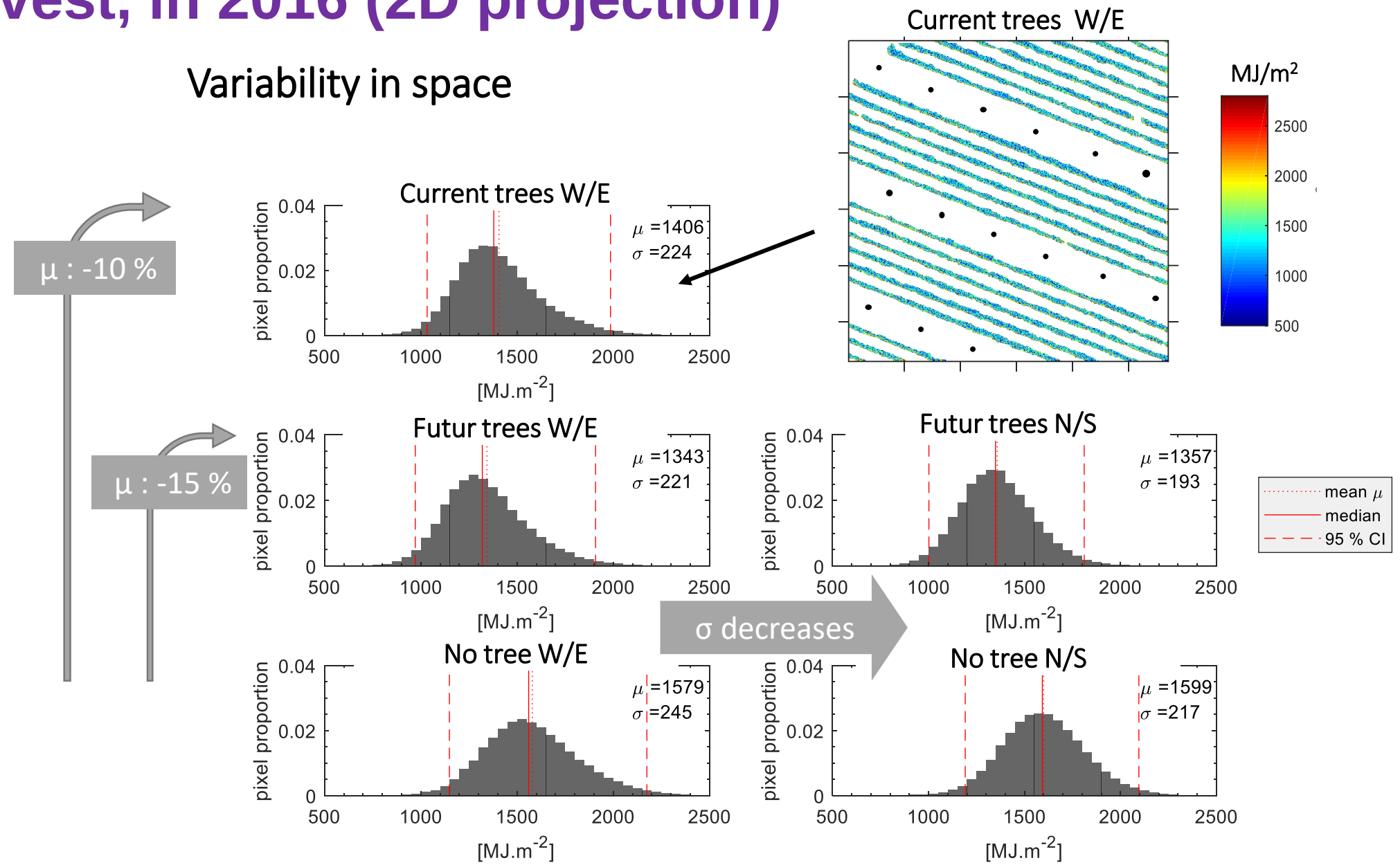
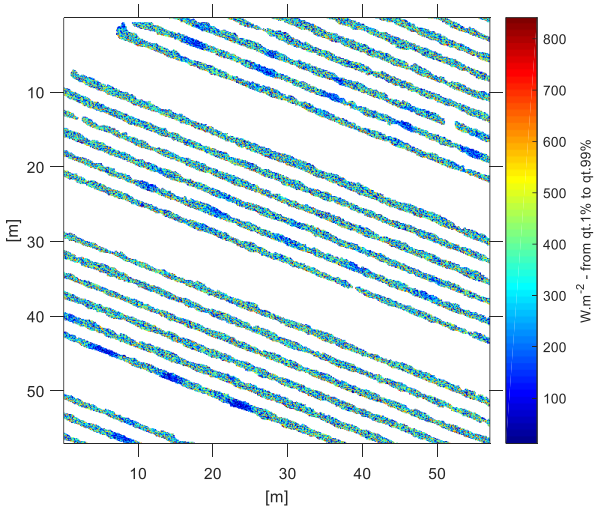


How important are « details » ?

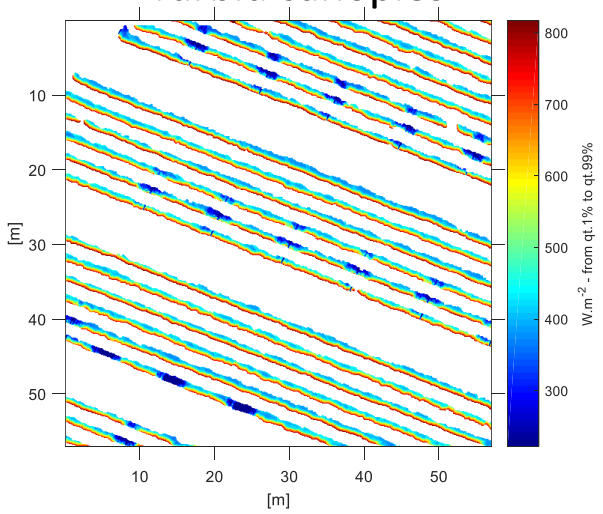
15/04/2016 15h00

E^{PAR}_{tot} = 370 W/m²
SKYL = 33 %

3D objects + diffuse light + scattering



Turbid canopies



→ Tree: Turbid trees allowing sunflecks equival object representations

→ Vine: the climate of turbid and object representations differ at plant scale

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15/04/2016 15h00

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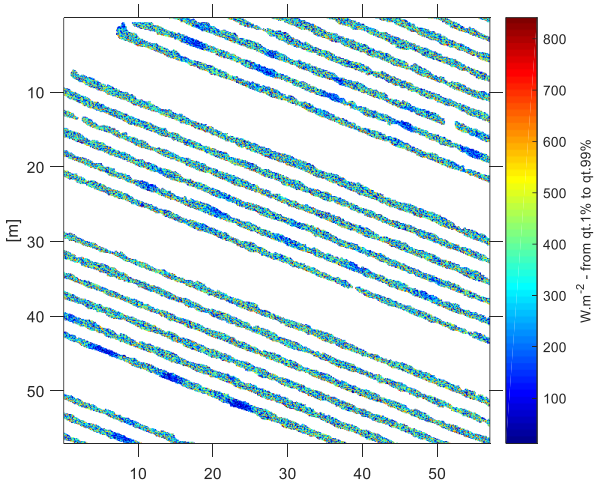
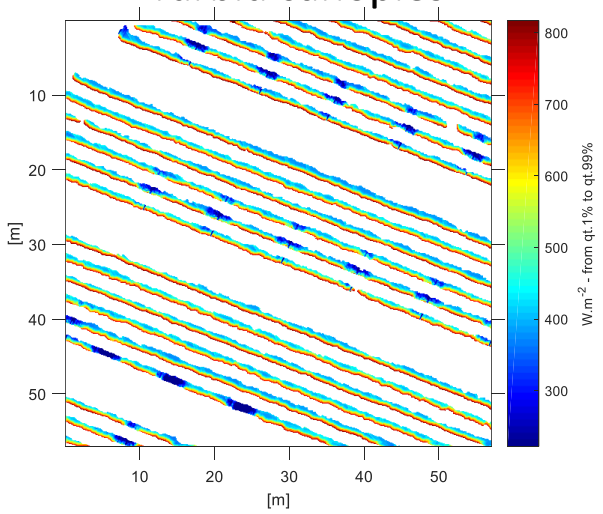
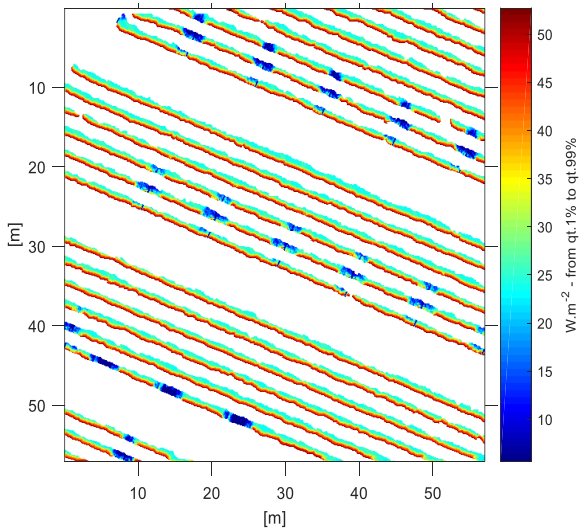


Turbid canopies



Turbid + direct light only + no scattering

SKYL = 0 %



→ Tree: Turbid trees allowing sunflecks equival object representations

→ Vine: the climate of turbid and object representations differ at plant scale

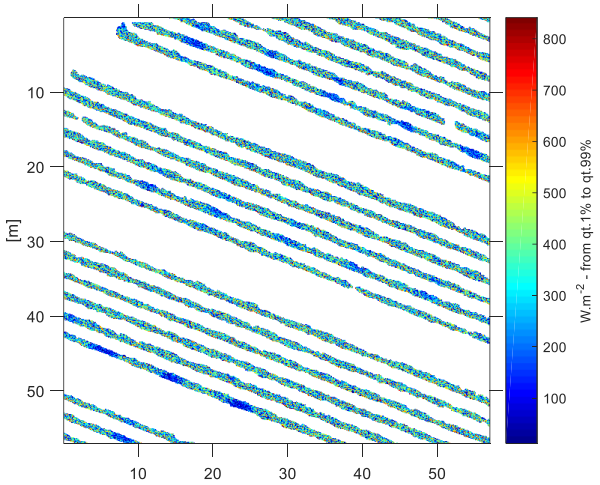
→ Diffuse PAR and multiple scattering show important contribution to radiative budget

How important are « details » ?

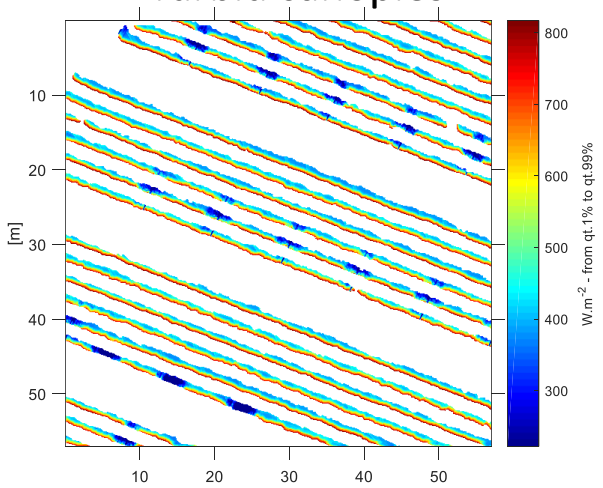
15/04/2016 15h00

E^{PAR}_{tot} = 370 W/m²
SKYL = 33 %

3D objects + diffuse light + scattering

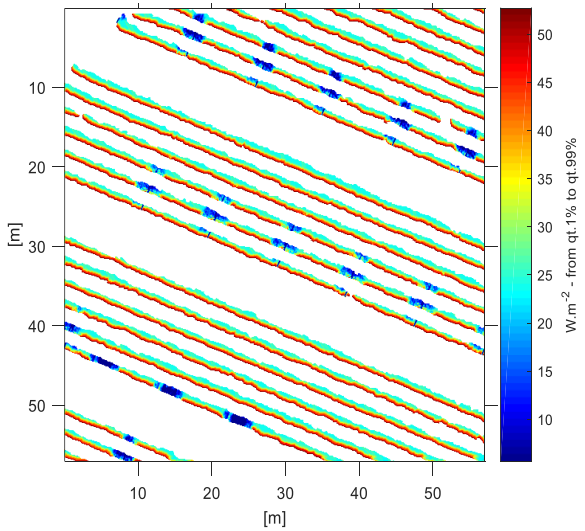


Turbid canopies

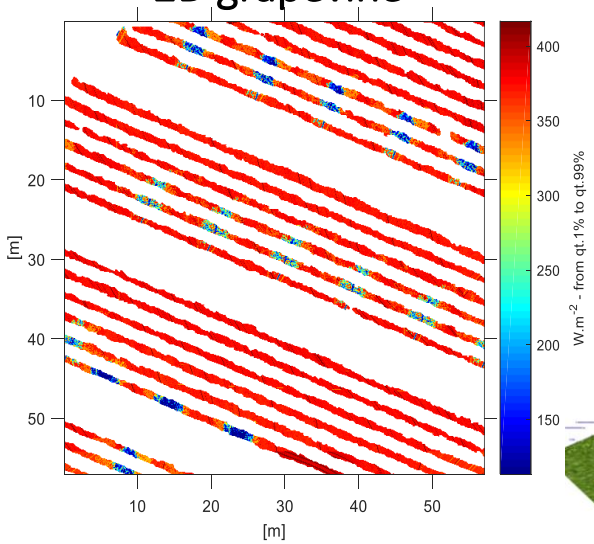


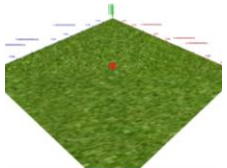
SKYL = 0 %

Turbid + direct light only + no scattering



2D grapevine





→ Tree: Turbid trees allowing sunflecks equival object representations

→ Vine: the climate of turbid and object representations differ at plant scale

→ Diffuse PAR and multiple scattering show important contribution to radiative budget

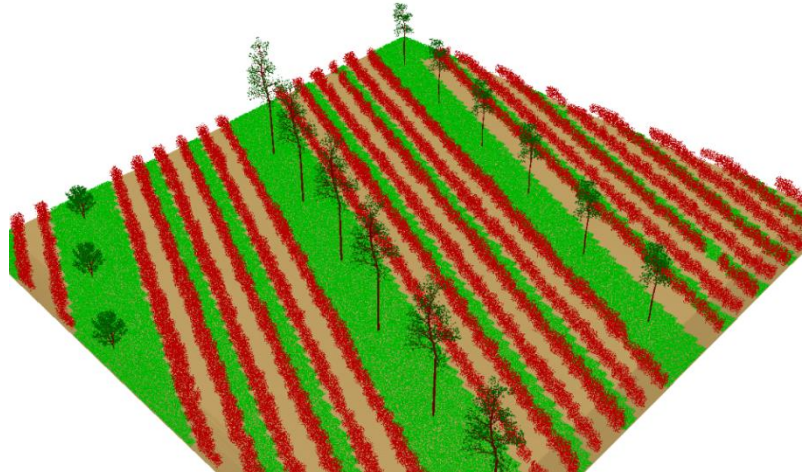
→ Modelling 3D architecture of grapevine is essential

Conclusions and perspectives

First references ever obtained

- ✓ Shading from AF trees show low impact on the available PAR in this context.
- ✓ Orientation only impacts spatial variability of light absorbance.
- ✓ Methodological approach:
  - ✓ Calibrated meteorological sequence
  - ✓ 3D representation of vegetation

→ An infinity of new contexte and arrangements can be modelled



Limitations and perspectives for improvements

ATTENTION!

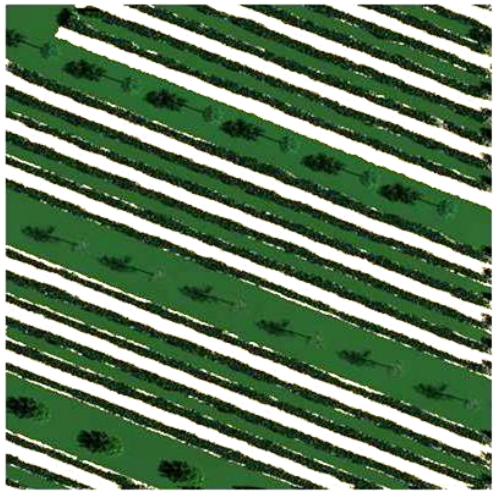
Too intense cloudiness in the PAR due to modelling cloud with aerosol phase functions. → **Tree shade is certainly understimated under clear-sky conditions or moderate cloudiness**	New runs of simulations are being processed with a new version of DART allowing more accurate modelling of clouds
Tree foliage density seems low	Searching for new tree models
NOT YET VALIDATED vegetation optical properties	Spectrometer measures / Simulation of images

Perspectives for optical parameters correction: simulated image vs. UAV borne image

Captured RGB Image

Simulated image

Agroforestry area



No tree area

Thank you for your attention!

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