DART Forest Scene Setup Tutorial

DART Tutorial

2025-12-03

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1 Overview

This tutorial provides a step-by-step guide for setting up a forest scene simulation in DART (Discrete Anisotropic Radiative Transfer). DART is a comprehensive 3D radiative transfer model designed for simulating radiative budget and remote sensing acquisitions of natural and urban landscapes. This tutorial focuses on creating a high-resolution forest scene with detailed 3D tree models and proper optical properties.

2 Prerequisites

Before starting this tutorial, ensure you have:

- DART software installed (Version 5.10.5 or later)
- The `DART_forest_scene.zip` file containing all necessary input files
- Basic understanding of radiative transfer modeling
- Sufficient computational resources (12-core processor recommended)

ℹ About DART

DART is developed by the CESBIO laboratory (Centre d'Etudes Spatiales de la BIOsphère) and provides both forward and inverse modeling capabilities for optical remote sensing. For more information, visit the DART manual.

3 Part 1: Initial Setup

3.1 Extracting and Organizing Files

The first step is to properly organize the DART project files:

! File Organization

Extract the `DART_forest_scene.zip` file and copy all contents **except** the `DART_directory/user_data/simulations/forest_scene/input` folder to your DART installation directory. The structure should look like:

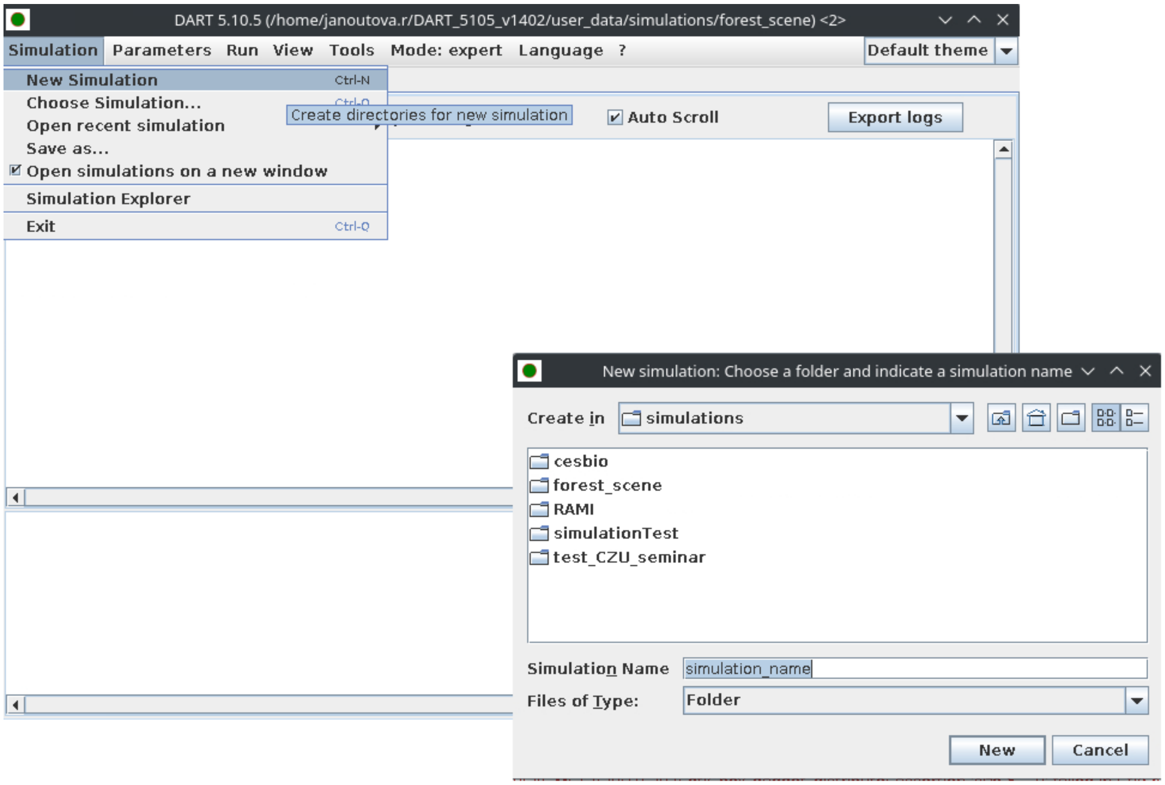
- `DART/database` ← Copy database files here
- `DART/user_data` ← Copy other files here (except input folder)

This ensures all necessary optical properties, 3D models, and configuration files are in the correct locations.

3.2 Creating a New Simulation

To begin your forest scene simulation:

1. Open DART
2. Click on **Simulation** → **New Simulation**
3. Enter your simulation name (e.g., “forest_scene”)
4. Click **“New”**



DART 5.10.5 (/home/janoutova.r/DART_5105_v1402/user_data/simulations/forest_scene) <2>

New simulation: Choose a folder and indicate a simulation name

Create in: simulations

Simulation Name: simulation_name

Files of Type: Folder

Figure 1: DART main menu showing the Simulation options and New Simulation dialog

As shown in Figure 1, the dialog allows you to specify the simulation name and location within your simulations folder.

Simulation Management Tips

- Keep all simulations in the default `simulations` folder for easier management
- You can create folder structures within the simulations directory
- Use **“Choose Simulations...”** if you have an existing simulation to import
- Use descriptive names for your simulations for easy identification

3.3 Opening the Editor

After creating your simulation:

1. Click on **Parameters** → **Editor**
2. The DART Simulation Editor window will open
3. You're now ready to configure your simulation parameters

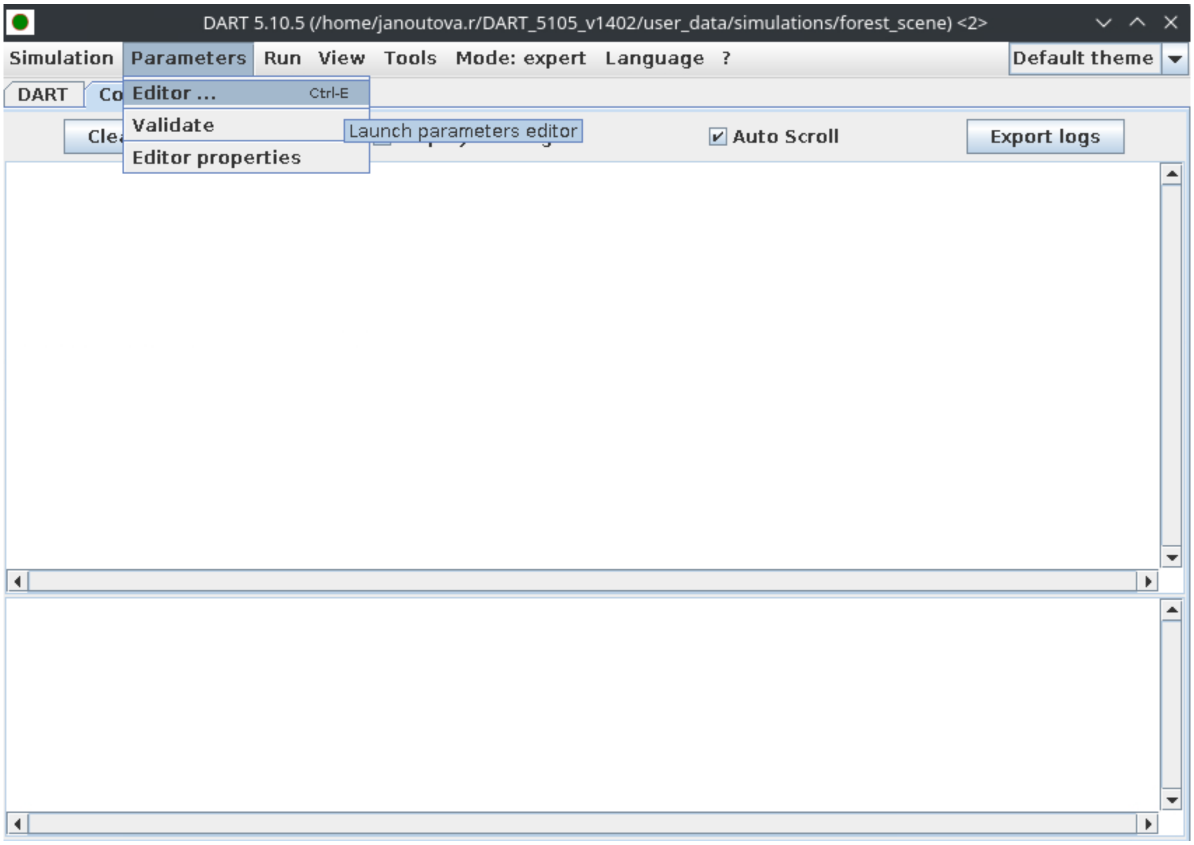


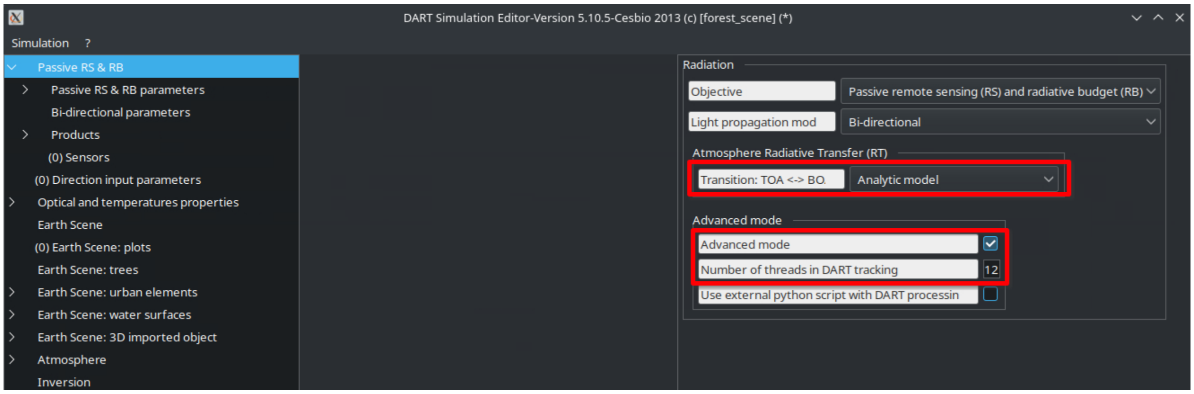
Figure 2: Opening the DART Editor from Parameters menu

The Editor interface (Figure 2) provides access to all simulation parameters through an organized tree structure on the left side of the window.

4 Part 2: Core Simulation Parameters

4.1 Basic Configuration

The first configuration screen allows you to set fundamental simulation parameters:


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation
?
Passive RS & RB
Passive RS & RB parameters
Bi-directional parameters
Products
(0) Sensors
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Atmosphere
Inversion

Radiation

Objective: Passive remote sensing (RS) and radiative budget (RB)

Light propagation mod: Bi-directional

Atmosphere Radiative Transfer (RT)

Transition: TOA <-> BO. Analytic model

Advanced mode

Advanced mode ☑

Number of threads in DART tracking 12

Use external python script with DART processin ☐

Figure 3: DART Editor showing basic configuration parameters including atmosphere settings, advanced mode, and thread configuration

! Critical Settings

Atmosphere Simulation: - Enable atmosphere simulation even if you only need "bottom of atmosphere" products - This ensures more accurate radiative transfer calculations **Threading Configuration:** - Switch to **Advanced Mode** - Set **Number of threads in DART tracking** to **12** - This optimizes performance on multi-core systems **Radiative Transfer Mode:** - For high spatial resolution forest scenes, use **bi-directional Light propagation mode (DART Lux)** - This provides the most accurate and computationally efficient results for detailed 3D scenes
These settings are highlighted in Figure 3.

i Python Integration

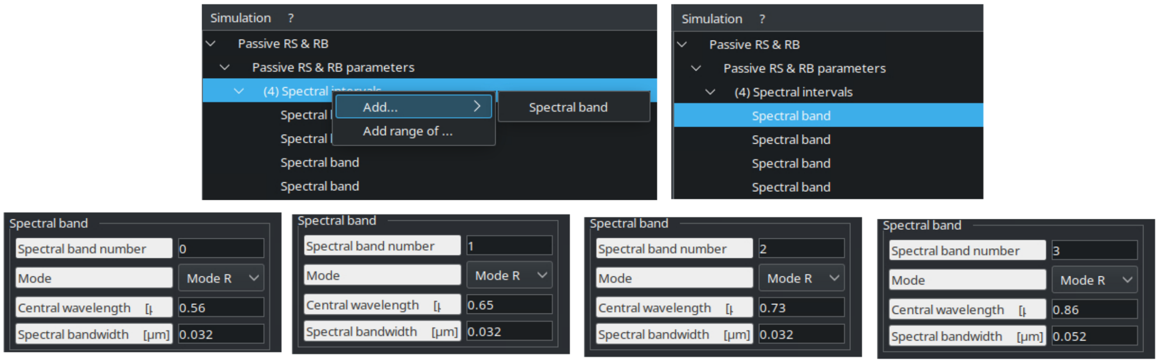
The DART team provides Python scripts that can be implemented directly in DART or used for data preparation. These scripts offer additional automation capabilities. Refer to the DART manual for more details on Python integration.

4.2 Spectral Band Configuration

Configure the spectral bands for your simulation:

1. Right-click on **"Spectral intervals"**
2. Select **Add...** → **Spectral band**
3. Add four spectral bands with the following specifications:

Band Number	Mode	Central Wavelength (m)	Bandwidth (m)
0	Mode R	0.56	0.032
1	Mode R	0.65	0.032
2	Mode R	0.73	0.032
3	Mode R	0.85	0.052



Spectral band

Spectral band number	0
Mode	Mode R
Central wavelength [μ	0.56
Spectral bandwidth [μm]	0.032

Spectral band

Spectral band number	1
Mode	Mode R
Central wavelength [μ	0.65
Spectral bandwidth [μm]	0.032

Spectral band

Spectral band number	2
Mode	Mode R
Central wavelength [μ	0.73
Spectral bandwidth [μm]	0.032

Spectral band

Spectral band number	3
Mode	Mode R
Central wavelength [μ	0.86
Spectral bandwidth [μm]	0.052

Figure 4: Configuration dialogs for four spectral bands showing Mode, Central wavelength, and Spectral bandwidth parameters

Figure 4 shows the configuration windows for all four spectral bands. Each band is set to Mode R (reflectance) with specific central wavelengths and bandwidths appropriate for vegetation monitoring.

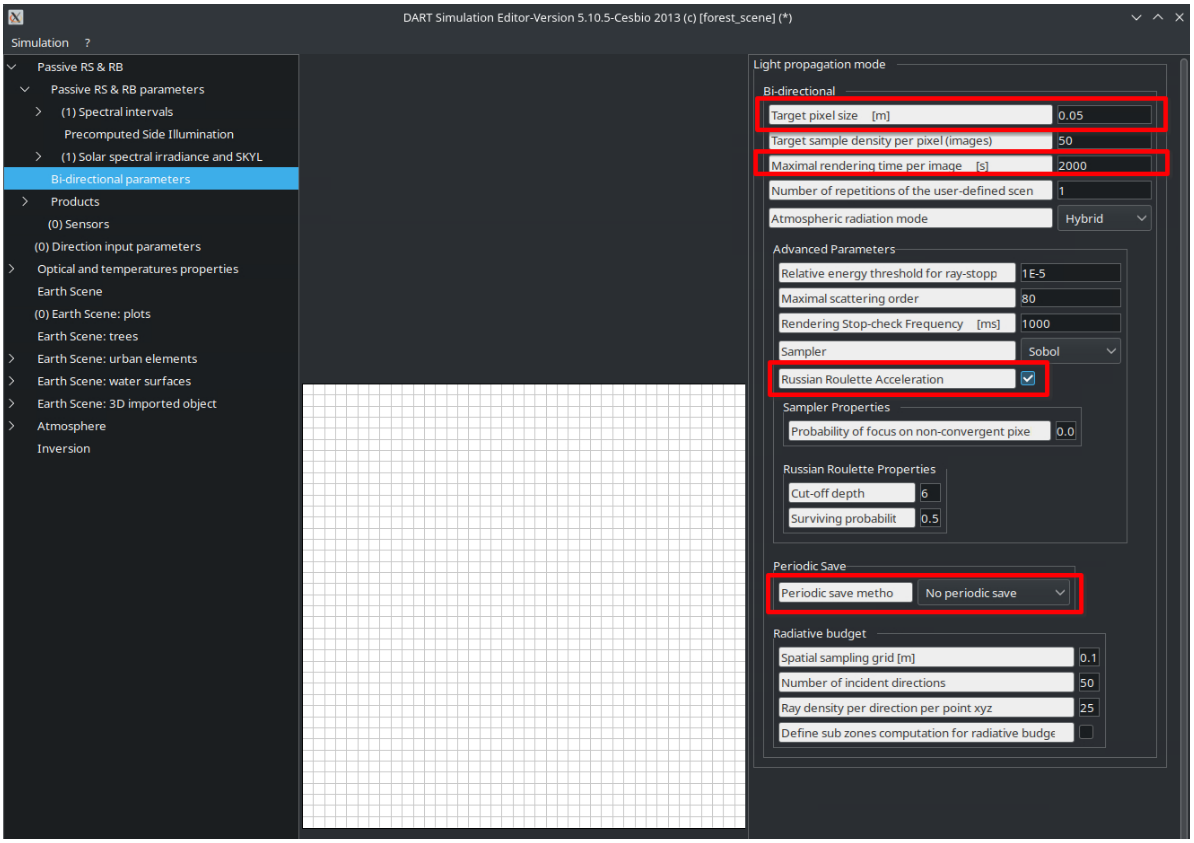
Working with Multiple Bands

- For larger numbers of spectral bands, use **“Add range of...”** method
- If bands have varying bandwidths, directly modify the `$your_simulation_name/input/phase.xml` file
- This approach is more efficient for hyperspectral simulations

5 Part 3: Scene Configuration

5.1 Bi-directional Parameters

Configure the image rendering and computation parameters:


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation
?
Passive RS & RB
Passive RS & RB parameters
(1) Spectral intervals
Precomputed Side Illumination
(1) Solar spectral irradiance and SKYL
Bi-directional parameters
Products
(0) Sensors
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Atmosphere
Inversion

Light propagation mode

Bi-directional

Target pixel size [m]: 0.05
Target sample density per pixel (images): 50
Maximal rendering time per image [s]: 2000
Number of repetitions of the user-defined scen: 1
Atmospheric radiation mode: Hybrid

Advanced Parameters

Relative energy threshold for ray-stopp: 1E-5
Maximal scattering order: 80
Rendering Stop-check Frequency [ms]: 1000
Sampler: Sobol
Russian Roulette Acceleration: ☑

Sampler Properties

Probability of focus on non-convergent pixe: 0.0

Russian Roulette Properties

Cut-off depth: 6
Surviving probabilit: 0.5

Periodic Save

Periodic save metho: No periodic save

Radiative budget

Spatial sampling grid [m]: 0.1
Number of incident directions: 50
Ray density per direction per point xyz: 25
Define sub zones computation for radiative budge: □

Figure 5: Bi-directional parameters panel showing pixel size, rendering settings, and radiative budget options

❗ Key Parameters

Image Resolution: - Set **Target pixel size** [m] to **0.05** (5 cm) - This provides high-resolution output suitable for detailed analysis
Optimized Parameters: These values are results of optimization and consultation with the DART team: - **Target sample density per pixel (images):** 50 - **Maximal rendering time per image:** 2000 - **Number of repetitions of the user-defined scene:** 1
Radiation Settings: - **Sampler:** Sobol - **Russian Roulette Acceleration:** Enable (checked)
Periodic Save: - **Periodic save method:** No periodic save
All these parameters are shown in Figure 5 with their recommended values highlighted.

ℹ Parameter Optimization

When starting a new simulation type, it's recommended to verify these parameters for your specific: - Scene type (forest, urban, agricultural) - Spatial resolution requirements - Spectral resolution needs
Parameter optimization can significantly affect both accuracy and computation time.

5.2 Output Products Configuration

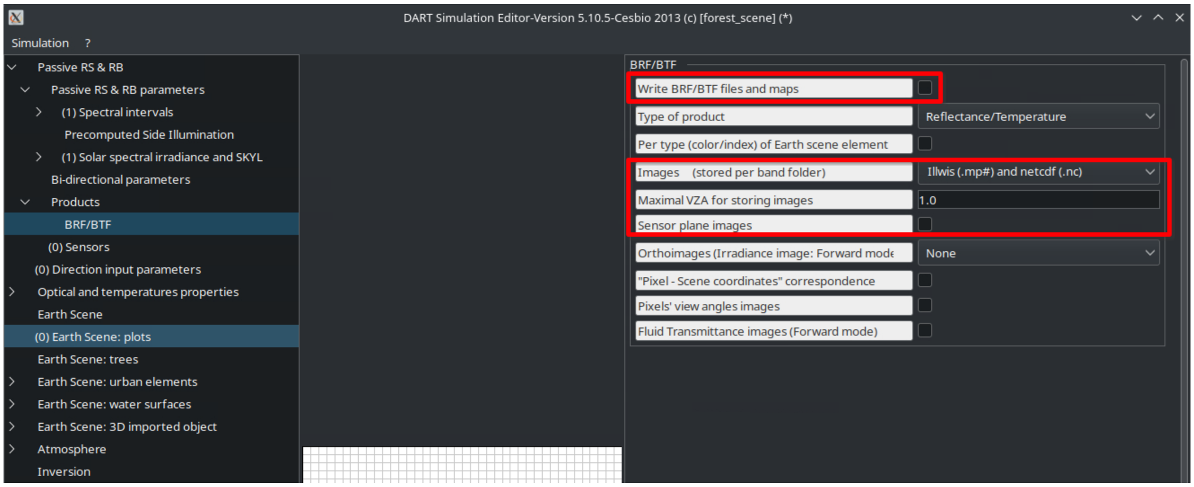
Configure which products DART will generate:

1. Navigate to **Products → BRF/BTF**
2. Enable **"Write BRF/BTF files and maps"**
3. Set **Type of color/model of Earth scene element:** Reflectance/Temperature
4. Configure **Images - stored per band (folder):**
    - Format: **Ilwis (.mpr) and netcdf (.nc)**
    - Maximum VZA for storing images: **1.0**
5. Disable **Sensor plane images**

As shown in Figure 6, only the necessary outputs are enabled to minimize computation time and storage requirements.

Output Format

- DART is transitioning to netcdf as the primary output format
- Ilwis format is included here for compatibility with this tutorial
- Additional products can be enabled but will increase computation time and storage


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation ?
Passive RS & RB
Passive RS & RB parameters
(1) Spectral intervals
Precomputed Side Illumination
(1) Solar spectral irradiance and SKYL
Bi-directional parameters
Products
BRF/BTF
(0) Sensors
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Atmosphere
Inversion

BRF/BTF

Write BRF/BTF files and maps	□
Type of product	Reflectance/Temperature
Per type (color/index) of Earth scene element	□
Images (stored per band folder)	Illwis (.mp#) and netcdf (.nc)
Maximal VZA for storing images	1.0
Sensor plane images	□
Orthoimages (Irradiance image: Forward mode	None
"Pixel - Scene coordinates" correspondence	□
Pixels' view angles images	□
Fluid Transmittance images (Forward mode)	□

Figure 6: Products configuration panel showing BRF/BTF settings and image format options

requirements

- Only enable the products you actually need for your analysis

6 Part 4: Optical Properties

6.1 Leaf Optical Properties

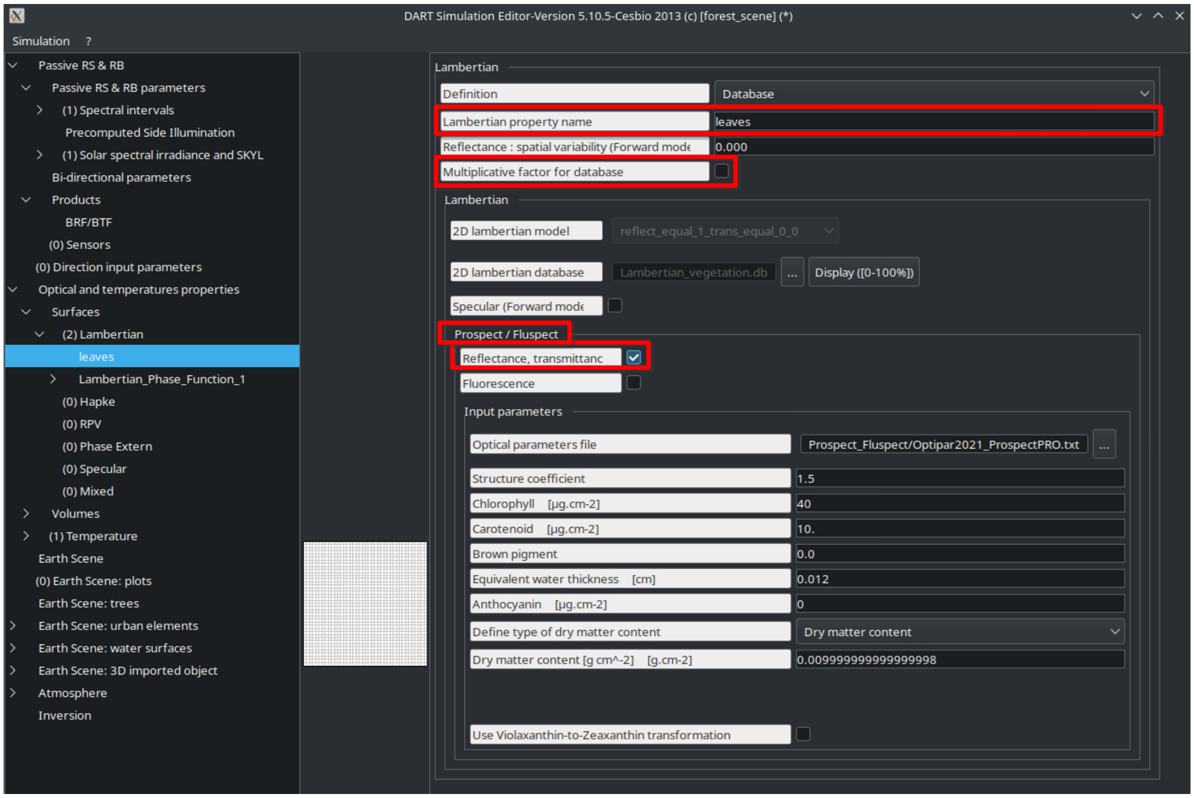
Define the spectral properties of leaves using the PROSPECT model:

1. Right-click on **"Lambertian"** section
2. Select **Add → Lambertian** (or modify the default)
3. Configure the following:

Basic Settings: - **Lambertian property name:** "leaves" - Disable **"Multiplicative factor for database"** - Enable **"Reflectance, transmittance"** in the Prospect section

PROSPECT Parameters: Use the PROSPECT leaf radiative transfer model with these default biochemical parameters: - **Structure coefficient:** 1.5 - **Chlorophyll:** 40 - **Carotenoid:** 10 - **Brown pigment:** 0.0 - **Equivalent water thickness:** 0.012 - **Anthocyanin:** 0 - **Dry matter content:** Dry matter content

Figure 7 demonstrates the complete PROSPECT configuration for leaf optical properties, including all biochemical parameters that drive the spectral response.


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation
?
Passive RS & RB
Passive RS & RB parameters
(1) Spectral intervals
Precomputed Side Illumination
(1) Solar spectral irradiance and SKYL
Bi-directional parameters
Products
BRF/BTF
(0) Sensors
(0) Direction input parameters
Optical and temperatures properties
Surfaces
(2) Lambertian
leaves
Lambertian_Phase_Function_1
(0) Hapke
(0) RPV
(0) Phase Extern
(0) Specular
(0) Mixed
Volumes
(1) Temperature
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Atmosphere
Inversion
...
Display ([0-100%])

Lambertian

Definition: Database

Lambertian property name: leaves

Reflectance : spatial variability (Forward mode: 0.000

Multiplicative factor for database ☐

Lambertian

2D lambertian model: reflect_equal_1_trans_equal_0_0

2D lambertian database: Lambertian_vegetation.db

Specular (Forward mode ☐

Prospect / Fluspect

Reflectance, transmittanc ☑

Fluorescence ☐

Input parameters

Optical parameters file: Prospect_Fluspect/Optipar2021_ProspectPRO.txt

Structure coefficient: 1.5

Chlorophyll [µg.cm-2]: 40

Carotenoid [µg.cm-2]: 10.

Brown pigment: 0.0

Equivalent water thickness [cm]: 0.012

Anthocyanin [µg.cm-2]: 0

Define type of dry matter content: Dry matter content

Dry matter content [g cm^-2] [g.cm-2]: 0.009999999999999998

Use Violaxanthin-to-Zeaxanthin transformation ☐

Figure 7: Lambertian optical properties configuration for leaves using PROSPECT model with biochemical parameters

ℹ PROSPECT Model

The PROSPECT model is a leaf-level radiative transfer model that simulates leaf optical properties based on biochemical composition. These parameters will be used for: - Look-Up Table (LUT) generation - Parameter retrieval from remote sensing images - Sensitivity analysis
The multiplicative factor option allows scaling of optical properties by a constant value when needed.

6.2 Bark Optical Properties

Define spectral properties for tree bark:

1. Right-click on **"Lambertian"**
2. Select **Add → Lambertian**
3. Configure:

Database Selection: - **Lambertian property name:** "bark" - Disable **"Multiplicative factor for database"** - **2D lambertian database:** Select `lanzhot_materials.db` - **2D lambertian model:** Select `trunk_FA_SY_QE_sp_Lanzhot_fix`

The bark optical properties (Figure 8) use measured spectral reflectance data from the Lanzhot forest site, providing realistic bark reflectance characteristics.

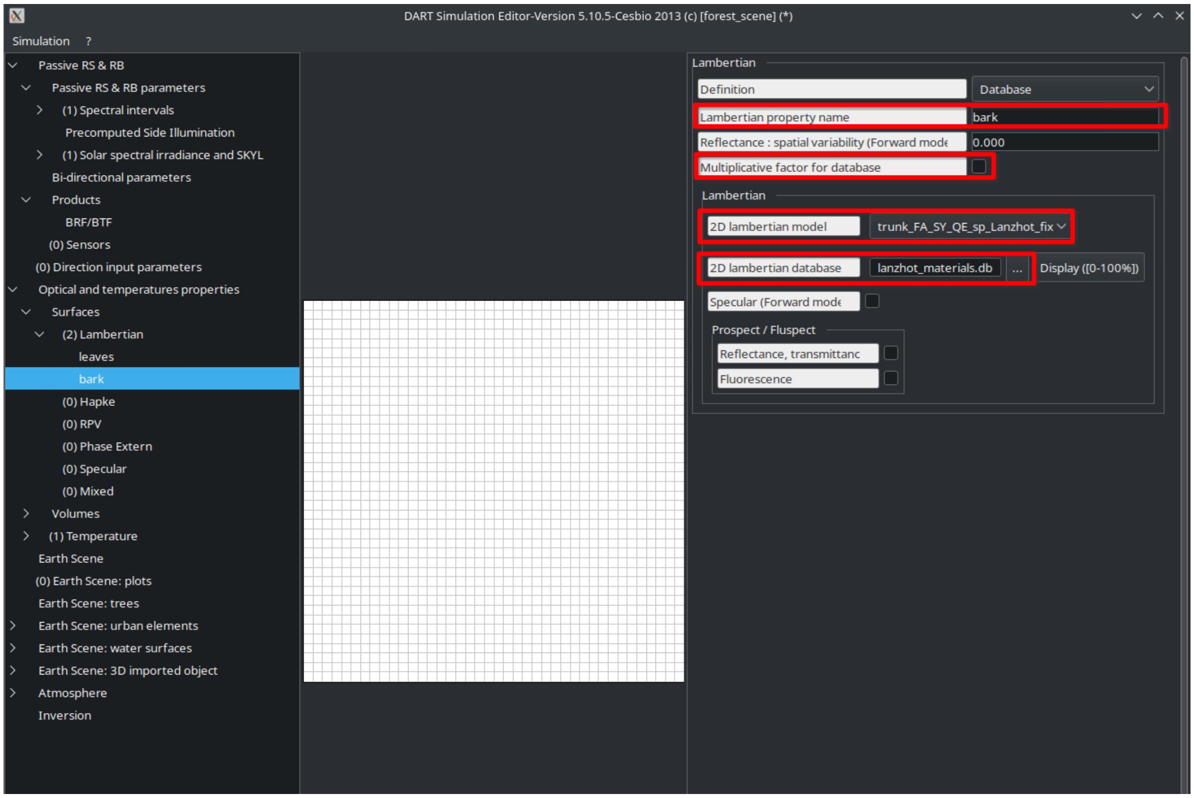
Optical Property Databases

- The `lanzhot_materials.db` file should be in your `DART/database` folder (from the extracted zip)
- You can also use optical properties from DART's default `Lambertian_vegetation.db`
- Use **DART Database Manager** (Tools menu) to create or modify optical property databases
- Measured optical properties provide more realistic simulations than generic values

6.3 Ground Optical Properties

Define the forest floor spectral properties:

1. Right-click on the bark optical properties
2. Select **Duplicate**
3. Modify:


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation
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Passive RS & RB
Passive RS & RB parameters
(1) Spectral intervals
Precomputed Side Illumination
(1) Solar spectral irradiance and SKYL
Bi-directional parameters
Products
BRF/BTF
(0) Sensors
(0) Direction input parameters
Optical and temperatures properties
Surfaces
(2) Lambertian
leaves
bark
(0) Hapke
(0) RPV
(0) Phase Extern
(0) Specular
(0) Mixed
Volumes
(1) Temperature
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Atmosphere
Inversion
Lambertian
Prospect / Fluspect
...
Display ([0-100%])

Lambertian

Definition: Database

Lambertian property name: bark

Reflectance : spatial variability (Forward mode: 0.000

Multiplicative factor for database: □

Lambertian

2D lambertian model: trunk_FA_SY_QE_sp_Lanzhot_fix

2D lambertian database: lanzhot_materials.db

Specular (Forward mode: □

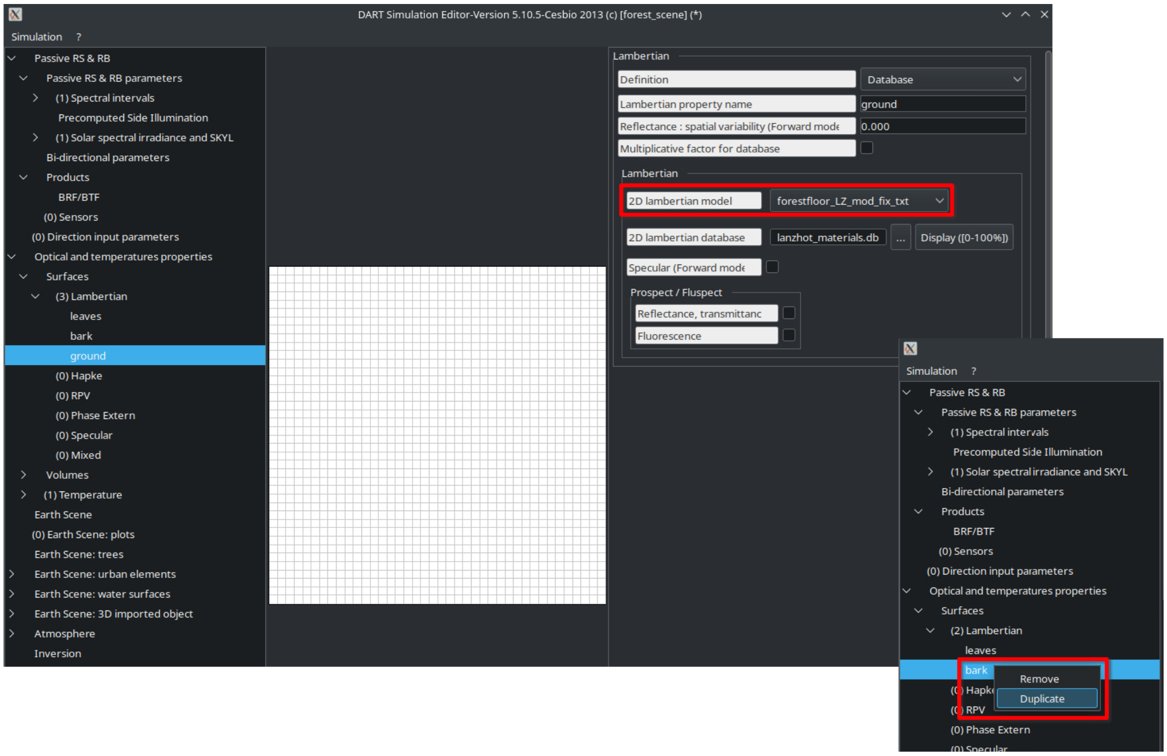
Prospect / Fluspect

Reflectance, transmittanc: □

Fluorescence: □

Figure 8: Lambertian optical properties configuration for bark using measured spectral data from lanzhot_materials database

- **Lambertian property name:** “ground”
- **2D lambertian model:** Select `forestfloor_LZ_mod_fix_txt`



DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)

Lambertian

Definition: Database

Lambertian property name: ground

Reflectance : spatial variability (Forward mode: 0.000

Multiplicative factor for database ☐

Lambertian

2D lambertian model: forestfloor_LZ_mod_fix_txt

2D lambertian database: lanzhot_materials.db ... Display ([0-100%])

Specular (Forward mode ☐

Prospect / Fluspect

Reflectance, transmittanc ☐

Fluorescence ☐

Simulation ?
Passive RS & RB
Passive RS & RB parameters
(1) Spectral intervals
Precomputed Side Illumination
(1) Solar spectral irradiance and SKYL
Bi-directional parameters
Products
BRF/BTF
(0) Sensors
(0) Direction input parameters
Optical and temperatures properties
Surfaces
(3) Lambertian
leaves
bark
ground
(0) Hapke
(0) RPV
(0) Phase Extern
(0) Specular
(0) Mixed
Volumes
(1) Temperature
Earth Scene
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Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Atmosphere
Inversion
Simulation ?
Passive RS & RB
Passive RS & RB parameters
(1) Spectral intervals
Precomputed Side Illumination
(1) Solar spectral irradiance and SKYL
Bi-directional parameters
Products
BRF/BTF
(0) Sensors
(0) Direction input parameters
Optical and temperatures properties
Surfaces
(2) Lambertian
leaves
bark
Remove
Duplicate
(0) Hapke
(0) RPV
(0) Phase Extern
(0) Specular

Figure 9: Lambertian optical properties configuration for ground/forest floor using forestfloor spectral data

This creates optical properties representing the forest understory and leaf litter, as shown in Figure 9.

7 Part 5: Earth Scene Configuration

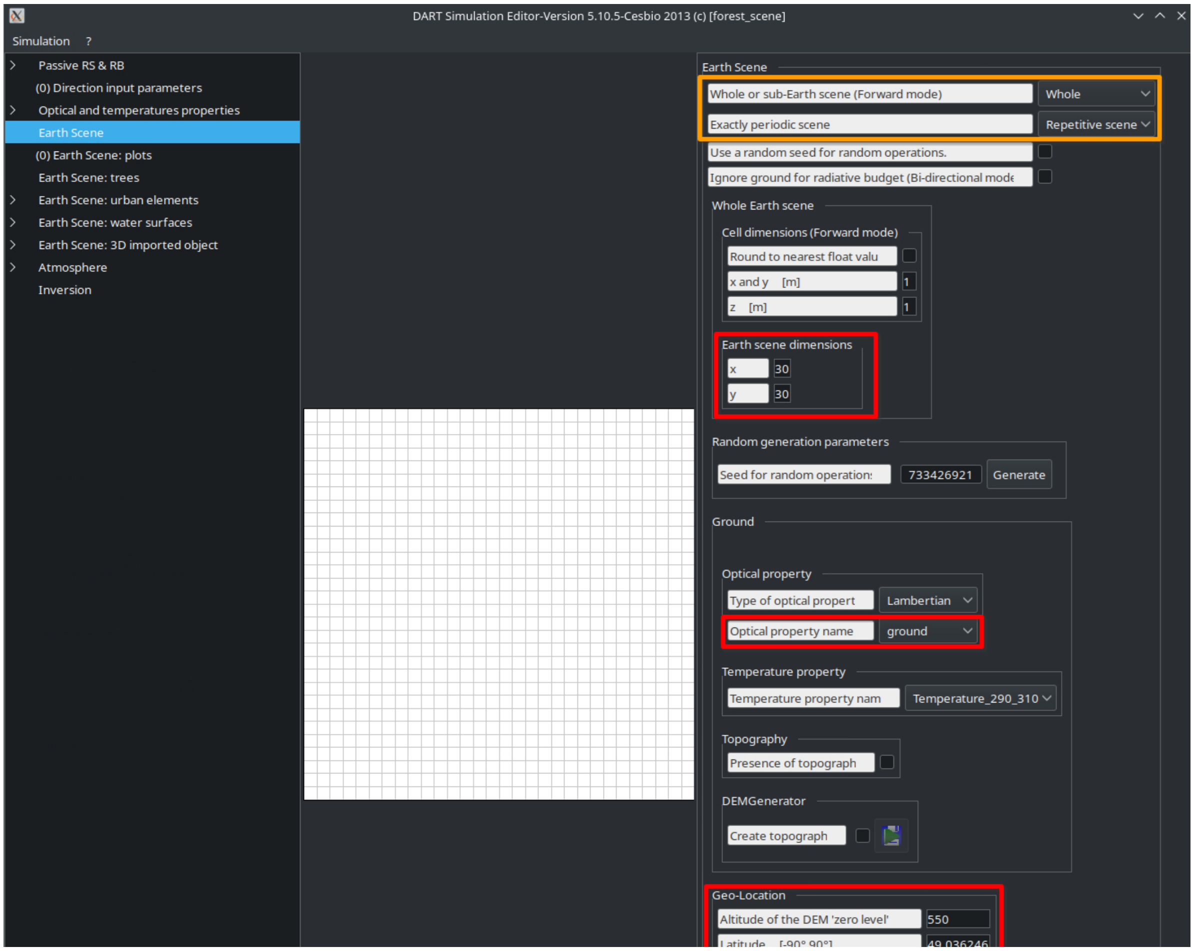
7.1 Scene Dimensions and Location

Set up the basic scene parameters:

Scene Dimensions: - **X max:** 30 m - **Y max:** 30 m

Ground Properties: - **Optical property name:** “ground”

Geographic Location: Set coordinates for central Czech Republic: - **Altitude of the DEM zero level:** 500 m - **Latitude:** [50°; 30’] - **Longitude:** [17°; 50’]


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene]
Simulation
?
Passive RS & RB
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Atmosphere
Inversion
Generate

Earth Scene

Whole or sub-Earth scene (Forward mode): Whole

Exactly periodic scene: Repetitive scene

Use a random seed for random operations. □

Ignore ground for radiative budget (Bi-directional mode □

Whole Earth scene

Cell dimensions (Forward mode)

Round to nearest float valu □

x and y [m]: 1

z [m]: 1

Earth scene dimensions

x: 30

y: 30

Random generation parameters

Seed for random operation: 733426921

Ground

Optical property

Type of optical propert: Lambertian

Optical property name: ground

Temperature property

Temperature property nam: Temperature_290_310

Topography

Presence of topograph □

DEMGenerator

Create topograph □

Geo-Location

Altitude of the DEM 'zero level': 550

Latitude [-90° 90°]: 49.036246

Figure 10: Earth Scene configuration panel showing scene dimensions, ground optical properties, and geographic location

Figure 10 displays the complete Earth Scene configuration, including the scene extent, ground properties, and geographic coordinates that define the simulation environment.

ℹ Scene Configuration Options

Exactly Periodic Scene: - **Isolated scene:** Light crossing edges disappears (boundary effects) - **Repetitive scene:** Scene is virtually replicated around the edges (reduces boundary effects) - **Infinite slope:** Appropriate for sloped terrain
Cell Dimensions: - These parameters are irrelevant for bi-directional mode - In other modes, they correspond to simulated image spatial resolution

8 Part 6: 3D Scene Objects

8.1 Importing Tree Field Data

Add the tree locations and specifications:

1. Right-click on **"Object fields"**
2. Select **Add → Field**
3. **Field description file:** Select `beech.txt` (from the extracted zip)
4. **Name:** "Field"
5. Enable **"Show this field's objects in the 2D view"**

Figure 11 shows the field import interface where you specify the text file containing tree positions and properties.

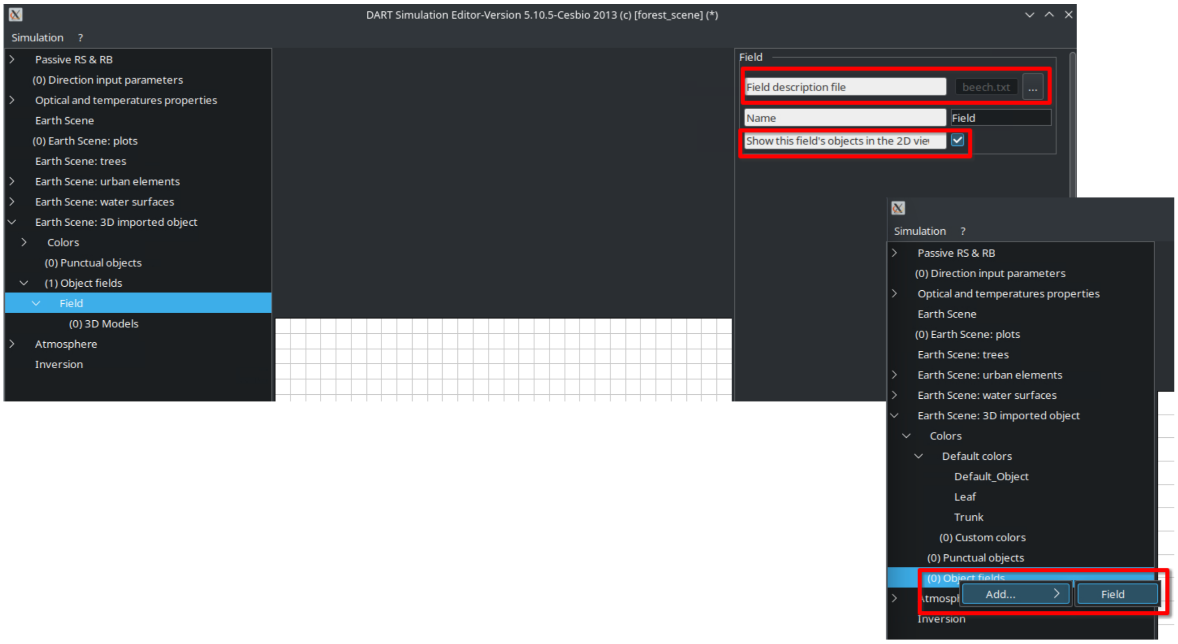
ℹ Field File Format

The `beech.txt` file contains information for each tree: - Species/object type identifier - XY position coordinates - Scaling factor (tree size) - Rotation angles
This format allows efficient specification of multiple objects without manually placing each one. Refer to the DART manual for detailed file format specifications.

8.2 Importing 3D Tree Models

Import the first tree model:

1. Right-click on **"3D Models"**
2. Select **Import file**
3. Choose the first 3D object file: `beech_20` (from extracted files)


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation ?
Passive RS & RB
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Colors
(0) Punctual objects
(1) Object fields
Field
(0) 3D Models
Atmosphere
Inversion
Simulation ?
Passive RS & RB
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Colors
Default colors
Default_Object
Leaf
Trunk
(0) Custom colors
(0) Punctual objects
(0) Object fields
Add...
Field
Atmosp
Inversion

Field

Field description file beech.txt ...

Name Field

Show this field's objects in the 2D vie ☑

Figure 11: Field import dialog showing the beech.txt file selection and configuration options

Configuration: - **Name:** "beech_20" - **Color:** Select a distinctive color (e.g., orange) - Keep other options at default

The 3D model import dialog (Figure 12) allows you to specify the model file, assign a name, and configure display properties including color coding for easy identification in the 2D view.

3D Object Creation

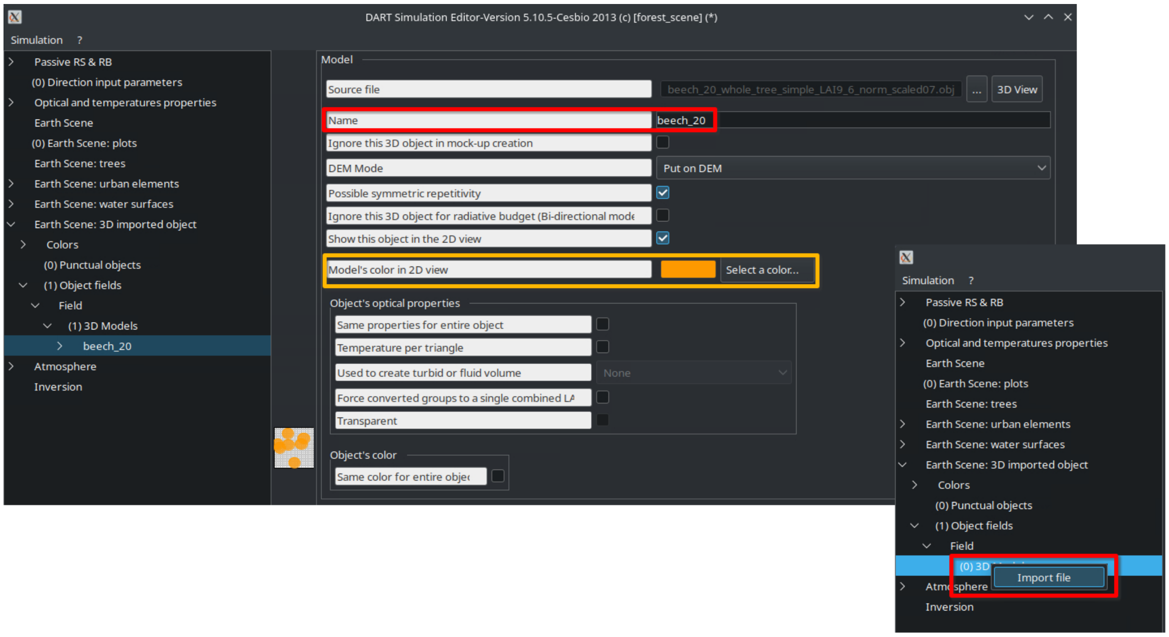
DART includes a **"Creation of 3D objects"** tool for generating simple geometric crown shapes filled with leaf facets. While less detailed than full 3D scanned models, this can be sufficient for many applications and is computationally efficient.

8.3 Configuring Leaf Groups

For the leaves group within the 3D object:

1. Expand the tree model in the hierarchy
2. Select the leaves group
3. Configure:

Group Settings: - **Name:** "leaves" - Enable **"Double face"**


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation ?
Passive RS & RB
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Colors
(0) Punctual objects
(1) Object fields
Field
(1) 3D Models
beech_20
Atmosphere
Inversion
Model
...
3D View
Select a color...
Object's optical properties
Object's color
Import file
(0) 3D

Source file: beech_20_whole_tree_simple_LAI9_6_norm_scaled07.obj
Name: beech_20
Ignore this 3D object in mock-up creation ☐
DEM Mode: Put on DEM
Possible symmetric repetitivity ☑
Ignore this 3D object for radiative budget (Bi-directional mode ☐
Show this object in the 2D view ☑
Model's color in 2D view: 🟧
Same properties for entire object ☐
Temperature per triangle ☐
Used to create turbid or fluid volume: None
Force converted groups to a single combined LA ☐
Transparent ☐
Same color for entire objec ☐

Figure 12: 3D model import interface showing file selection, naming options, and display settings for the beech_20 tree model

Optical Properties: - **Type of optical property:** Lambertian - **Optical property name:** "leaves"

Display: - **Group's color:** Leaf (green)

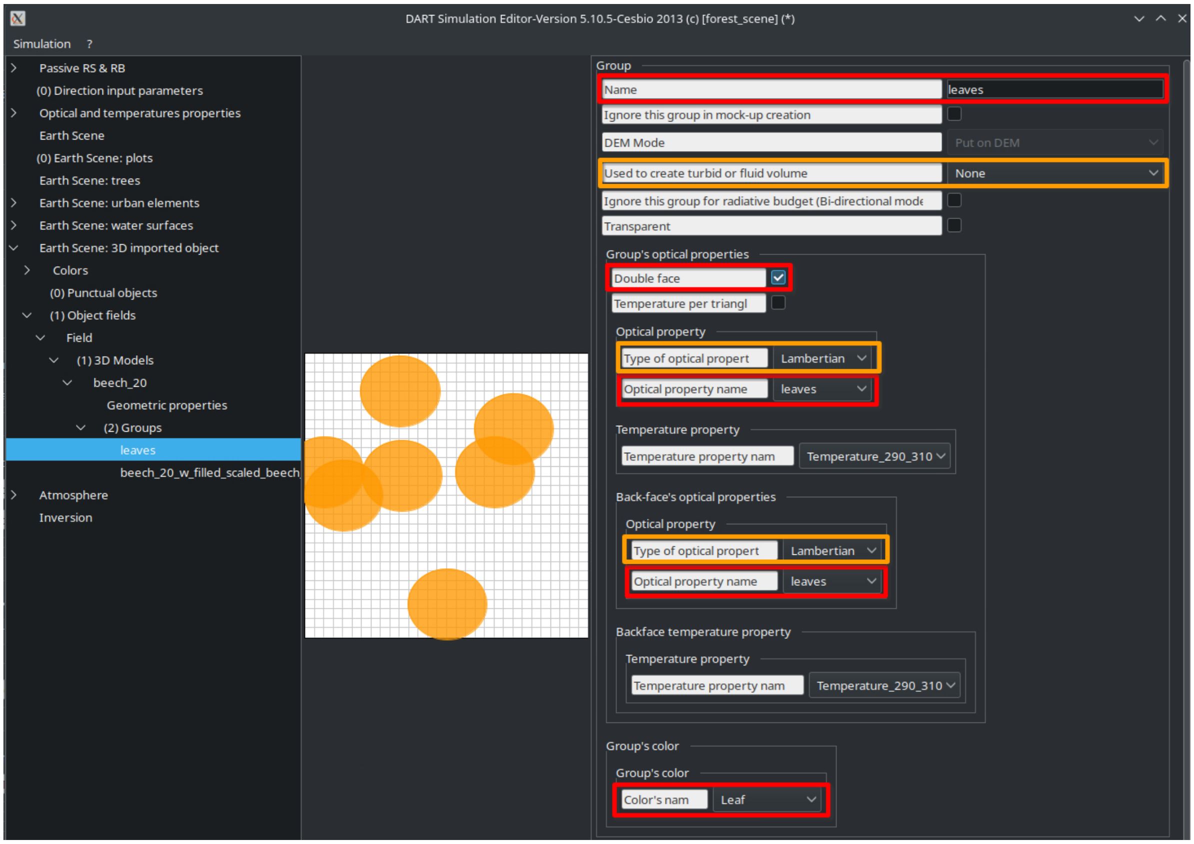
Figure 13 demonstrates the leaves group configuration within the 3D object hierarchy, with the 2D view showing the spatial distribution of trees in the scene.

! Double Face Option

The "Double face" option is **critical** for leaves. It ensures: - Both sides of leaf facets have optical properties - Proper simulation of leaf transmittance - Accurate light scattering within the canopy
Without this option, the back face of leaves would be transparent, leading to incorrect radiative transfer calculations.

ℹ Turbid Medium Alternative

The **"Used to create turbid or fluid volume"** option converts 3D objects into a turbid medium representation. This is useful for: - Easily changing LAI values without multiple 3D models - Computational efficiency in some cases


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation
?
Passive RS & RB
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Colors
(0) Punctual objects
(1) Object fields
Field
(1) 3D Models
beech_20
Geometric properties
(2) Groups
leaves
beech_20_w_filled_scaled_beech
Atmosphere
Inversion

Group

Name: leaves

Ignore this group in mock-up creation ☐

DEM Mode: Put on DEM

Used to create turbid or fluid volume: None

Ignore this group for radiative budget (Bi-directional mode ☐

Transparent ☐

Group's optical properties

Double face ☑

Temperature per triangl ☐

Optical property

Type of optical propert: Lambertian

Optical property name: leaves

Temperature property

Temperature property nam: Temperature_290_310

Back-face's optical properties

Optical property

Type of optical propert: Lambertian

Optical property name: leaves

Backface temperature property

Temperature property

Temperature property nam: Temperature_290_310

Group's color

Group's color

Color's nam: Leaf

Figure 13: Leaves group configuration showing double face option, optical property assignment, and the 2D view with colored tree crowns

> However, it reduces spatial accuracy and makes bi-directional mode less efficient. Use only when appropriate for your application.

8.4 Configuring Woody Parts

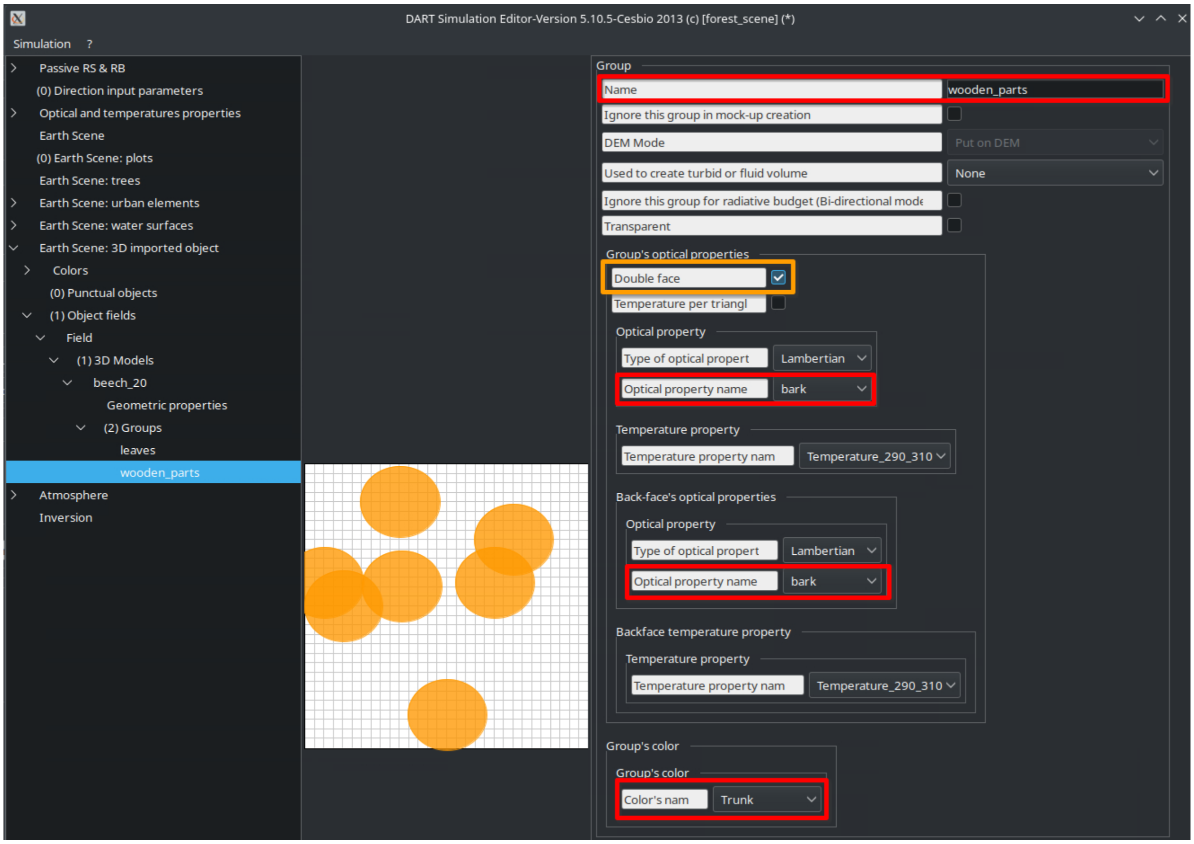
For the trunk and branches group:

1. Select the wooden parts group
2. Configure:

Group Settings: - **Name:** “wooden_parts” - Enable **“Double face”** (recommended)

Optical Properties: - **Type of optical property:** Lambertian - **Optical property name:** “bark”

Display: - **Group’s color:** Trunk (brown)


DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation
?
Passive RS & RB
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Colors
(0) Punctual objects
(1) Object fields
Field
(1) 3D Models
beech_20
Geometric properties
(2) Groups
leaves
wooden_parts
Atmosphere
Inversion

Group

Name	wooden_parts
Ignore this group in mock-up creation	□
DEM Mode	Put on DEM
Used to create turbid or fluid volume	None
Ignore this group for radiative budget (Bi-directional mode	□
Transparent	□

Group's optical properties

Double face	☑
Temperature per triangl	□

Optical property

Type of optical propert	Lambertian
Optical property name	bark

Temperature property

Temperature property nam	Temperature_290_310

Back-face's optical properties

Optical property

Type of optical propert	Lambertian
Optical property name	bark

Backface temperature property

Temperature property

Temperature property nam	Temperature_290_310

Group's color

Group's color

Color's nam	Trunk

Figure 14: Woody parts group configuration showing optical property assignment to bark and the 2D scene view

The woody parts configuration (Figure 14) assigns bark optical properties to trunk and branch components of the tree model.

Double Face for Woody Parts

For trunks and branches with no transmittance, double face is technically unnecessary **if** all facet normals are correctly oriented. However, enabling it is safer unless you're certain about facet orientation, as it prevents rendering artifacts.

8.5 Adding All Tree Models

Repeat the import and configuration process for all remaining 3D tree models:

- `beech_27`
- `beech_28`
- `beech_62`

For each model: 1. Import the 3D file 2. Set a unique name 3. Assign a distinctive color for visualization 4. Configure leaf groups with "leaves" optical properties 5. Configure woody groups with "bark" optical properties 6. Enable double face for both groups

Visualization

When all models are imported and configured, the 2D editor view (Figure 15) displays colored circles representing tree crowns at their specified locations. Different colors help distinguish between different tree models or size classes. The spatial distribution shown here matches the specifications in the beech.txt field file.

9 Part 7: Atmospheric Configuration (Optional)

The atmosphere section provides detailed control over atmospheric radiative transfer:

10 Atmospheric Parameters

If you have measured or observed atmospheric data, you can configure:

Atmosphere Database: - Select appropriate atmospheric model (e.g., BIRND_JULY2020.db)

Gas Composition: - Temperature profile (US standard models available) - Ozone and other gas vertical profiles - CO2 mixing ratio - Water vapor content

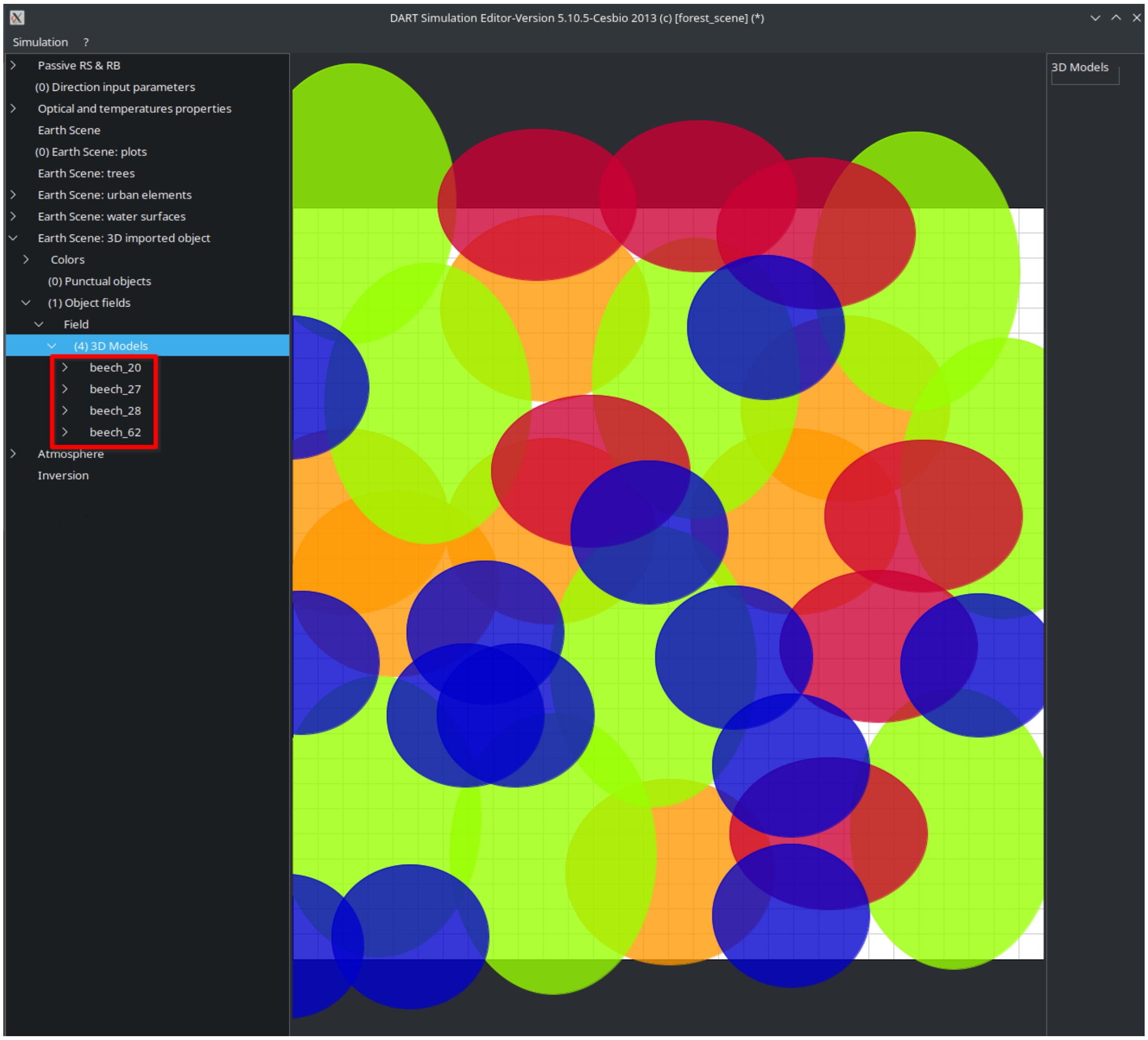
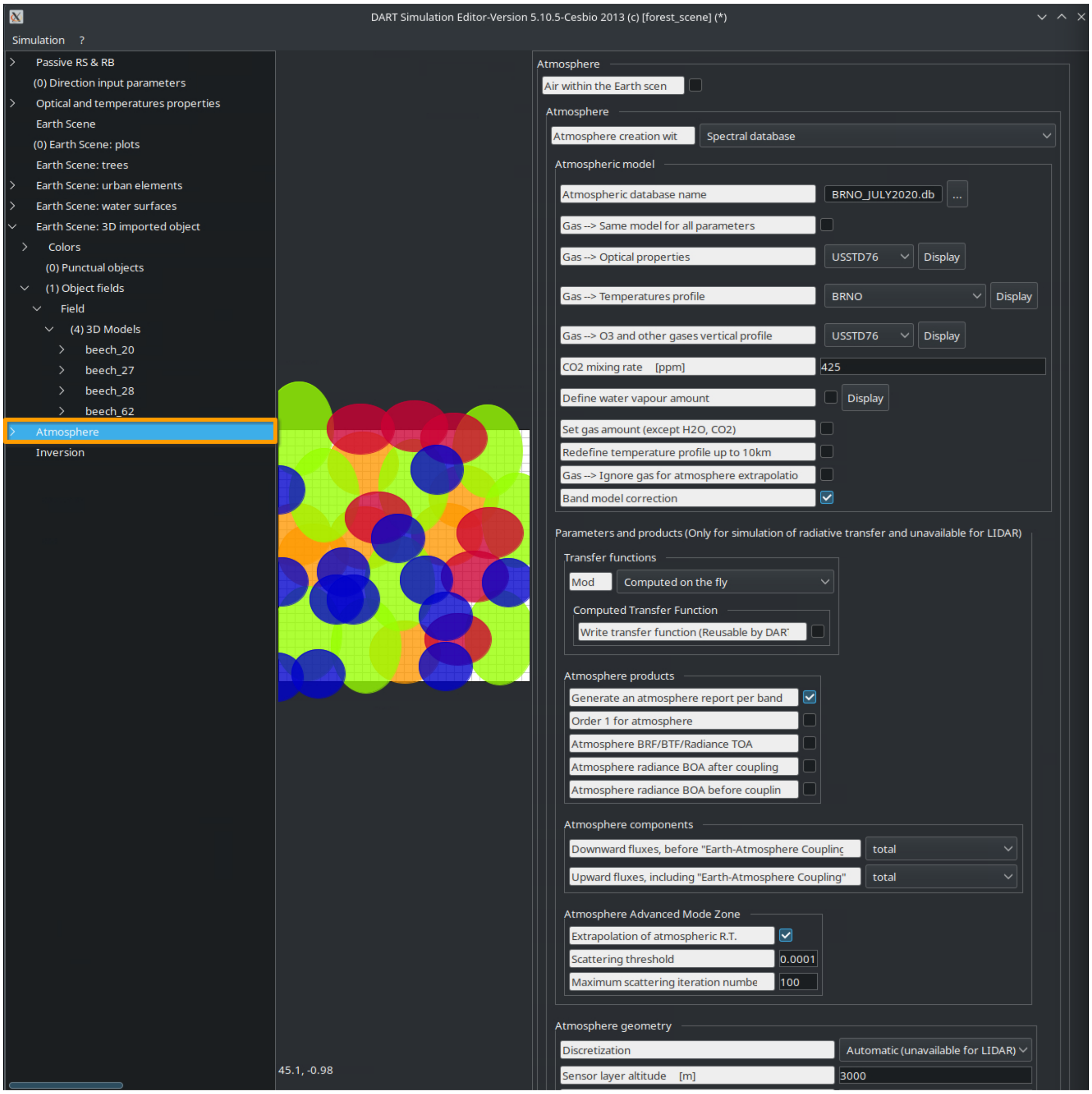

DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)
Simulation
?
Passive RS & RB
(0) Direction input parameters
Optical and temperatures properties
Earth Scene
(0) Earth Scene: plots
Earth Scene: trees
Earth Scene: urban elements
Earth Scene: water surfaces
Earth Scene: 3D imported object
Colors
(0) Punctual objects
(1) Object fields
Field
(4) 3D Models
beech_20
beech_27
beech_28
beech_62
Atmosphere
Inversion
3D Models

Figure 15: Complete 2D view of the forest scene showing all imported tree models as colored circles representing different tree types and sizes



DART Simulation Editor-Version 5.10.5-Cesbio 2013 (c) [forest_scene] (*)

Simulation ?

- Passive RS & RB
- (0) Direction input parameters
- Optical and temperatures properties
- Earth Scene
- (0) Earth Scene: plots
- Earth Scene: trees
- Earth Scene: urban elements
- Earth Scene: water surfaces
- Earth Scene: 3D imported object
  - Colors
  - (0) Punctual objects
  - (1) Object fields
    - Field
      - (4) 3D Models
        - beech_20
        - beech_27
        - beech_28
        - beech_62
- Atmosphere
- Inversion

45.1, -0.98

Atmosphere

Air within the Earth scen ☐

Atmosphere

Atmosphere creation wit: Spectral database

Atmospheric model

Atmospheric database name: BRNO_JULY2020.db ...

Gas --> Same model for all parameters ☐

Gas --> Optical properties: USSTD76 Display

Gas --> Temperatures profile: BRNO Display

Gas --> O3 and other gases vertical profile: USSTD76 Display

CO2 mixing rate [ppm]: 425

Define water vapour amount ☐ Display

Set gas amount (except H2O, CO2) ☐

Redefine temperature profile up to 10km ☐

Gas --> Ignore gas for atmosphere extrapolatio ☐

Band model correction ☑

Parameters and products (Only for simulation of radiative transfer and unavailable for LIDAR)

Transfer functions

Mod: Computed on the fly

Computed Transfer Function

Write transfer function (Reusable by DAR ☐

Atmosphere products

Generate an atmosphere report per band ☑

Order 1 for atmosphere ☐

Atmosphere BRF/BTF/Radiance TOA ☐

Atmosphere radiance BOA after coupling ☐

Atmosphere radiance BOA before couplin ☐

Atmosphere components

Downward fluxes, before "Earth-Atmosphere Coupling: total

Upward fluxes, including "Earth-Atmosphere Coupling": total

Atmosphere Advanced Mode Zone

Extrapolation of atmospheric R.T. ☑

Scattering threshold: 0.0001

Maximum scattering iteration numbe: 100

Atmosphere geometry

Discretization: Automatic (unavailable for LIDAR)

Sensor layer altitude [m]: 3000

Figure 16: Atmosphere configuration panel showing atmospheric database selection, gas profiles, aerosol properties, and advanced mode settings

Aerosol Properties: - Set gas amounts (H2O, CO2) - Configure aerosol optical depth - Define atmospheric components (Downward fluxes, Upward fluxes)

Advanced Settings: - Atmosphere extrapolation parameters - Scattering threshold - Maximum scattering iteration number - Atmosphere geometry (discretization, sensor layer altitude)

These parameters (Figure 16) significantly affect top-of-atmosphere and atmospheric correction simulations.

11 Part 8: Running the Simulation

11.1 Saving and Validation

Before running:

1. Click the **Save** button in the Editor
2. Verify no error messages appear
3. Review the 2D scene view to confirm proper placement
4. Close the Editor

11.2 Running DART Modules

Execute the simulation:

1. In the main DART window, click **Run → DART**
2. This runs all four modules in sequence:
   - **Direction:** Calculates sun and viewing geometry
   - **Phase:** Processes spectral and optical properties
   - **Maket:** Constructs the 3D scene
   - **Dart:** Performs radiative transfer calculations

Figure 17 displays the Run menu with all DART modules. The execution order is important, as each module depends on the outputs of previous modules.

! Module Dependencies

First Run: - All modules must be executed
Subsequent Runs: - Only run modules affected by parameter changes - Module dependencies: - Direction: Affects sun/sensor geometry - Phase: Affects spectral bands and optical properties - Maket: Affects scene structure and objects - Dart: Affected by all previous modules
This selective execution saves considerable computation time during parameter optimiza-

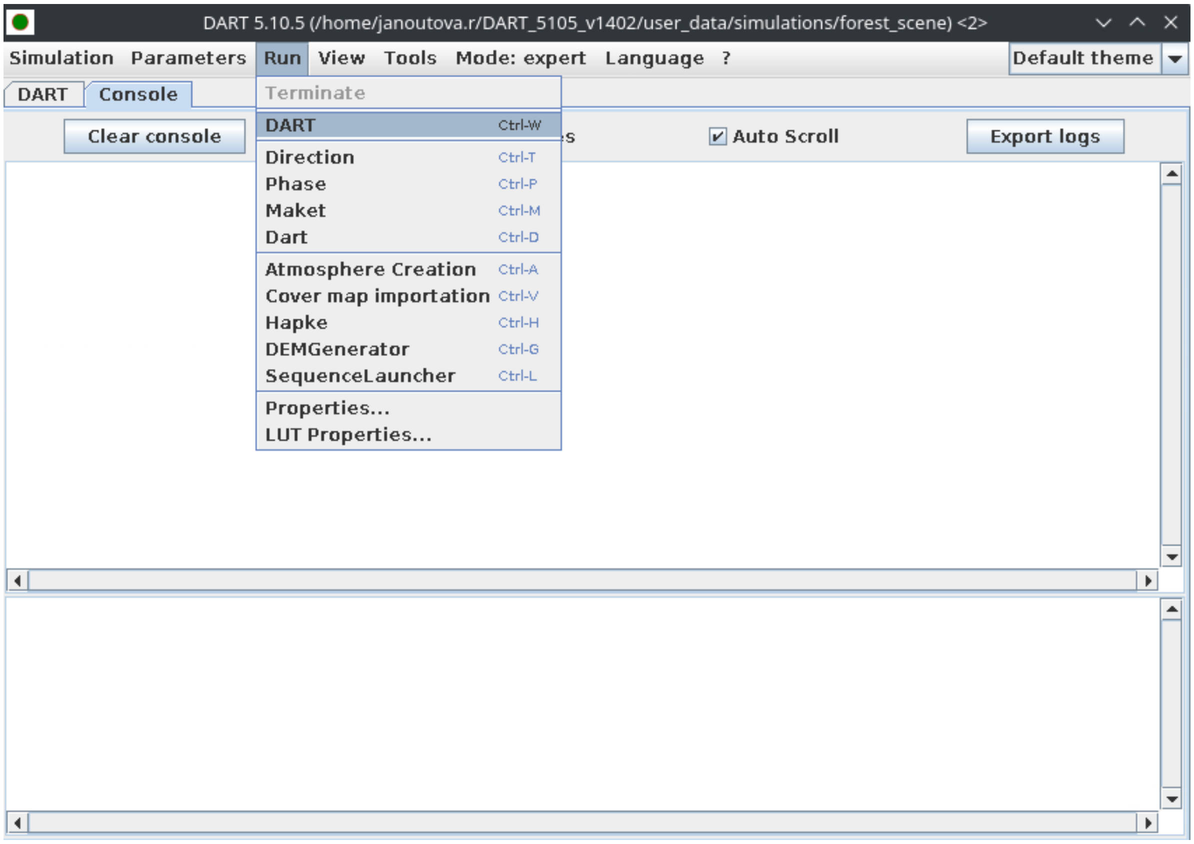


Figure 17: DART Run menu showing all available modules including Direction, Phase, Maket, Dart, and auxiliary tools

tion.

Computation Time

Expected computation times vary based on: - Number of spectral bands (currently 4) - Scene complexity (30m × 30m with multiple trees) - Spatial resolution (5 cm pixels) - Number of threads (12 recommended)
For this configuration, expect 30-60 minutes on a modern 12-core system.

12 Part 9: Sequence Launcher for LUT Generation

The Sequence Launcher is a powerful tool for generating Look-Up Tables (LUTs) by systematically varying parameters:

12.1 Setting Up a Sequence

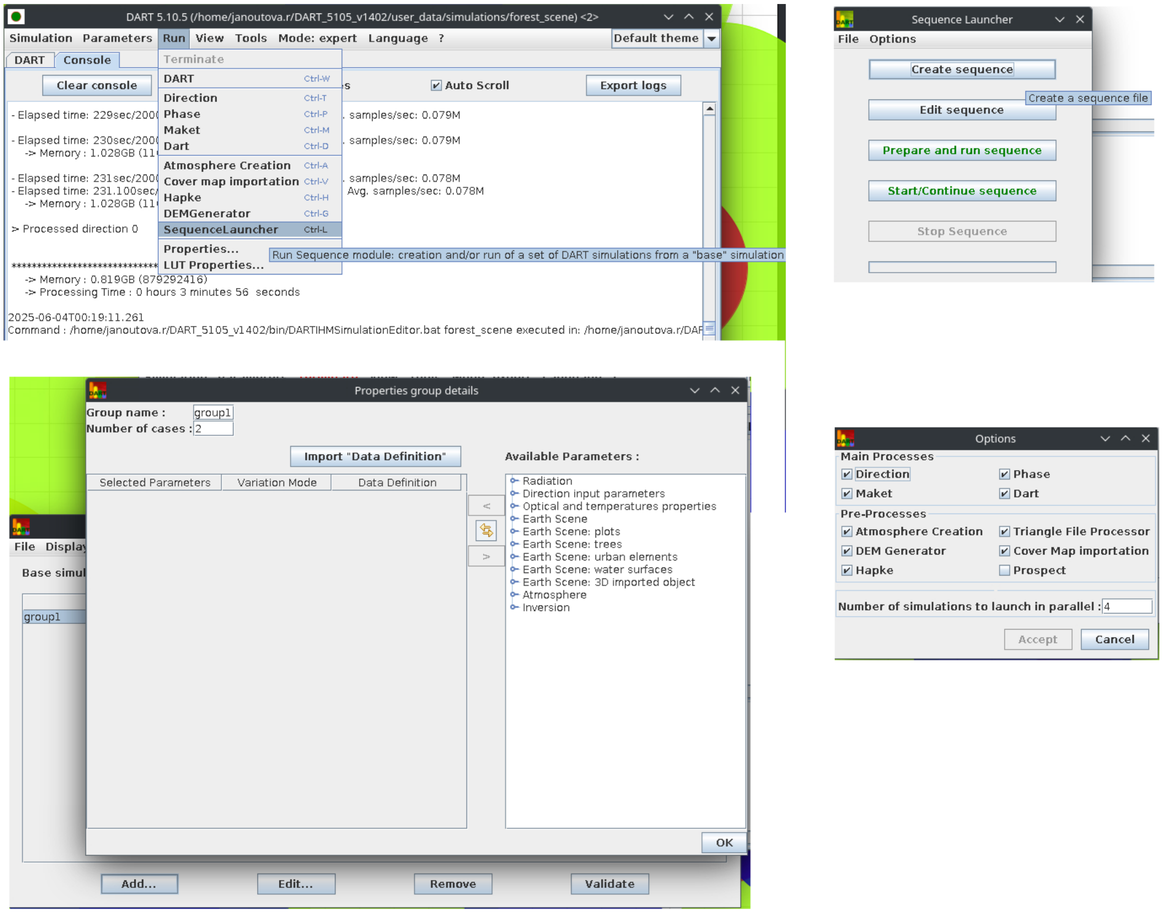
1. Click **Run → SequenceLauncher**
2. Click **"Create sequence"**
3. Click **"Add"**
4. Select parameters to vary:
   - Navigate through the parameter tree
   - Select optical properties or structural parameters
   - Define the range of values

Figure 18 shows the complete Sequence Launcher workflow, including the parameter selection dialog, the properties group details window, and the main processes configuration panel where you can specify which DART modules to run and how many simulations to execute in parallel.

12.2 Configuration Options

Parameter Selection: Choose which parameters to vary, such as: - PROSPECT biochemical parameters (Chlorophyll, LAI, etc.) - Structural parameters (tree dimensions, densities) - Atmospheric conditions - Sun angles

Process Configuration: In **Preferences → Process and threads to run:** - Select which modules to run (based on changed parameters) - Set number of parallel simulations - Each simulation uses the specified number of threads



Run Sequence module: creation and/or run of a set of DART simulations from a "base" simulation

```
- Elapsed time: 229sec/200(          . samples/sec: 0.079M

- Elapsed time: 230sec/200(          . samples/sec: 0.079M
   -> Memory : 1.028GB (11(

- Elapsed time: 231sec/200(          . samples/sec: 0.078M
- Elapsed time: 231.100sec/           Avg. samples/sec: 0.078M
   -> Memory : 1.028GB (11(

> Processed direction 0


******************************
   -> Memory : 0.819GB (879292416)
   -> Processing Time : 0 hours 3 minutes 56  seconds

2025-06-04T00:19:11.261
Command : /home/janoutova.r/DART_5105_v1402/bin/DARTIHMSimulationEditor.bat forest_scene executed in: /home/janoutova.r/DAF
```

Create a sequence file

Group name : group1
Number of cases : 2

☑ Direction
☑ Phase
☑ Maket
☑ Dart

☑ Atmosphere Creation
☑ Triangle File Processor
☑ DEM Generator
☑ Cover Map importation
☑ Hapke
☐ Prospect

Number of simulations to launch in parallel : 4

Figure 18: Sequence Launcher interface showing (left) execution progress, (center) parameter selection tree, and (right) process configuration options

Parallel Processing

Example configuration for 12-core system: - Threads per simulation: 3 - Parallel simulations: 4 - Total thread usage: 12
Balance parallel simulations and threads per simulation based on your system's capabilities and memory.

12.3 Running the Sequence

1. Click **"Prepare and run sequence"**
2. Monitor progress in the console window
3. Results will be saved in numbered subdirectories

LUT Applications

Generated LUTs are valuable for: - Parameter retrieval from remote sensing data - Sensitivity analysis - Model inversion - Uncertainty quantification - Training machine learning models
The systematic parameter variation creates a database relating scene parameters to simulated reflectance.

13 Summary and Best Practices

14 Scene Setup

Essential Steps: - Proper file organization in DART directories - Careful spectral band configuration - Appropriate spatial resolution for application - Realistic optical properties from measurements

Common Mistakes to Avoid: - Forgetting to enable double face for leaves - Incorrect spectral bandwidth settings - Insufficient spatial resolution - Isolated scene boundaries causing edge effects

15 Optical Properties

Best Practices: - Use measured optical properties when available - Validate PROSPECT parameters against lab measurements - Consider seasonal variations in leaf properties - Document all optical property sources

Considerations: - Bark properties vary by species and condition - Understory optical properties affect overall scene reflectance - Leaf age and health influence biochemical parameters

16 Computational Efficiency

Optimization Strategies: - Use appropriate thread count for your system - Enable Russian Roulette acceleration - Optimize rendering time parameters - Only generate needed output products - Use periodic scene boundaries to reduce edge effects

Resource Requirements: - RAM: 16-32 GB recommended for large scenes - Storage: Plan for large output files (GB per simulation) - CPU: Multi-core processor essential for reasonable run times

17 Quality Control

Validation Steps: - Visual inspection of 2D scene layout - Check for error messages in Editor - Verify spectral signatures are realistic - Compare with field measurements if available - Test with simplified scenes first

Troubleshooting: - Save frequently during setup - Test with single spectral band initially - Use smaller scene for parameter testing - Check DART manual for error messages

18 Advanced Topics

18.1 Custom 3D Objects

Creating your own tree models:

3D Object Requirements

DART accepts 3D objects in several formats: - OBJ (most common) - PLY - FBX (with conversion)

Requirements: - Properly defined groups (leaves, trunk, branches) - Correct facet normals - Reasonable polygon count (balance detail vs. computation) - Separate materials for different components

18.2 Python Integration

DART supports Python scripting for:

- Automated parameter sweeps
- Custom scene generation
- Post-processing workflows
- Integration with other tools

See the DART manual for Python API documentation.

18.3 Atmosphere Modeling

For detailed atmospheric studies:

- Use measured atmospheric profiles when available
- Consider aerosol optical depth variations
- Account for water vapor absorption
- Validate against AERONET data

18.4 Validation Approaches

Recommended validation methods:

1. **Lab measurements:** Compare PROSPECT outputs to spectroradiometer data
2. **Field campaigns:** Validate scene reflectance with handheld or UAV spectrometers
3. **Cross-comparison:** Compare with other radiative transfer models (PROSAIL, librat)
4. **Sensitivity analysis:** Use Sequence Launcher to assess parameter impacts

19 Additional Resources

ℹ Learning Resources

DART Documentation: - Official DART Website - User manual (included with installation) - Tutorial collection - Forum for user questions
Scientific Background: - Gastellu-Etchegorry et al. publications on DART methodology - Remote sensing textbooks on radiative transfer - PROSPECT model documentation
Community: - DART user mailing list - Annual DART training workshops - CESBIO laboratory contacts

⚠ Important Considerations

Model Limitations: - DART is computationally intensive for large scenes - Accuracy depends on input data quality - Simplified atmospheric models may not capture all effects - 3D object complexity affects computation time
Data Requirements: - Accurate 3D scene geometry - Validated optical properties - Appropriate atmospheric parameters - Sufficient computational resources
Application Scope: DART is suitable for: Forest and vegetation studies Urban remote sensing Precision agriculture Sensor design and testing
May be excessive for: Simple BRDF calculations (use simpler models) Very large spatial extents (consider other approaches) Real-time applications (computation time prohibitive)

20 Conclusion

This tutorial has walked through the complete workflow for setting up a forest scene simulation in DART. The combination of detailed 3D objects, measured optical properties, and physically-based radiative transfer provides a powerful tool for remote sensing research and application development.

Key takeaways:

1. **Proper setup is crucial:** Careful attention to file organization, optical properties, and scene configuration ensures successful simulations
2. **Bi-directional mode is optimal:** For high-resolution 3D scenes, DART Lux provides the best balance of accuracy and efficiency
3. **Validation is essential:** Compare simulations with field measurements whenever possible
4. **Sequence Launcher enables systematic analysis:** Use this tool for parameter studies and LUT generation
5. **Computational resources matter:** Plan for significant computation time and storage requirements

The skills developed in this tutorial provide a foundation for more advanced DART applications, including multi-temporal studies, sensor simulation, and parameter retrieval from remote sensing data.

This tutorial is based on DART version 5.10.5. While the core concepts remain consistent across versions, specific interface details may vary. Always refer to the official DART documentation for the most current information.

21 Appendix: Common Issues and Solutions

22 Installation Issues

Problem: DART won't start - Check Java installation (required) - Verify environment variables - Run from command line for error messages

Problem: Database files not found - Verify file paths in simulation settings - Check that extracted files are in correct DART directories - Use absolute paths if relative paths fail

23 Simulation Errors

Problem: Out of memory errors - Reduce scene size or resolution - Decrease number of threads - Increase Java heap size in DART configuration

Problem: Very slow execution - Verify thread count settings - Check for excessive output products - Consider using coarser resolution for testing

24 Output Issues

Problem: Images not generated - Check "Products" configuration - Verify maximal VZA settings - Ensure sufficient disk space - Check write permissions

Problem: Unexpected spectral values - Verify optical property assignments - Check for missing double face settings - Validate PROSPECT parameters

25 Scene Configuration

Problem: Trees not visible in 2D view - Enable "Show this field's objects in the 2D view" - Check field file format and paths - Verify tree positions are within scene bounds

Problem: Optical properties not applied - Confirm optical property names match - Check database file paths - Verify group assignments in 3D objects