



北京林业大学
Beijing Forestry University



北京师范大学
BEIJING NORMAL UNIVERSITY

2023 RAMI workshop on Radiative Transfer Modelling

LESS: a ray-tracing based 3D radiative transfer model for realistic forest canopies

Jianbo Qi , Donghui Xie, Kun Zhou, Guangjian Yan

Beijing Normal University, Beijing, China

Contact: jianboqi@bnu.edu.cn

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Outline

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Introduction of the LESS model

02

Applications of LESS in remote sensing

03

Future developments of LESS

04

Concluding remarks



Outline

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Introduction of the LESS model

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Applications of LESS in remote sensing

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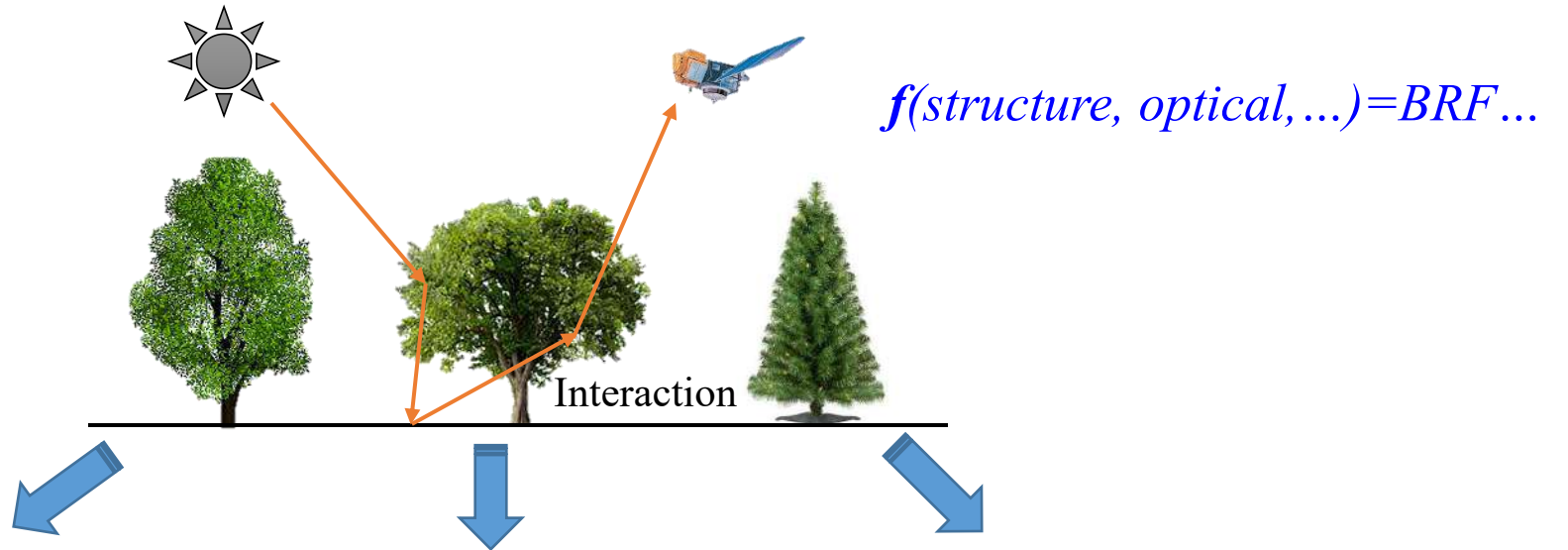
Future developments of LESS

04

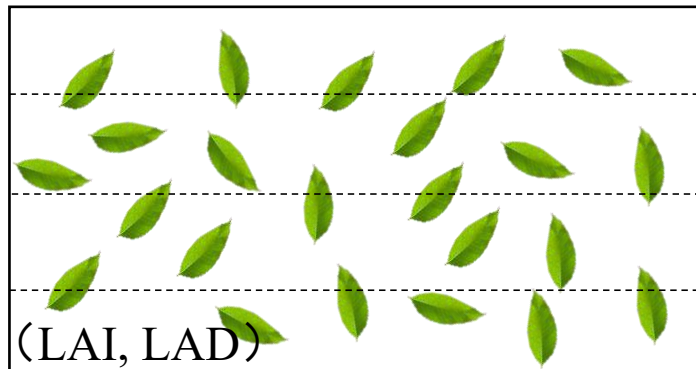
Concluding remarks

01 Introduction of the LESS model — Motivation

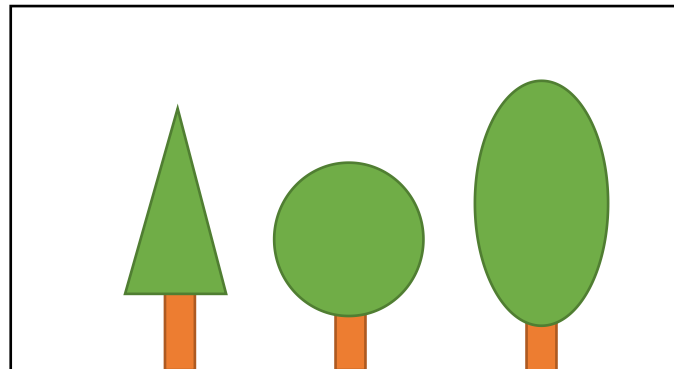
□ Radiative transfer model



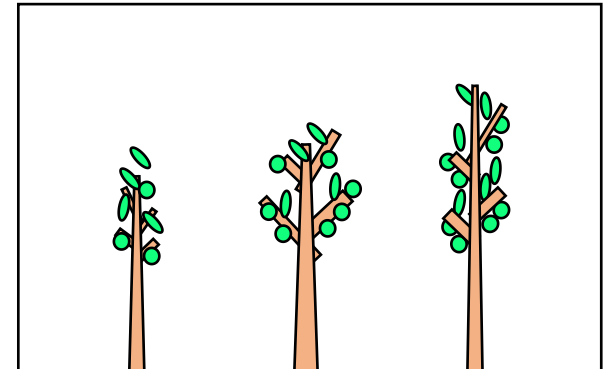
1D Radiative transfer model



Geometric-optical model



3D Radiative transfer model

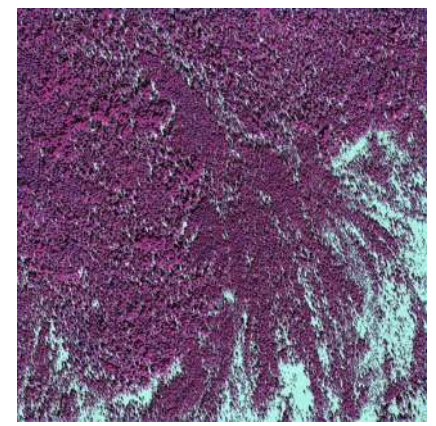
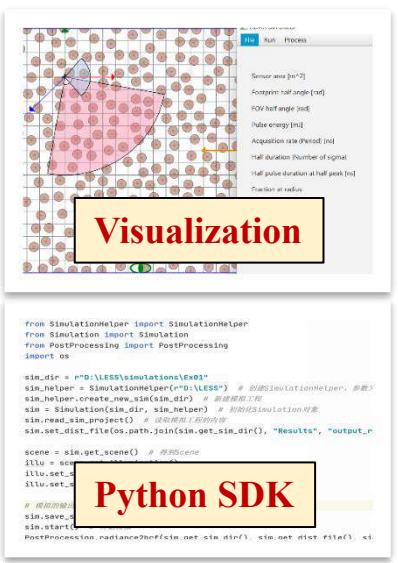
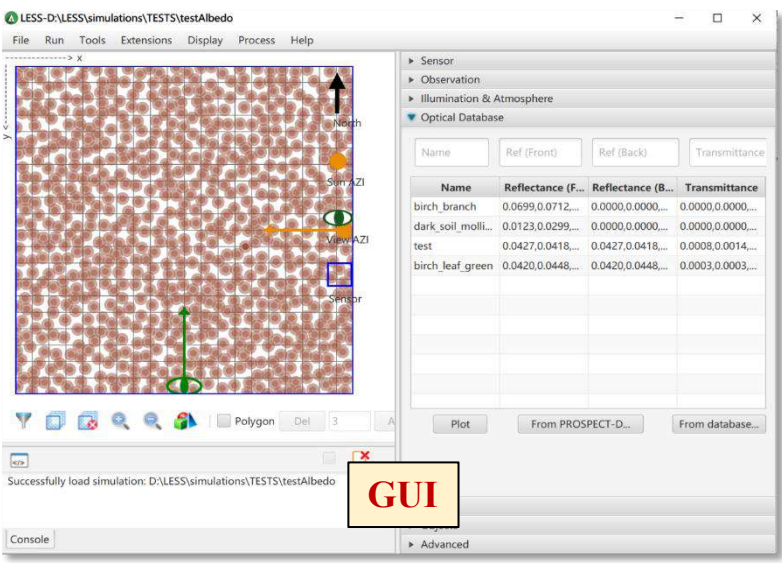


01 Introduction of the LESS model — The LESS model

LESS is an efficient ray-tracing based 3D radiative transfer model that can simulate:

- Multispectral/Hyperspectral images
- Bidirectional Reflectance factor (BRF)
- Thermal infrared images
- LiDAR signals
- Photon recollision probability,...

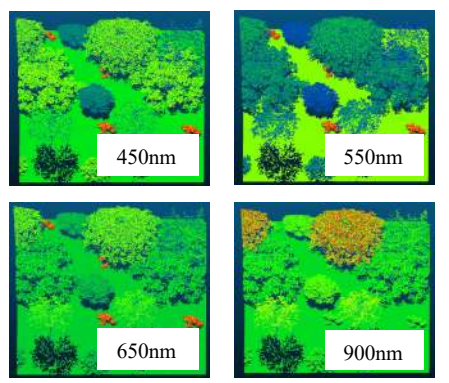
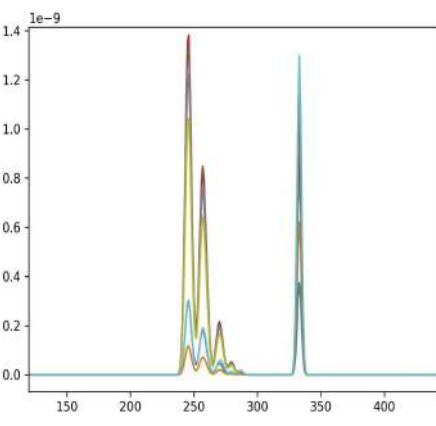
It also provides an easy-to-use GUI, and Python SDK:



Multispectral images(1km)



Fisheye images

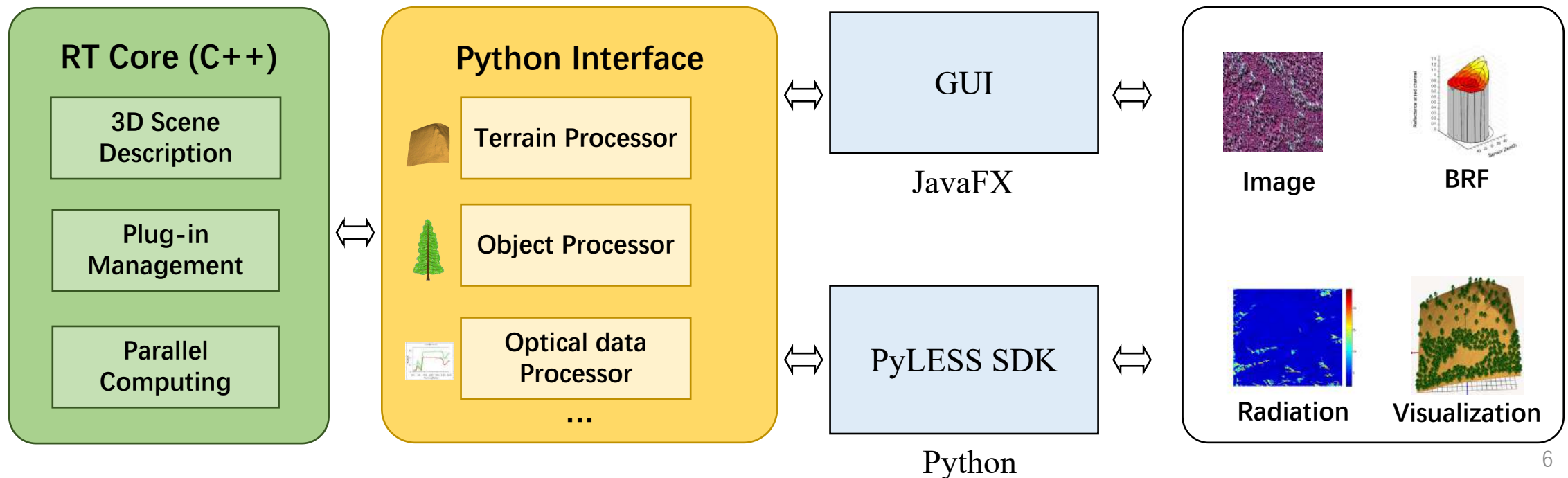


Hyperspectral LiDAR Waveform and point cloud

<http://lessrt.org/>

01 Introduction of the LESS model — The LESS model

- Developed since 2013 at Beijing Normal University, and formally released in 2019.
- The RT computation core is based on a heavily modified version of Mitsuba (V0.5), utilizing **the most recent technique from computer graphic community**.
- LESS has a flexible software architecture, providing **both Python SDK and Graphic User Interface (GUI)**.
- LESS implements both **forward ray-tracing and backward ray-tracing** for simulating various remote sensing signals.



01 Introduction of the LESS model — The LESS model

- LESS new versions are released at the website: <http://lessrt.org>, around 1~2 month per version.
- We provide a detailed user manual for both English and Chinese, and also video courses (Chinese only now).
- We provide ready-to-use RAMI scene for LESS.

Download LESS

New release:

If you have problems under Windows, please refer to [problems under windows](#) [注: 请不要使用中文路径]

2023-05-18 (version 2.1.1-2023-05-18):

Windows: [LESS-2.1.1-2023-05-18-win64](#). (百度网盘下载: [LESS-2.1.1-2023-05-18-win64](#))

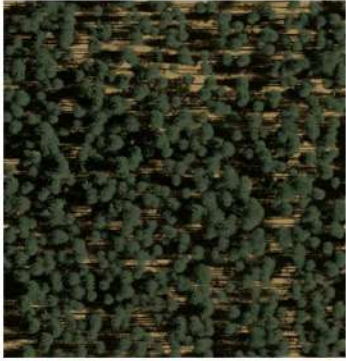

- We are pleased to announce that we added a very useful tool to generate python code automatically from GUI. (Tools->Generate Python Code), this tool automatically generate a python code according to the parameters you set with GUI. With this code (and the provided Python SDK), you can simply modify it and run without GUI. You can easily do the batch processing with this new features by loop some of parameters.
- The Python interpreter embedded within LESS has been upgraded to Python 3.10
- New alphashape algorithm has been implemented for the tool [【3D Forest From LIDAR \(ALS\)】](#), which has much more higher efficiency.
- The 3D display of object (in 3D object viewer) can choose to display selected groups only.

2023-04-11 (version 2.0.4-2023-04-11):

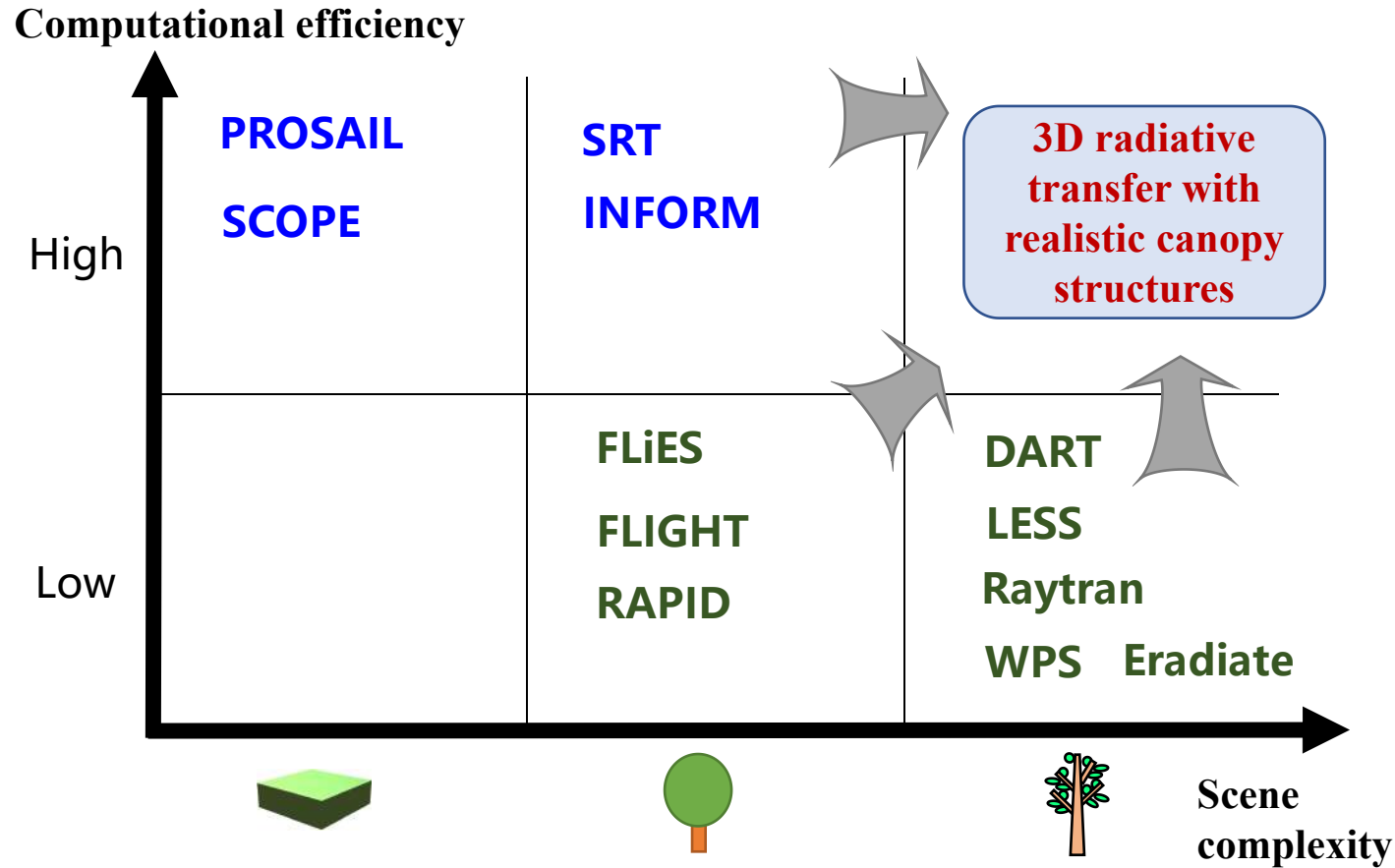
Windows: [LESS-2.0.4-2023-04-11-win64](#). (百度网盘下载: [LESS-2.0.4-2023-04-11-win64](#))

- A new module to convert ALS point cloud into LESS simulations([【Tools】 【3D Forest From LIDAR \(ALS\)】](#)). This tool automatically filters the point cloud, segments tree crown, estimates leaf area density, etc.
- The Python SDK supports runtime modification of solar and view angles, leaf and soil spectral properties, which enables to fast simulate reflectance when changing optical properties without modifying structural properties if required.

2023-03-02 (version 2.0.1-2023-03-02):

3	HET09_JBS_SUM		LAI Leaf: 3.835 LAI Wood: 1.934	0.557	百度网盘 Google Drive	PIAB shoot ACPL leaf ALGL leaf BEPE leaf FREX leaf POTR leaf TICO leaf
4	HET14_WCO_UND		LAI Leaf: 2.703 LAI Wood: 0.460	0.394	百度网盘 Google Drive	

01 Introduction of the LESS model — The LESS model



Analytical model: Describe complex canopy structures with analytical equations (new mathematical tools)

3D models: Implement computationally efficient radiative transfer simulations (acceleration, e.g., GPU, new numerical algorithms.)

How to describe 3D canopy structures?

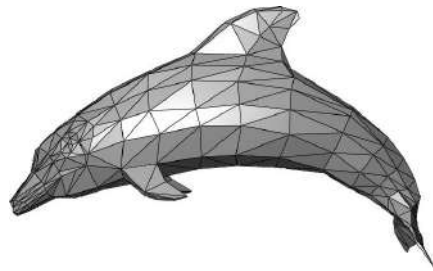


How to realize 3D radiative transfer simulation?

01 Introduction of the LESS model — 3D canopy representation

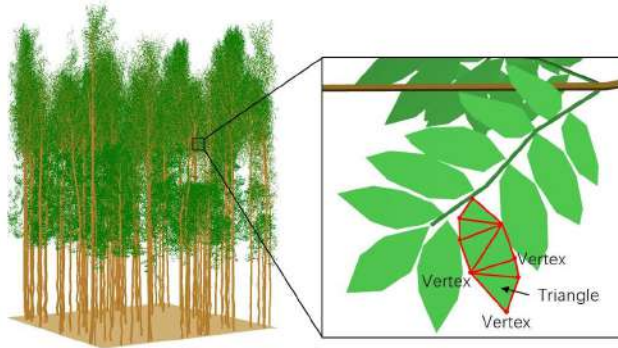
□ Triangle mesh

- A **set of triangles** to represent objects.



Example

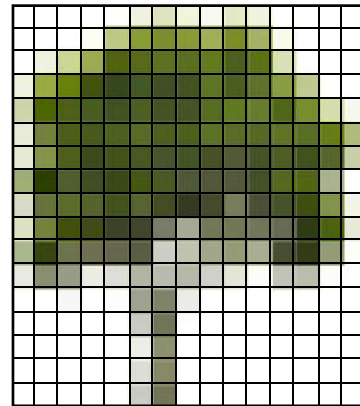
Triangle mesh representing a dolphin
(from *wikipedia*)



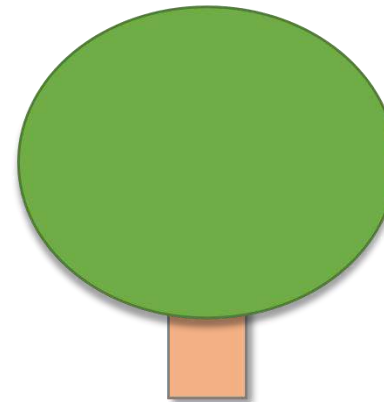
Triangle mesh representing forest

□ Turbid medium

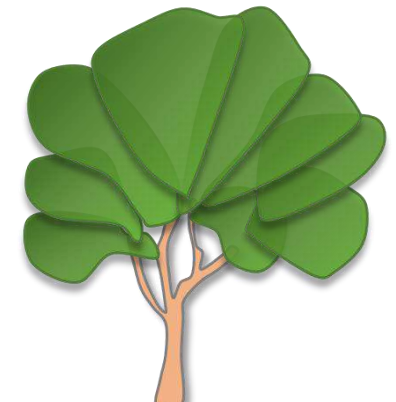
- **Canopy elements**, such as leaves, are assumed to be **infinitely small**, and are described with several **statistical parameters**.
- Usually, turbid medium is **bounded** by voxels, simple geometry objects, etc.



Regular voxel



Simple objects



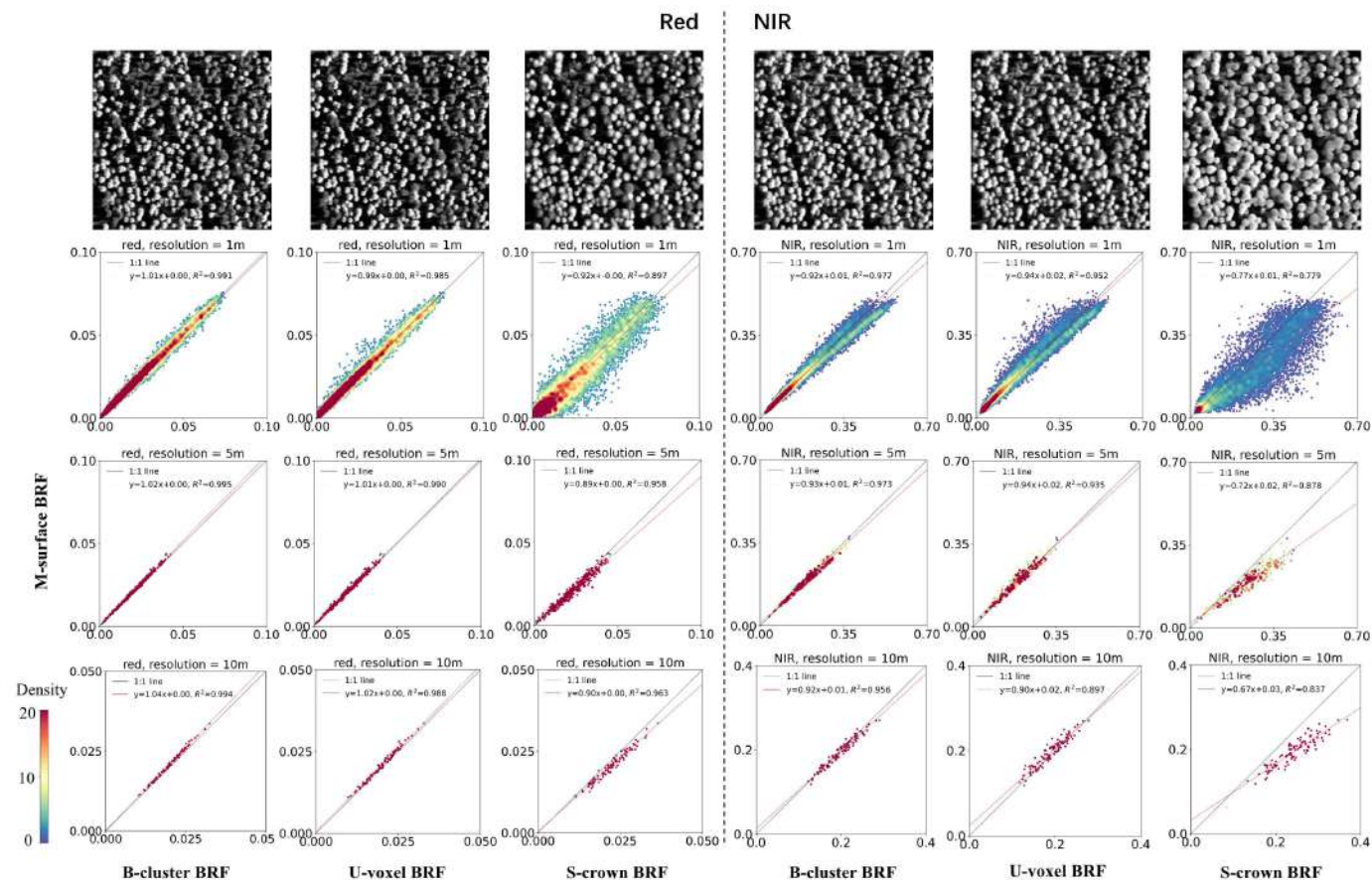
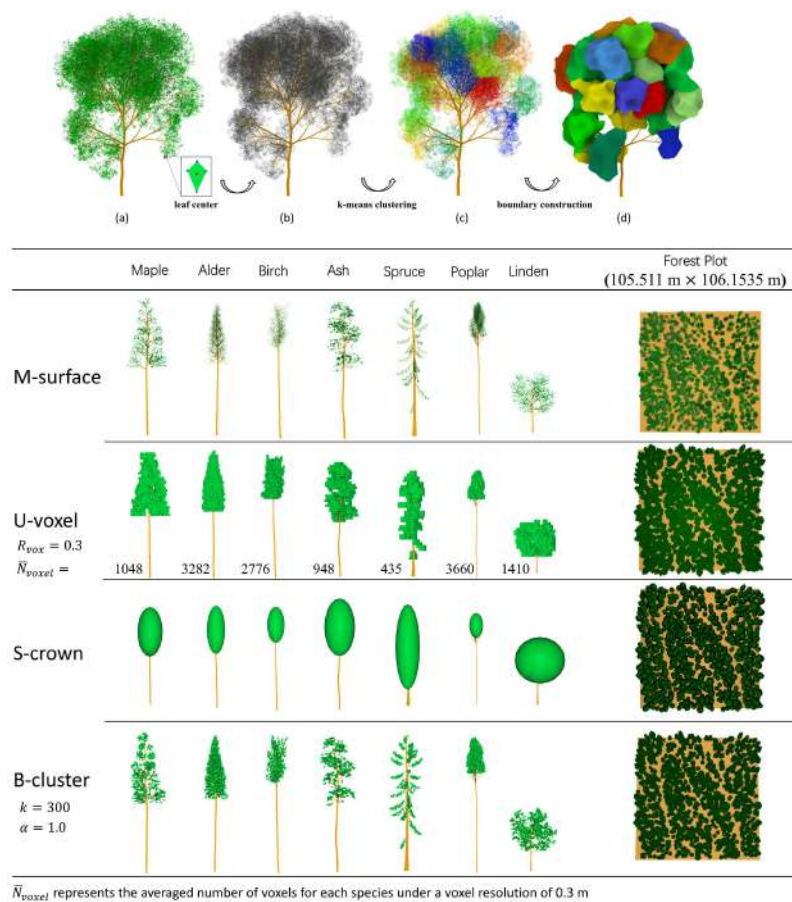
Alphashape

Example

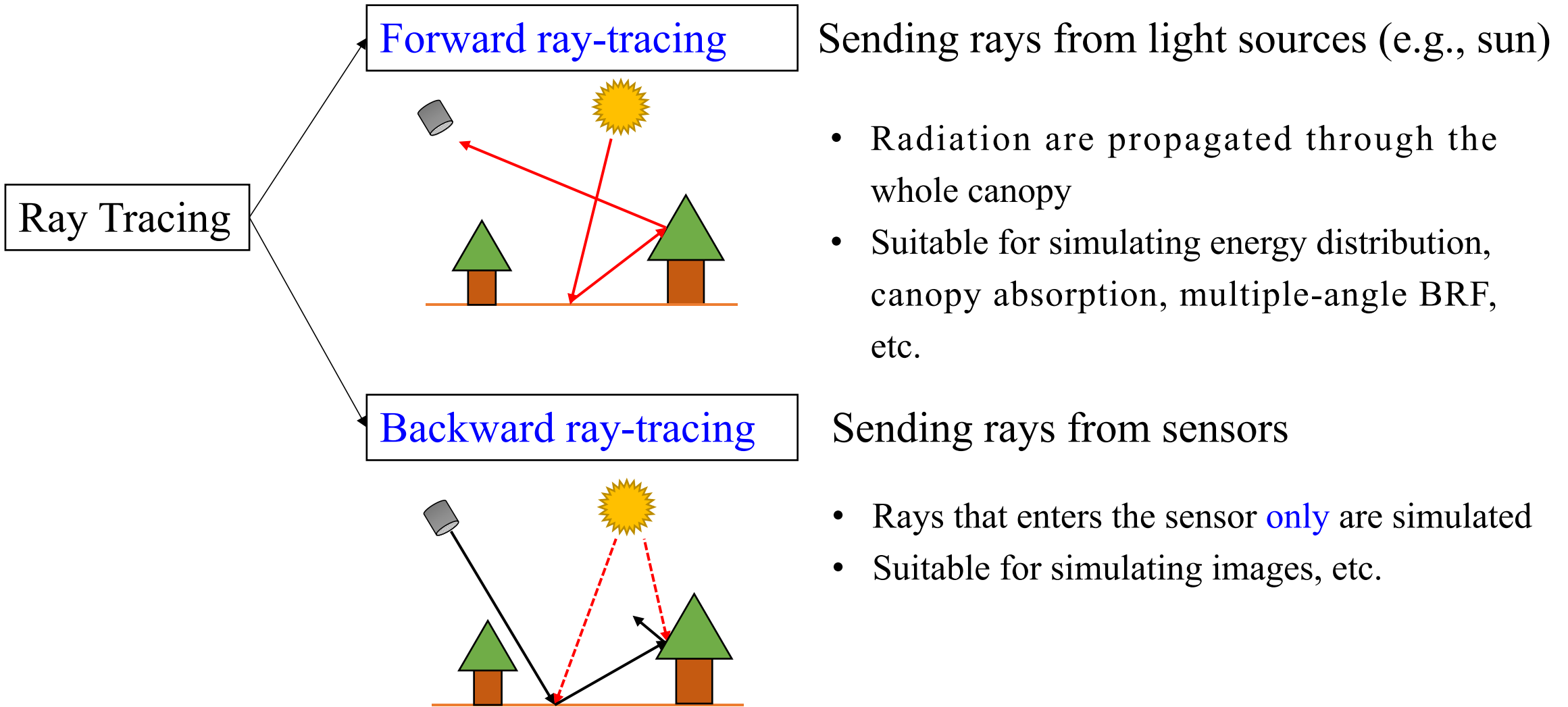
01 Introduction of the LESS model — 3D canopy representation

□ Turbid medium

- Comparing alphashape with triangle mesh representations.

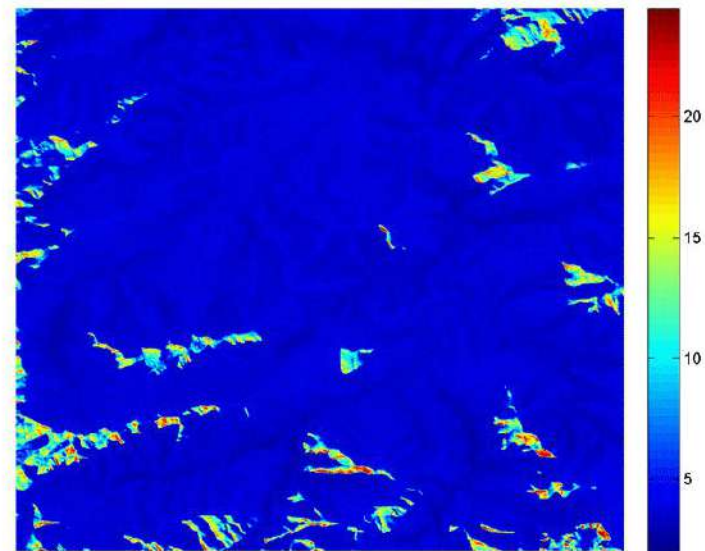
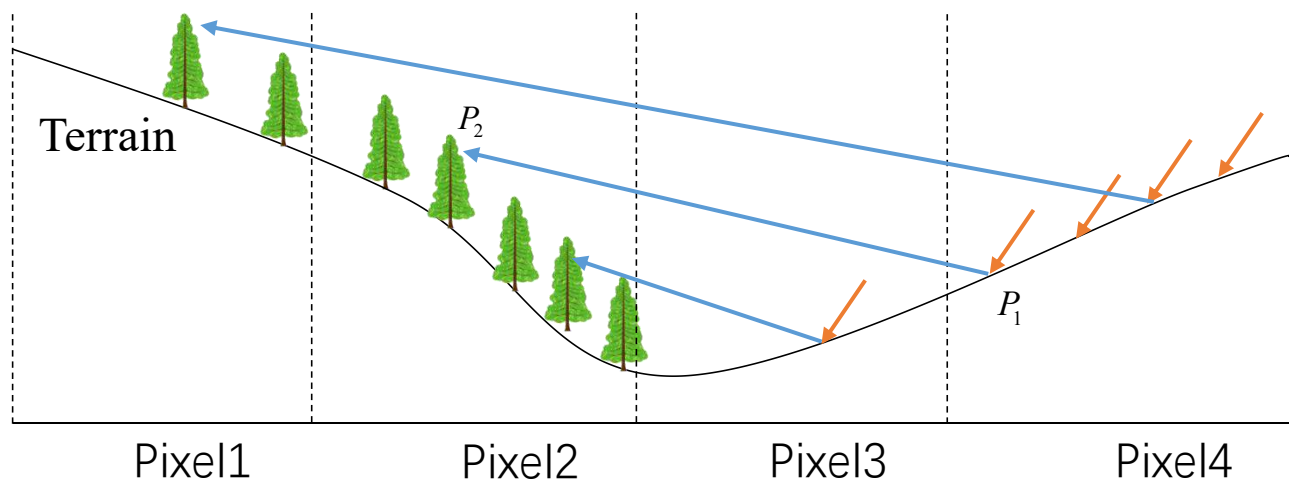


□ Ray tracing in LESS



□ Functionalities beyond BRFs and images

- Solar radiation over rugged terrain

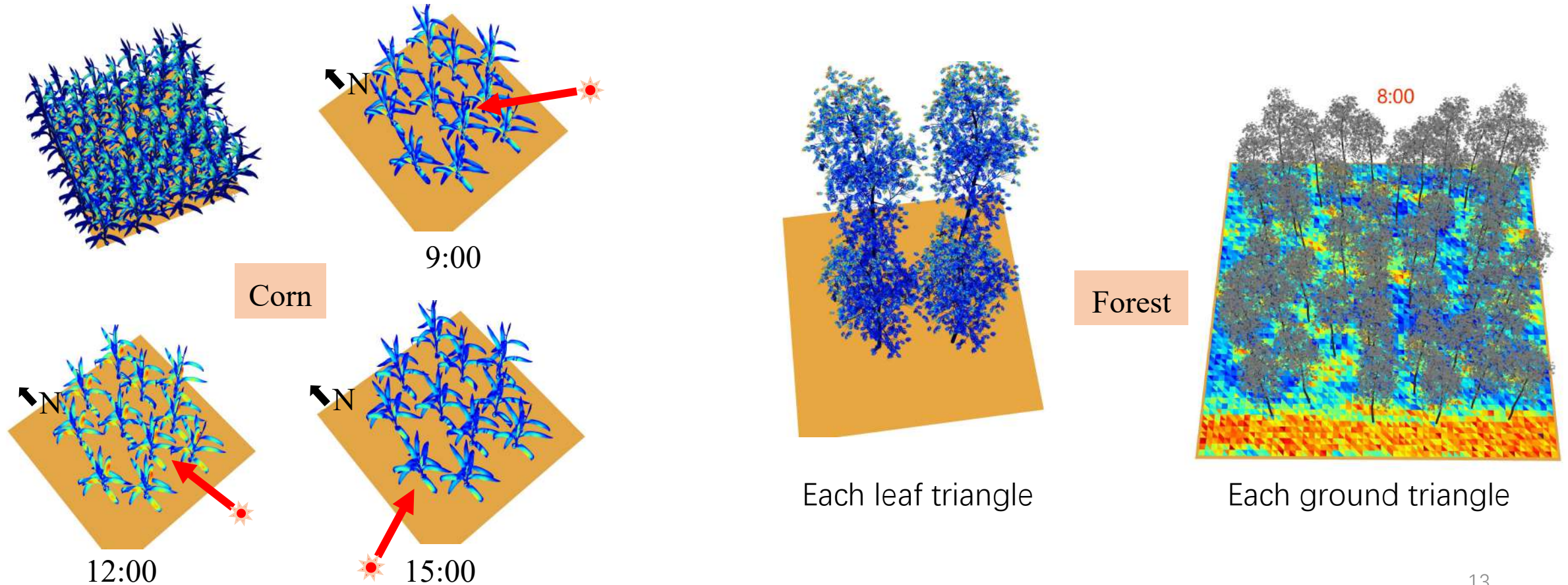


Record the incident and outgoing radiation for each pixels over rugged terrain with complex vegetation

01 Introduction of the LESS model — RT simulations

□ Functionalities beyond BRFs and images

- Absorbed energy per each triangle





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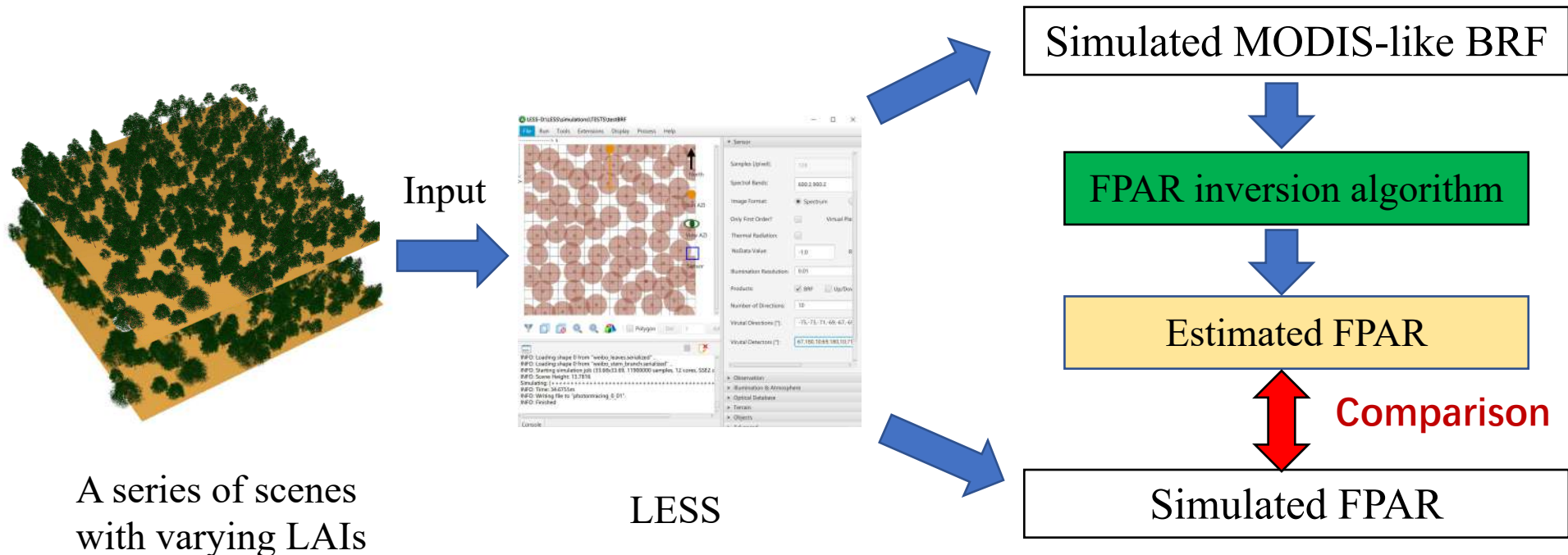
Future developments of LESS

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Concluding remarks

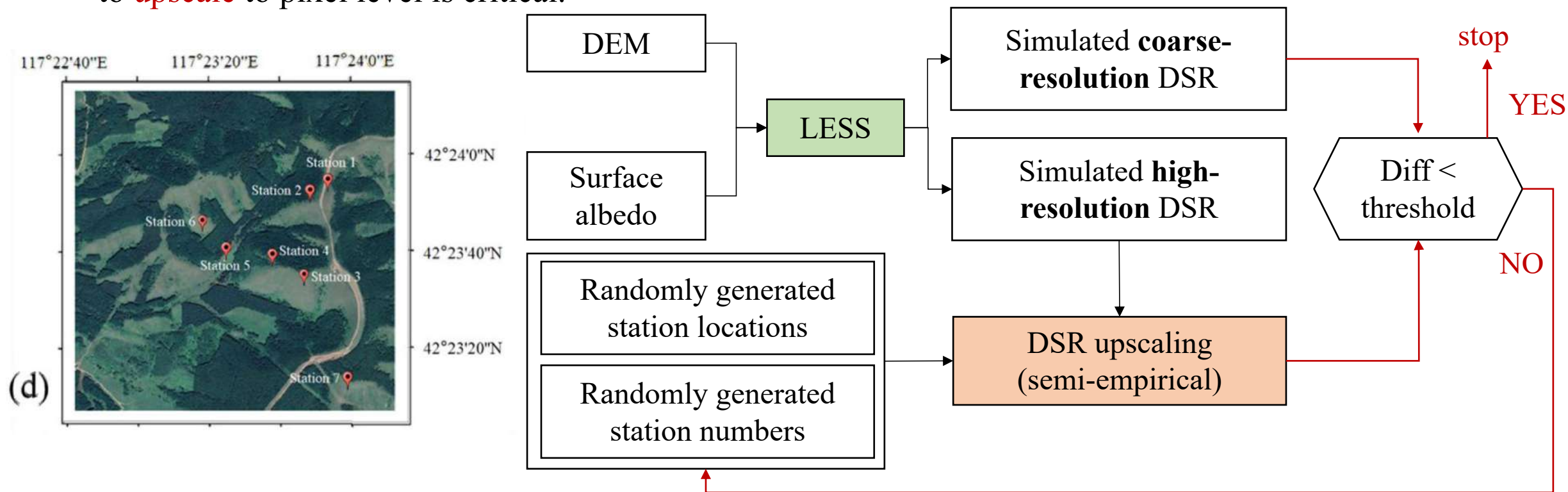
□ Case 1: Validation of FPAR inversion algorithm

Using **LESS-simulated FPAR** and its **corresponding BRF** to validate coarse-resolution FPAR inversion algorithm, with wood absorption considered.

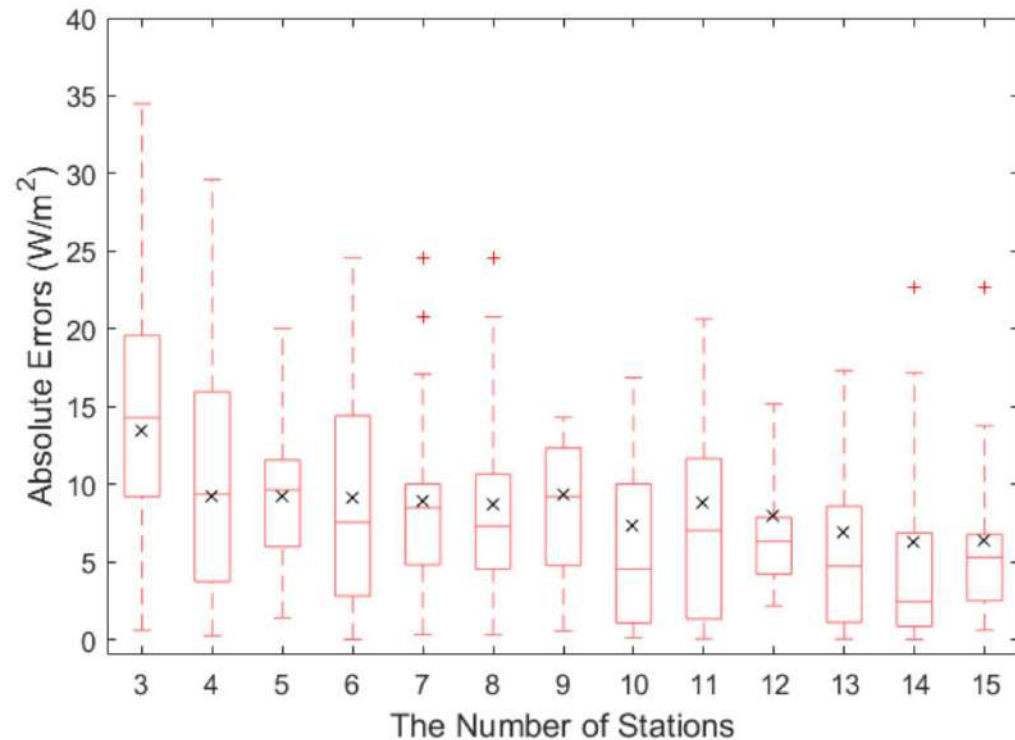


□ Case 2: Optimize DSR measurements over rugged terrains

- Validating **coarse-resolution DSR** is difficult because field measurements only cover a **point**.
- A method to choose **optimized measurement ground stations** (number and locations within the pixel) to **upscale** to pixel level is critical.

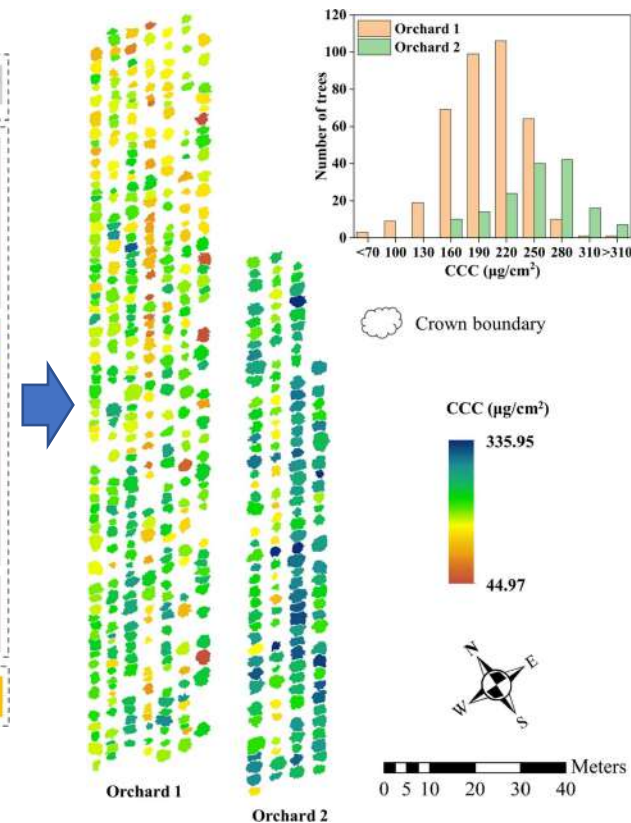
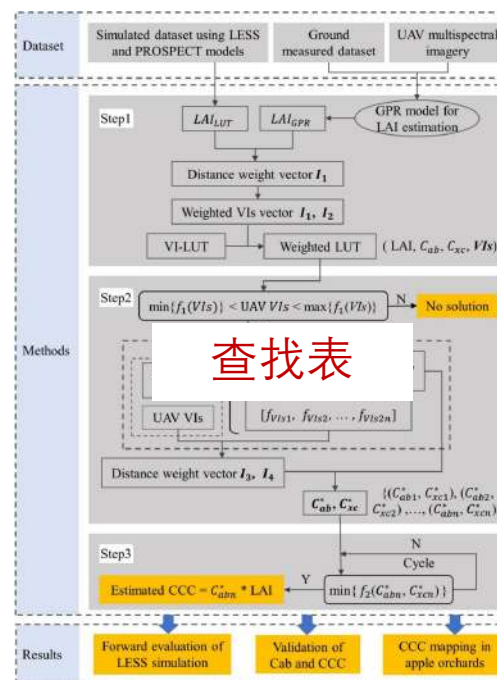
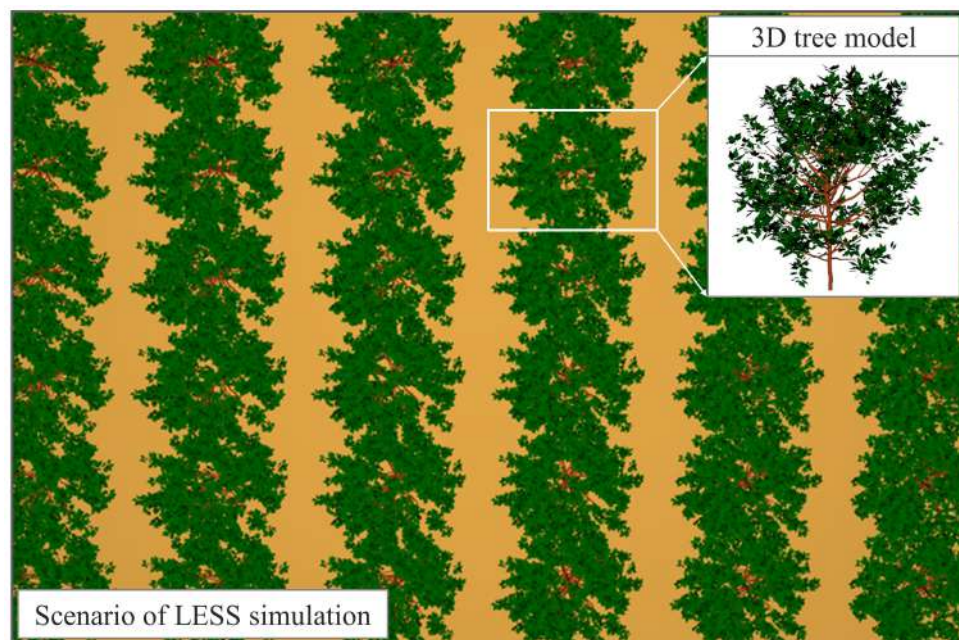


- Case 2: Optimize downward shortwave radiation (DSR) over rugged terrains
 - Upscaling errors change with the number of ground stations



Case 3: Estimating chlorophyll content at individual tree level

- Generating look-up-tables with LESS simulated BRF over individual apple trees, considering within-crown heterogeneity.



Jinpeng Chen, Hao Yang, et al., Estimating canopy-scale chlorophyll content in apple orchards using a 3D radiative transfer model and UAV multispectral imagery, 2022, Computers and Electronics in Agriculture.



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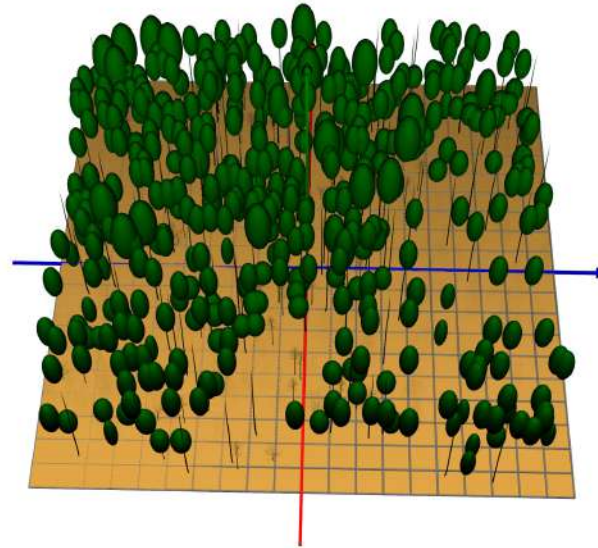
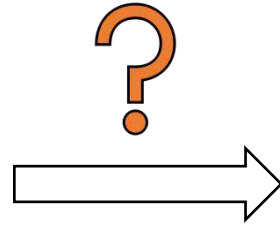
04 Concluding remarks

03 Future developments of LESS

- ❑ Computation efficiency is no longer a major difficulty.

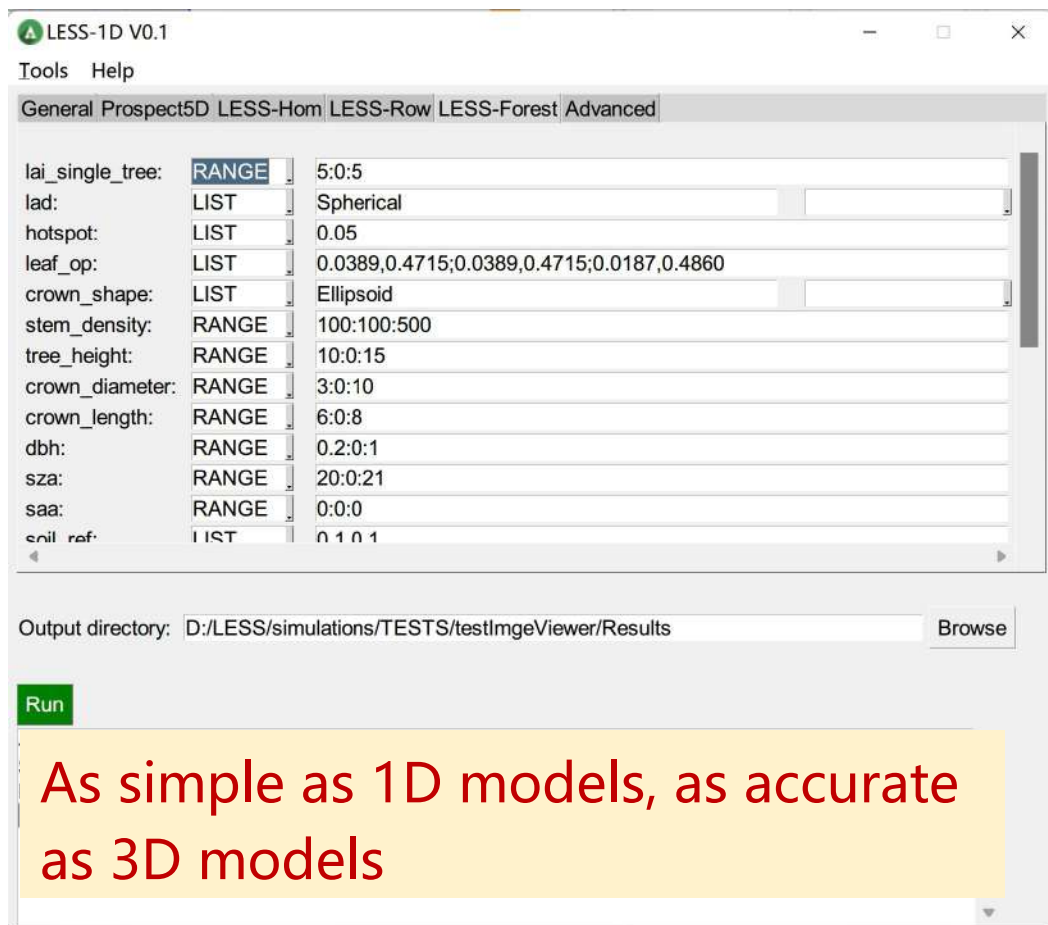
Increased CPU cores, Parallel computing, GPU,...

- ❑ How to construct more realistic 3D scenes matters...



According to our users: Construction of 3D forest scenes has been a major difficulty to use 3D models

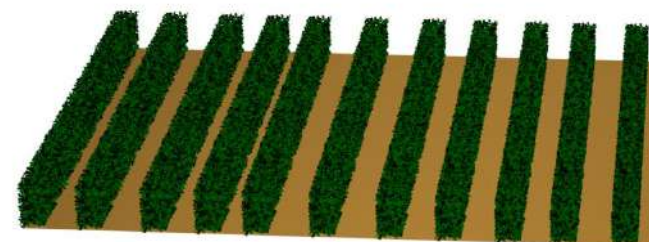
- Automatic generation of scenes according to statistical parameters that are identical to 1D models



LESS-Hom



LESS-Row



LESS-Forest



03 Future developments of LESS

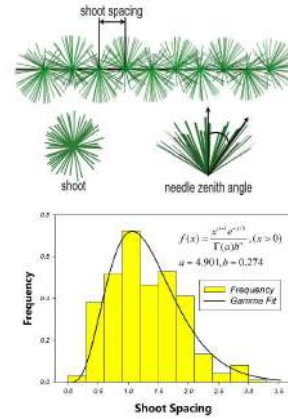
- Generating forest scenes from LiDAR data (TLS)



Point cloud



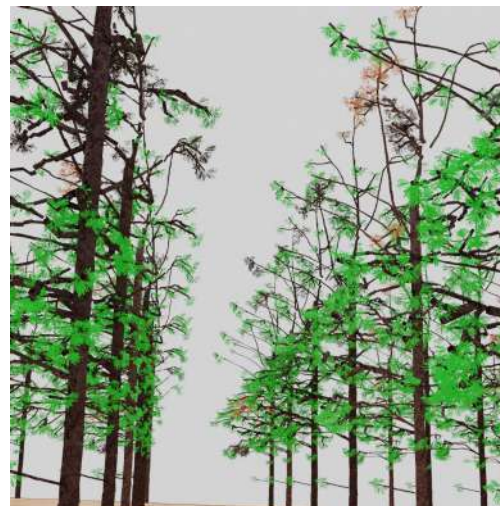
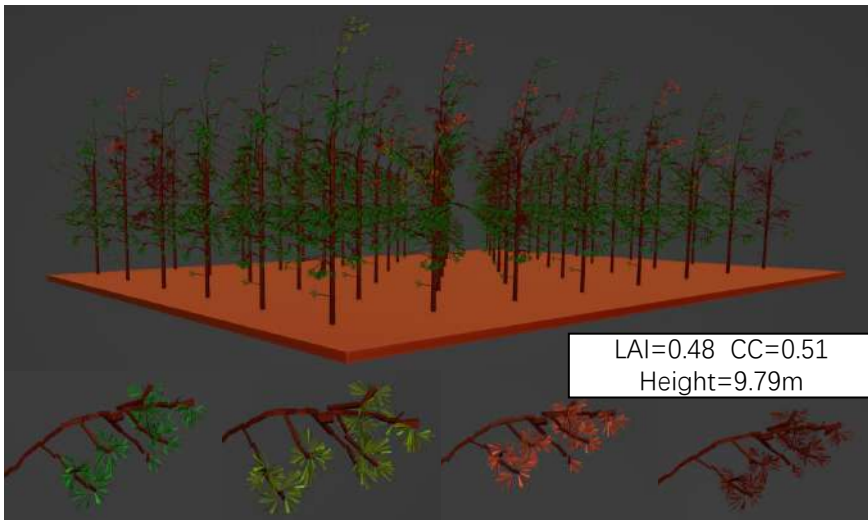
Branch reconstruction



Leaf addition



Individual trees



03 Future developments of LESS

- Reconstruction from Airborne LiDAR point cloud

3D Forest Creation from ALS

This tool will create a LESS simulation which can be customized later.

ALS data path [*.las]:

Crown Type: Voxel Alphashape Ellipsoid Cone Cylinder

Voxel Size [m]:

Segmentation Method: Watershed Hexagon Kmeans (CHM) Kmeans (Points)

Watershed window size [m][4.5 by default]:

Include Understory: Understory height threshold:

PAD Inversion method: Pulse tracing (need gps time) Point number (needs only XYZ)

User defined constant PAD [m2/m3]:

Total scene LAI (e.g., field-measurement):

Leaf Representation: Leaf as facet Single leaf area [m2]:

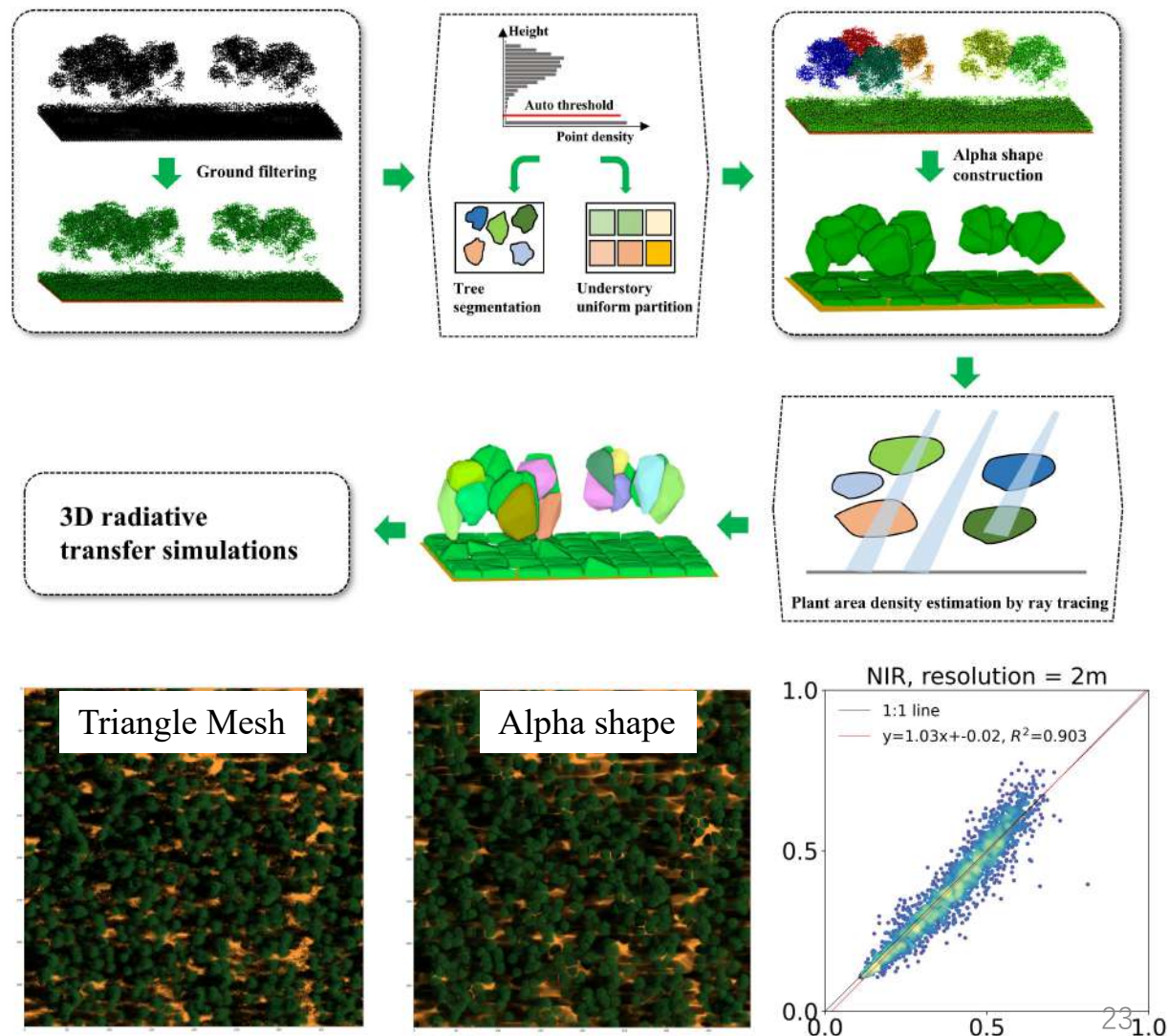
Output Directory:

LESS Project Name:

Leaf Angle Distribution: (for LESS simulations)

Leaf Optical Property: (modify the ref/trans value later)

*Watershed: suitable for sparse forest
*Hexagon: suitable for more dense and uniform canopies
*Kmeans: suitable for all canopies, but may be slower

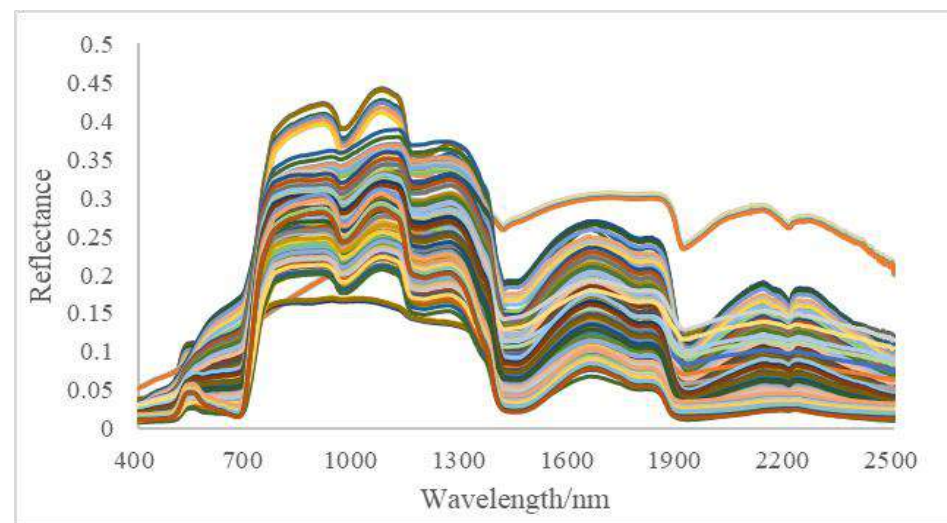
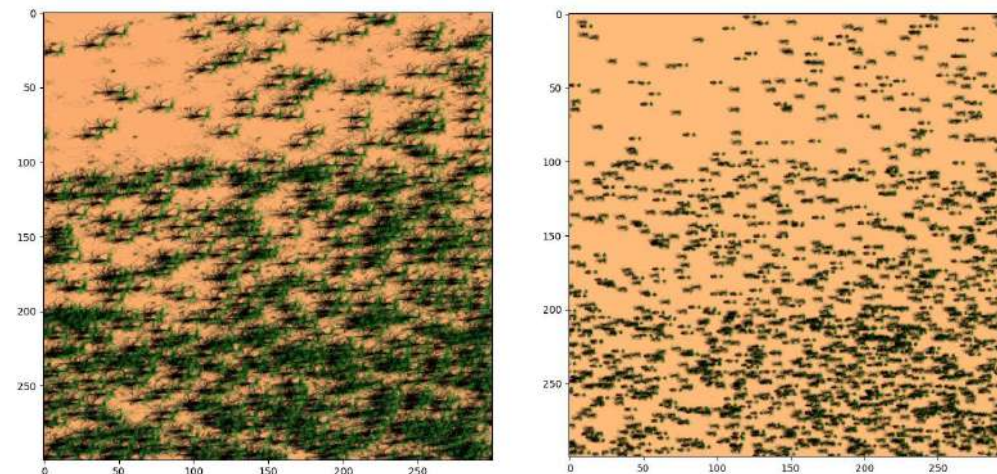


03 Future developments of LESS

- Generating ready-to-use database will facilitate the use of 3D RTM



LESSDB-GRASS: Around 3.7 million spectra range from 400 nm to 2500 nm with a spectral resolution 1 nm over varying grasslands. It can be used to optimize band selection, validate retrieval algorithms...



03 Future developments of LESS

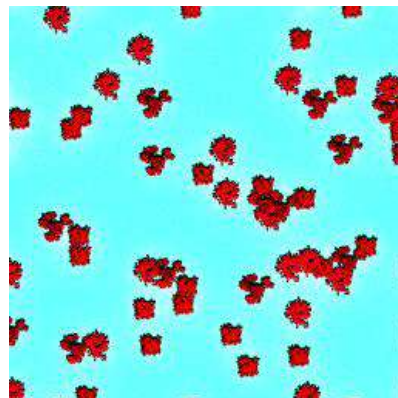
- Estimation of vegetation parameters using 3D RTM is now possible

But methods are to be developed, especially for high spatial resolution applications...

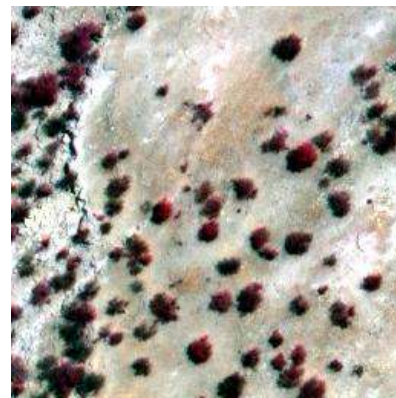
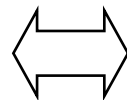
- LiDAR will be an important 3D data source

A lot of LiDAR data are now available...

- Spectral heterogeneity has significant impact on 3D RTM



Simulation



Real

Table 2: Selected countries with airborne LiDAR dataset available for public use.

Country	Uniform Resource Locator (URL)/Helpful Links
Australia	http://www.ga.gov.au/elvis/ http://www.opentopography.org/index.php
Denmark	https://download.kortforsyningen.dk/
Finland	https://tiedostopalvelu.maanmittauslaitos.fi/tp/kartta?lang=en
Germany	https://open.nrw/
Luxembourg	https://data.public.lu/en/datasets/LiDAR-projet-pilote-dun-releve-3d-du-territoire-luxembourgeois/
Netherlands	https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=9039d4ec38ed444587c46f8689f0435e
Norway	https://hoycedata.no/LaserInnsyn/
Italy	http://www.pcn.minambiente.it/mattm/en/online-the-new-procedure-for-the-request-of-LiDAR-data-and-or-interferometric-ps/
Philippines	https://lipad.dream.upd.edu.ph/
Scotland	https://remotesensingdata.gov.scot/
Slovenia	http://evode.arso.gov.si/index022.html?q=node/12
Spain	https://b5m.gipuzkoa.eus/ur/5000/es/G_22485/PUBLI&consulta=HAZLIDAR http://www.murcianatural.carm.es/natmur08/descarga.html http://centrodedescargas.cnig.es/CentroDescargas/buscadorCatalogo.do?codFamilia=LIDAR http://www.icgc.cat/en/
Switzerland	https://geoweb.so.ch/map/LiDAR
United Kingdom	http://environment.data.gov.uk/ds/survey/index.jsp#/survey http://www.ceda.ac.uk/
USA	http://www.opentopography.org/index.php https://coast.noaa.gov/inventory/ https://en.wikipedia.org/wiki/National_LiDAR_Dataset_(United_States)



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01 Introduction of the LESS model

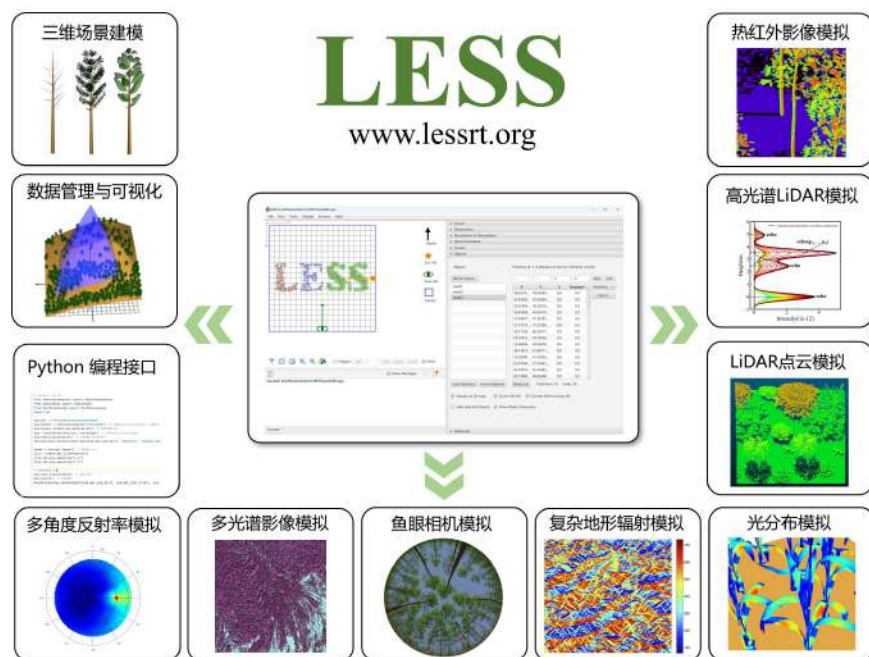
02 Applications of LESS in remote sensing

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04 Concluding remarks

04 Concluding remarks

- ❑ Radiative transfer models (RTMs) are essential to **understand the interaction** between solar radiation and vegetation canopies.
- ❑ LESS is a 3D RTM that supports **complex canopies**, and can simulate various remote sensing signals, including LiDAR and Solar-induced fluorescence...
- ❑ The **application** of 3D RTM will be an importance topic in the future.



The screenshot shows the LESS website homepage. The navigation bar includes links for LESS, Docs, Download, 3D Scenes, Demo, Publications, and Blog. The main content area features the LESS logo and a description: "A ray-tracing based 3D radiative transfer model, which is mainly designed for radiometric simulation over heterogeneous 3D scenes. It can simulate large-scale (e.g. > 1 km) satellite images and solar radiation over rugged terrain..." A "DOWNLOAD NOW" button is prominently displayed. Below the main content, a section titled "What is LESS ?" provides a detailed description of the model's capabilities and methods, including weighted forward photon tracing (FPT) and backward path tracing (BPT). A globe graphic is partially visible on the right side of the page.

Thank you!

Jianbo Qi
jianboqi@bnu.edu.cn