Vniversitat de València
Departament de Física de la Terra i Termodinàmica
IPL Laboratorio de Procesado de Imágenes

ARTMO: an Automated Radiative Transfer Models Operator toolbox for automated retrieval of biophysical parameters through model inversion

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- ARTMO concept
  - Main module
  - Design
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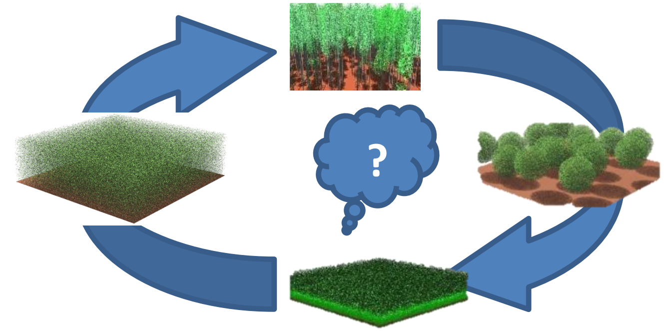
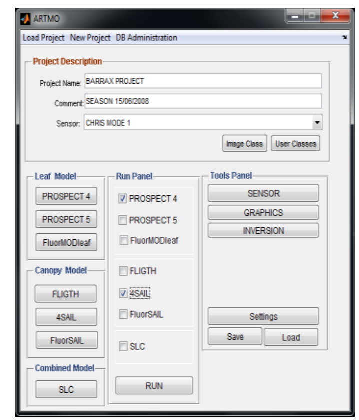
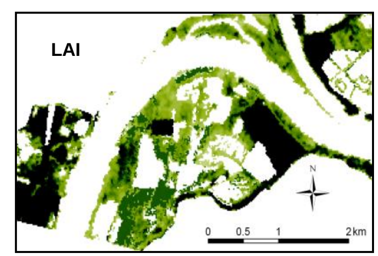
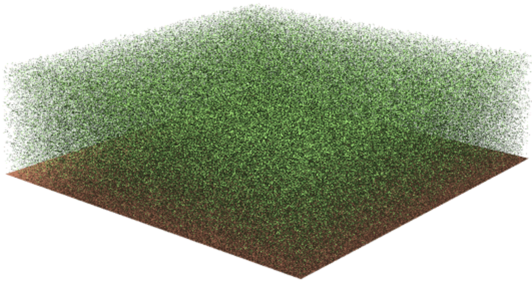
  - Canopy-level models
  - Graphics
  - Inversion
- Applications
  - Case study floodplain mapping
- Conclusions





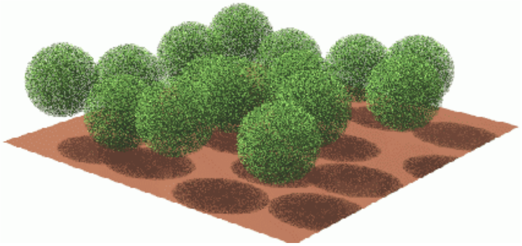


Rationale



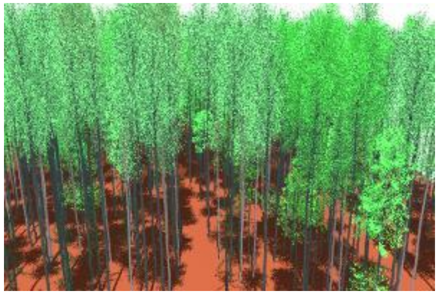
Radiative transfer (RT) modeling plays a key role for earth observation (EO) because it is needed to design and develop EO instruments, and to test and apply inversion algorithms.

A number of often highly specialized leaf and canopy RT models has been developed, each of which emanates from a different set of original requirements.



Currently there exists no user-friendly toolbox that brings these models together.

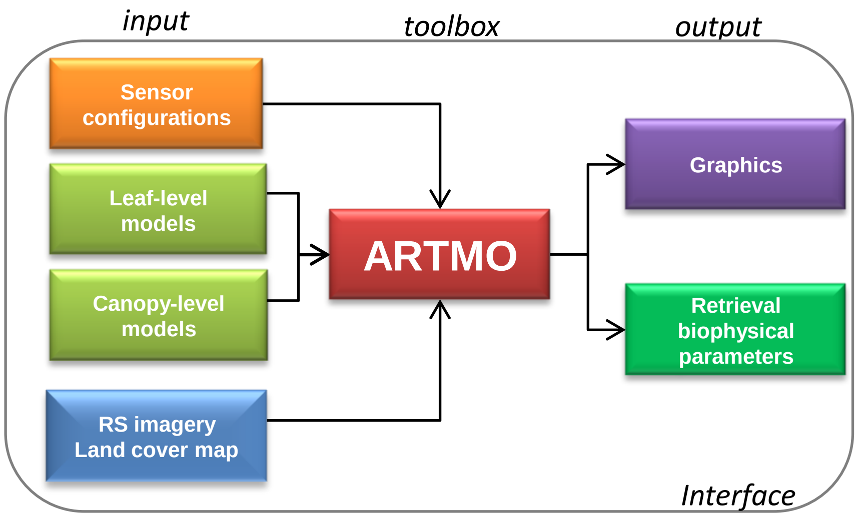
- RAMI only comparison excercise (ROMC)
- CRASh (Dorigo et al., 2009: PROSPECT+SAILh, class-based inversion)



Objectives

To develop a canopy radiative transfer toolbox that couples leaf-level models with canopy-level RT models for the simulation of reflectance data

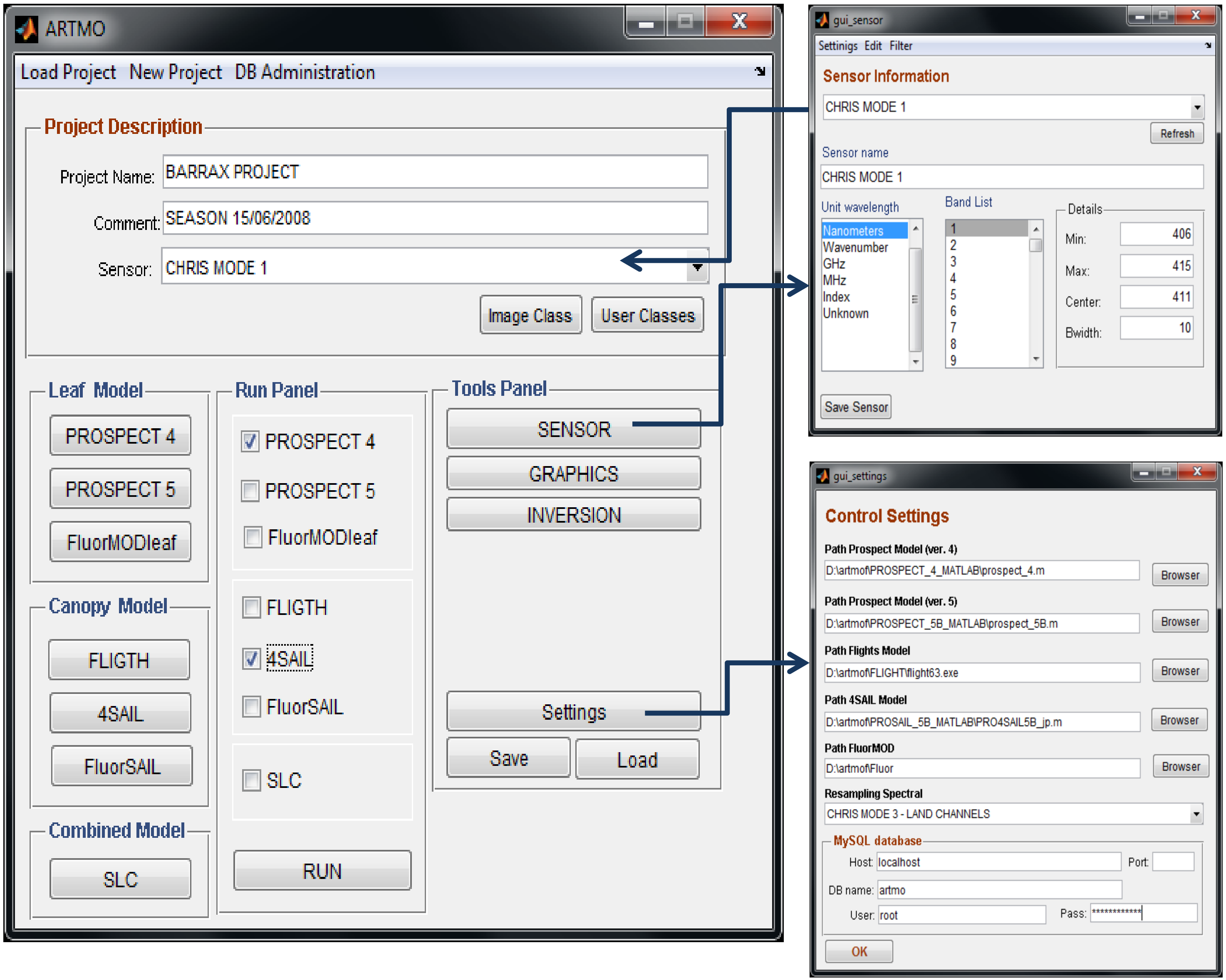
- For better understanding interactions terrestrial vegetation and solar radiation in VNIR
- Simulator for the development of new Earth observators
- (class-based) model inversion for retrieval of biophysical parameters



Required features:

- plug-n-play GUI
- any sensor
- 1D and 3D models
- fast and massive forward simulations
- flexible and easy access
- graphics module
- inversion module
- Class-based inversion (e.g. surface elements, sun-target-sensor geometry)

ARTMO main module



Selection of sensor or creation of own band settings

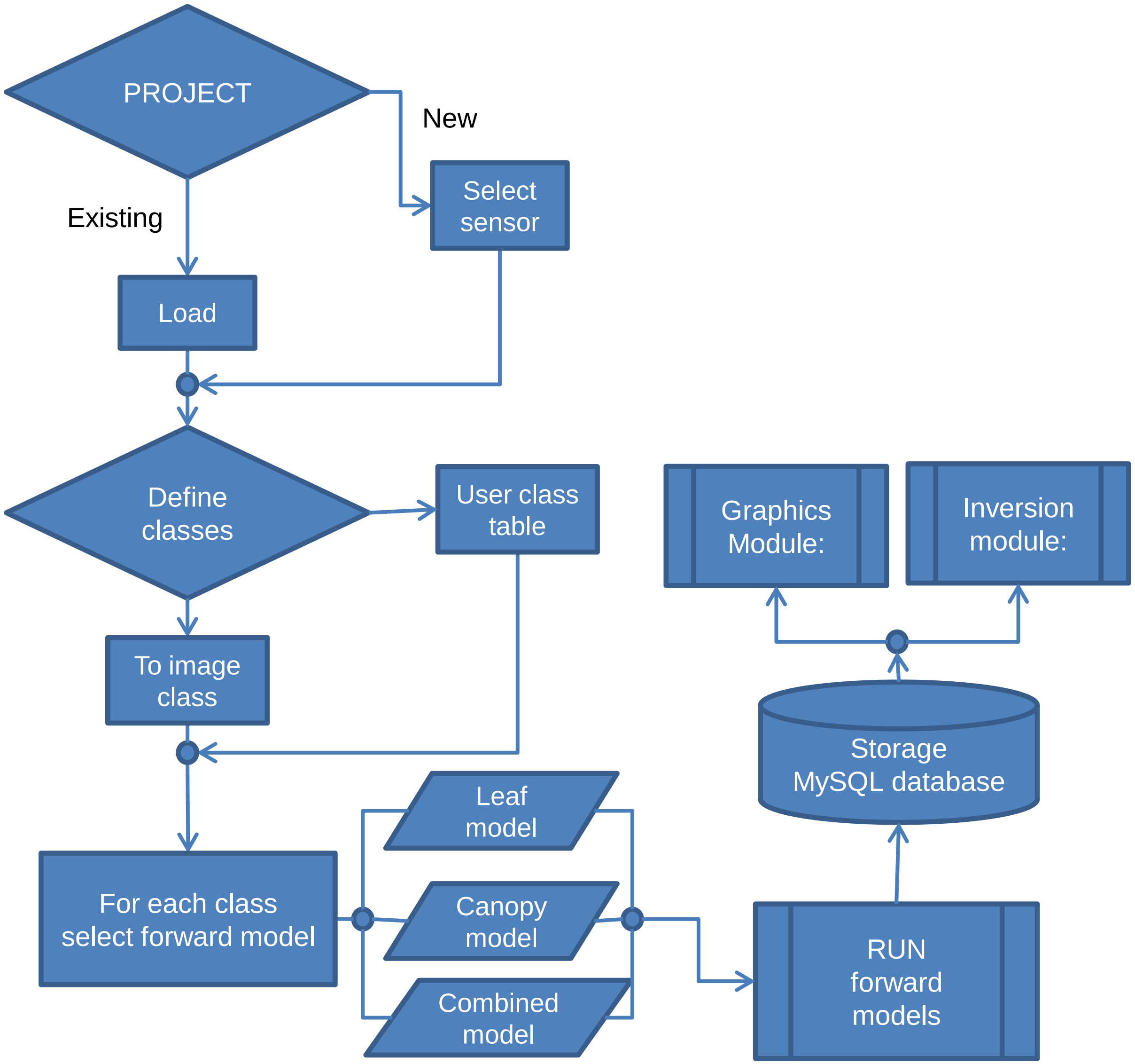
A number of sensors are already included:

- **CHRIS mode 1, 2, 3, 4, 5**
- **Sentinel-2**

Any spectral settings can be defined by the user.

All data automatically resampled to the selected sensor

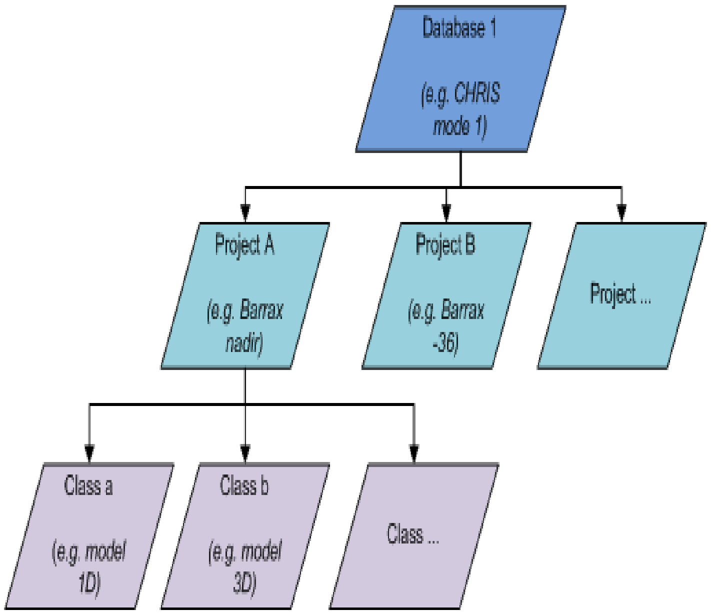
Design ARTMO

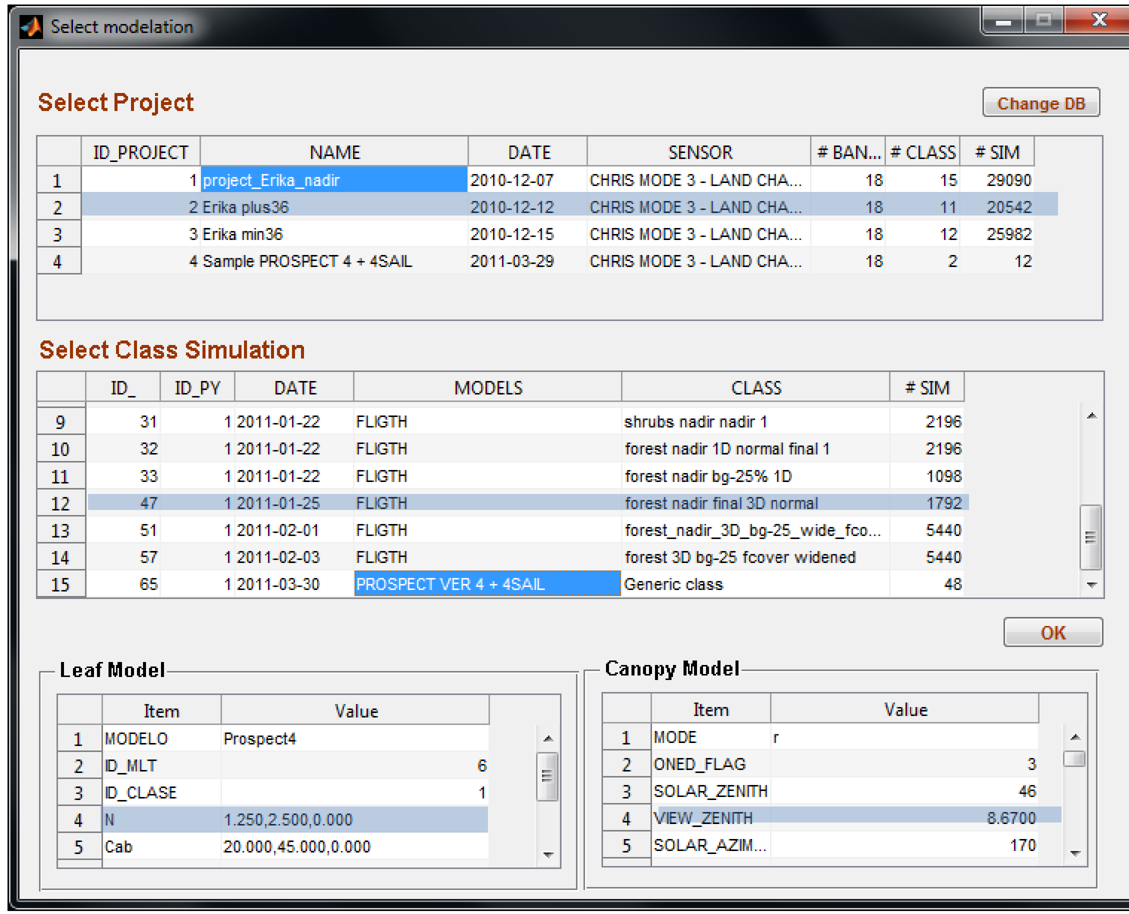


The core of ARTMO is a **MySQL** DB:

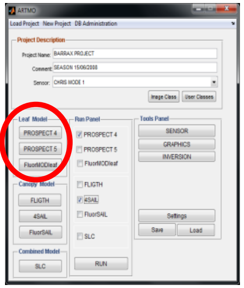
- Allows efficient massive storing
- Easy data retrieval through queries
- Spectral data linked with metadata (e.g. model inputs)
- Applicable both for forward simulations and model inversion

Data hierarchy and access

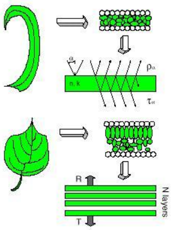




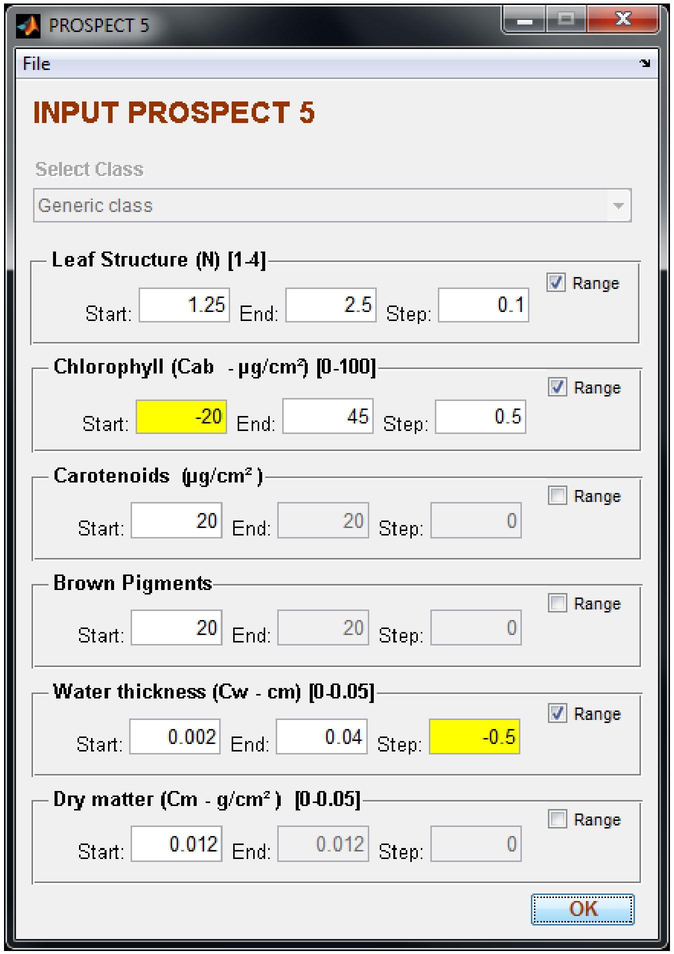
- Data storage and access hierarchically based
- All input parameters can be consulted

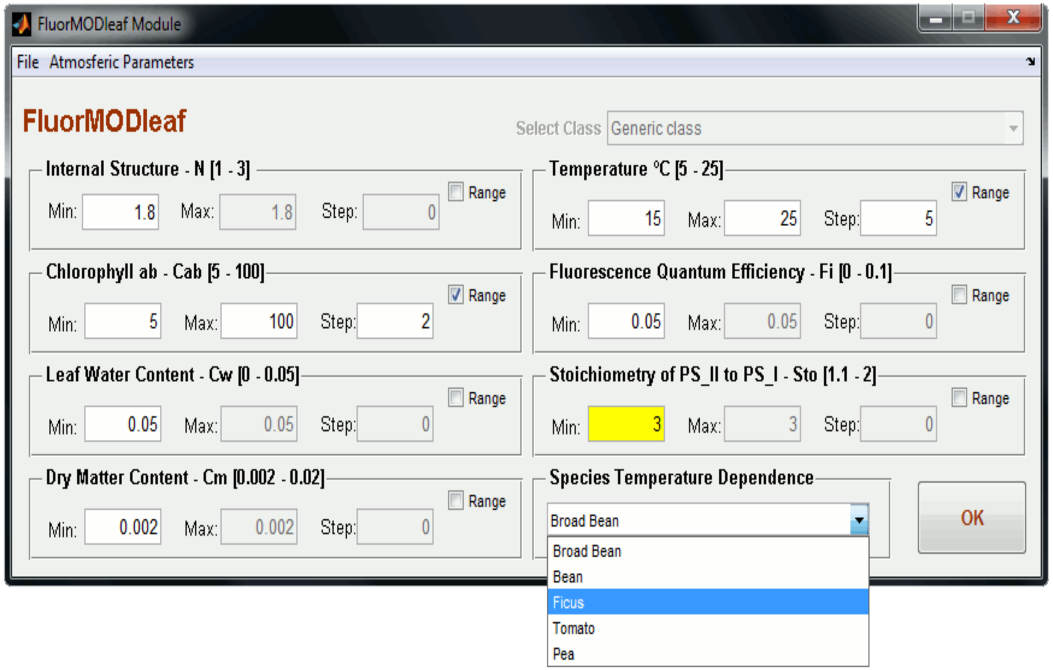


Leaf-level models

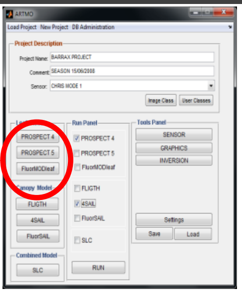


PROSPECT family

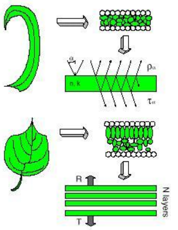


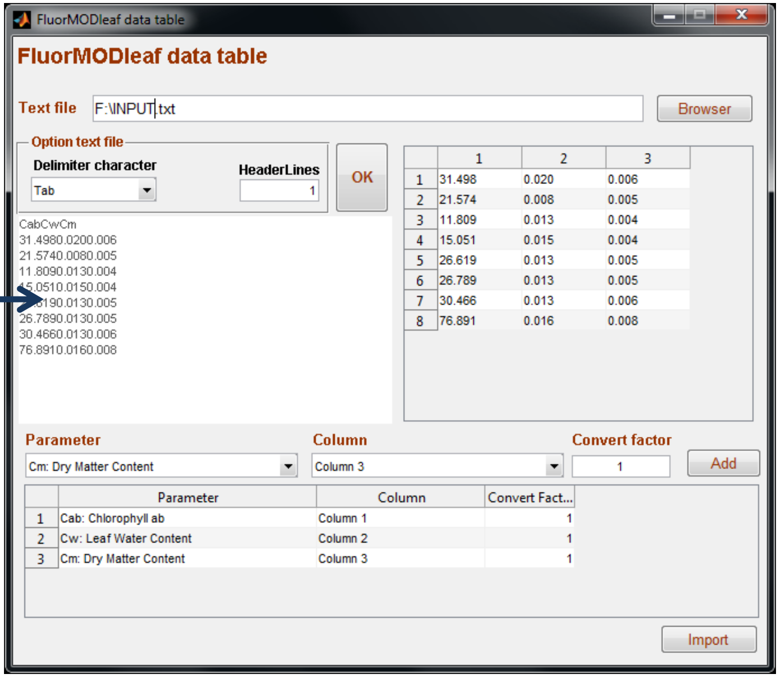


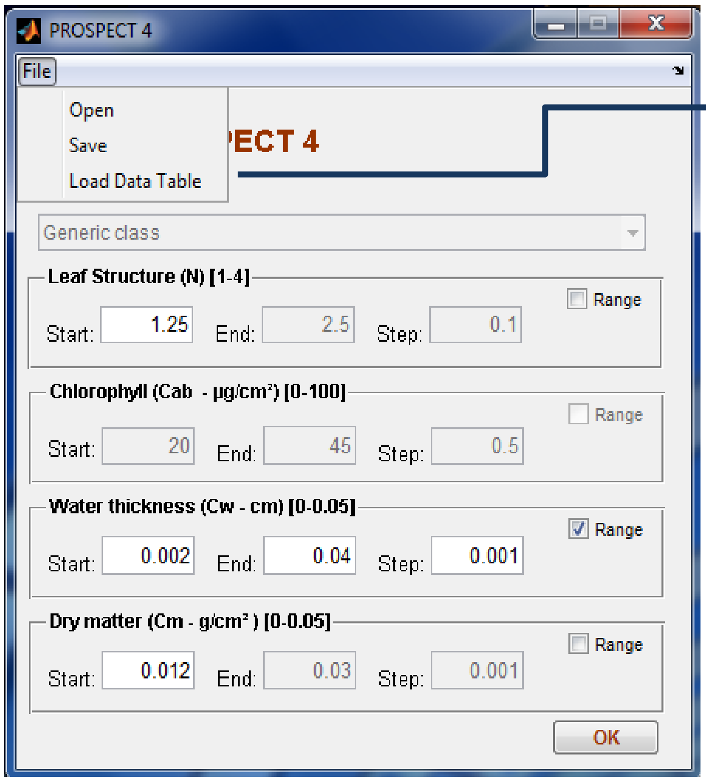
- Either one value can be inputted, or when the ‘range’ box is enabled a range of values can be inputted by providing first, last and step value
- When multiple ranges are inputted all combinations will be simulated
- When impossible values are inputted the box will turn yellow



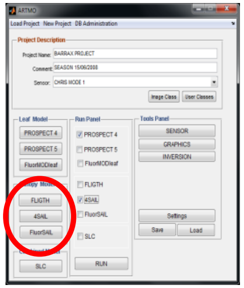
Leaf-level models



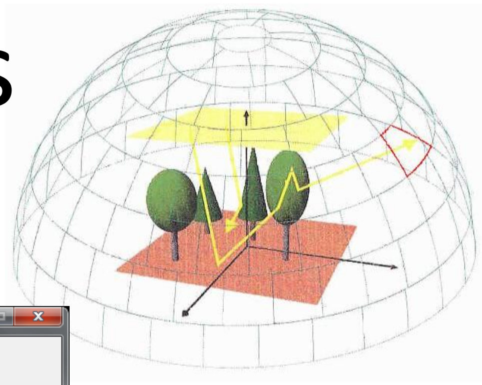




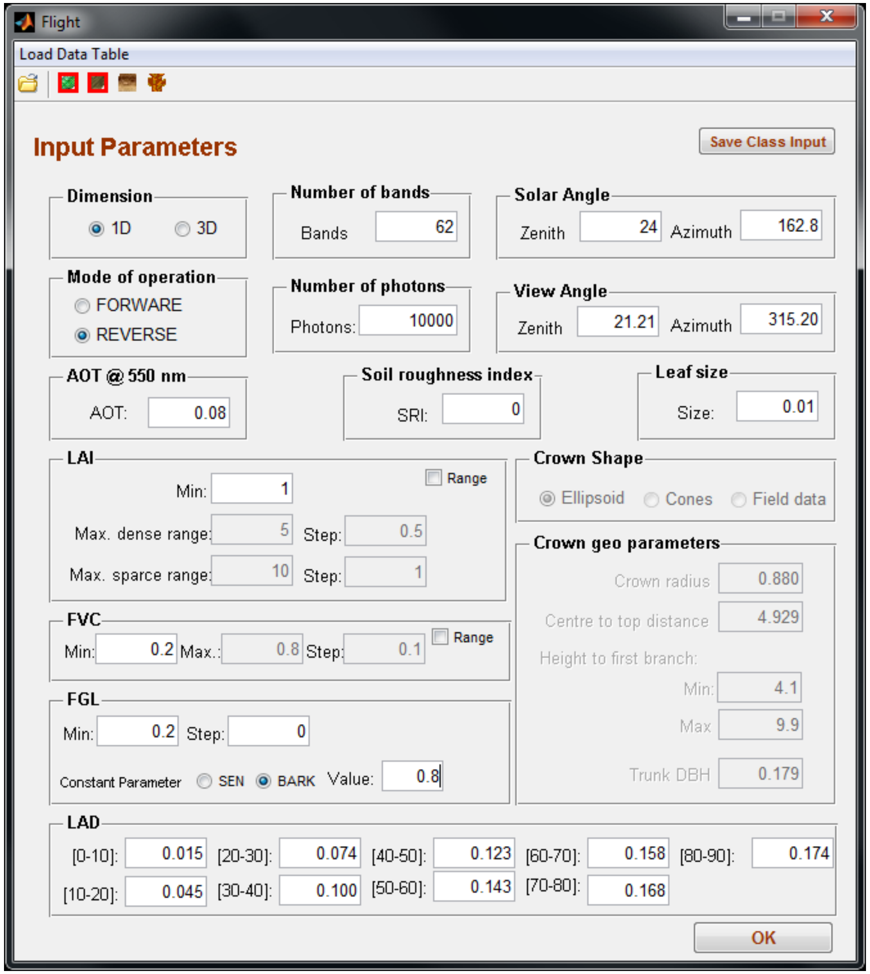
- Also own input data can be loaded.
- The data table window allows to open any text file, choose the right column, convert, and link with a model variable.
- The linked model variable is then disabled in the main input window.

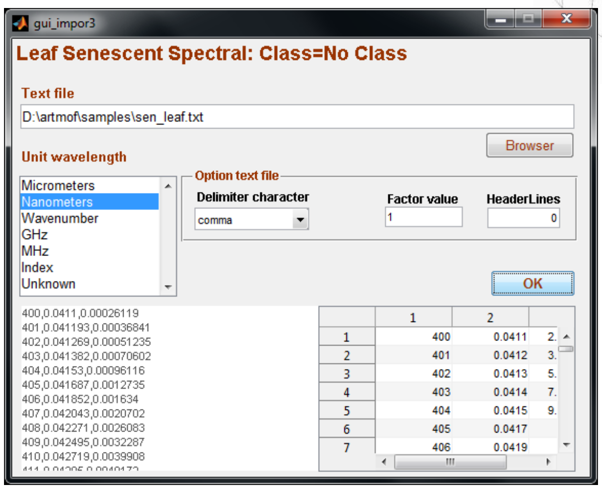


Canopy-level models



Ray tracing: FLIGHT

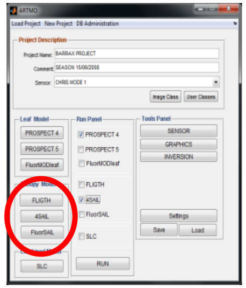




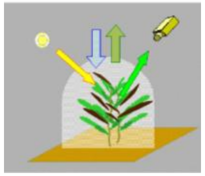
FLIGHT can run in 1D and in 3D. When 3D is selected the cropwn architecture parameters are enabled.

Green leaf, scenescent leaf , bark and soil spectra can be loaded by means of an import window

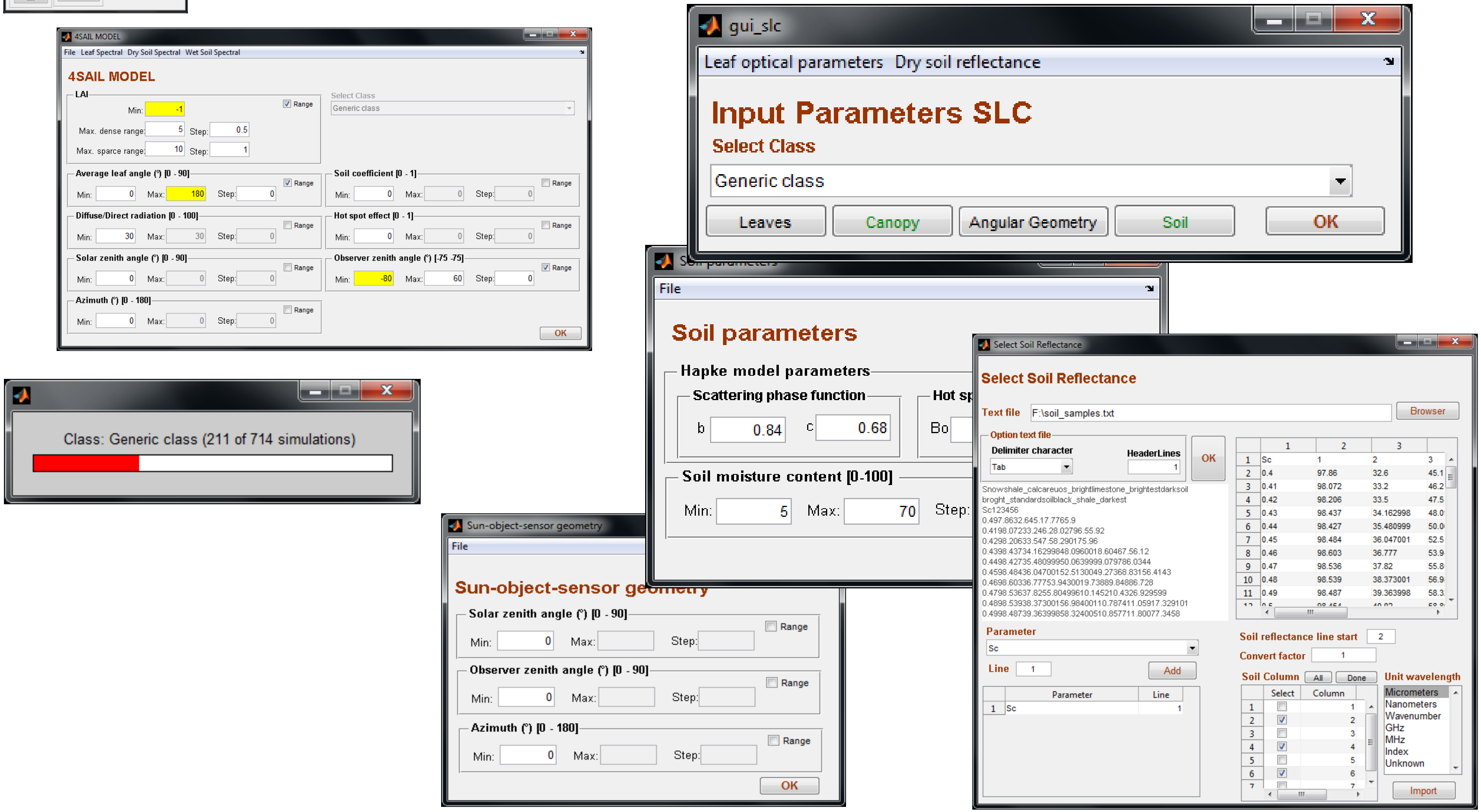
Green leaf can either come from a leaf-level model or from imported spectra.



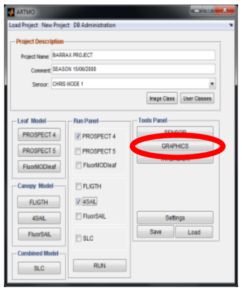
Canopy-level models

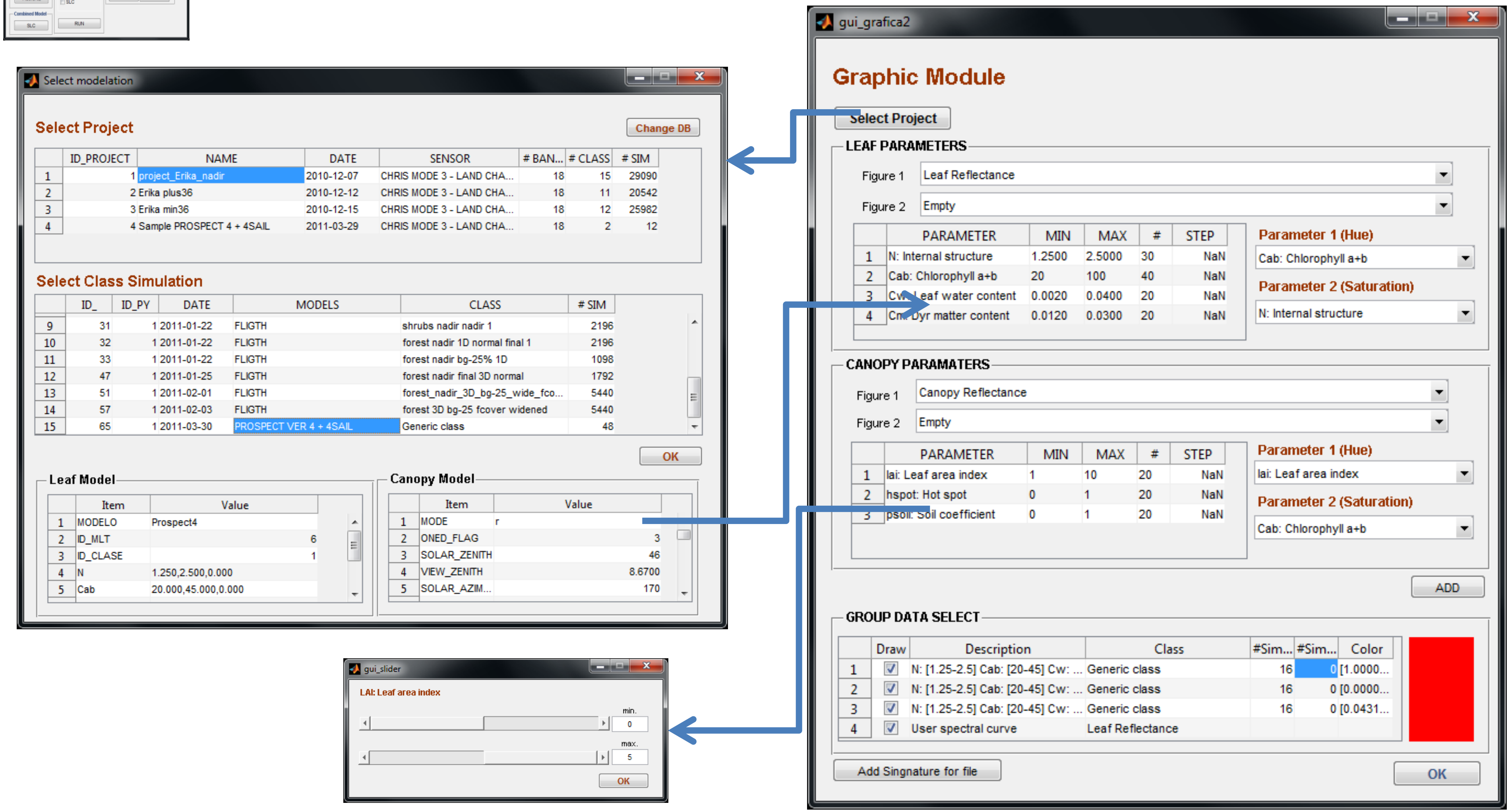


SAIL family

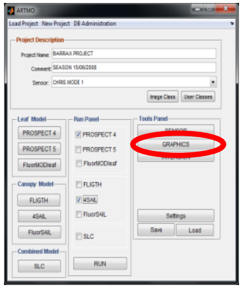


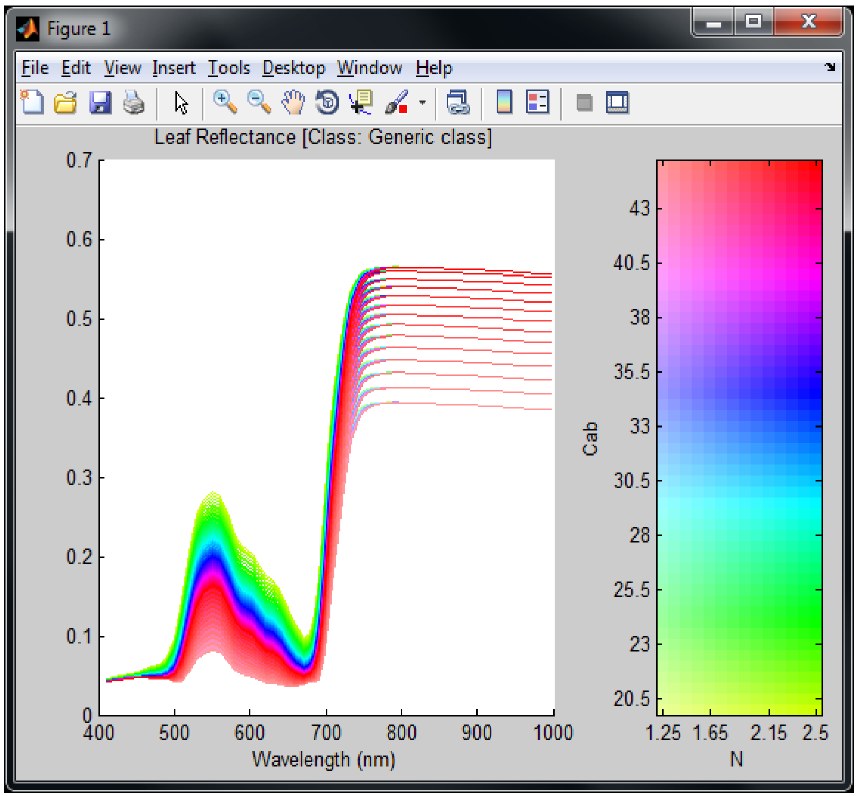
Graphics

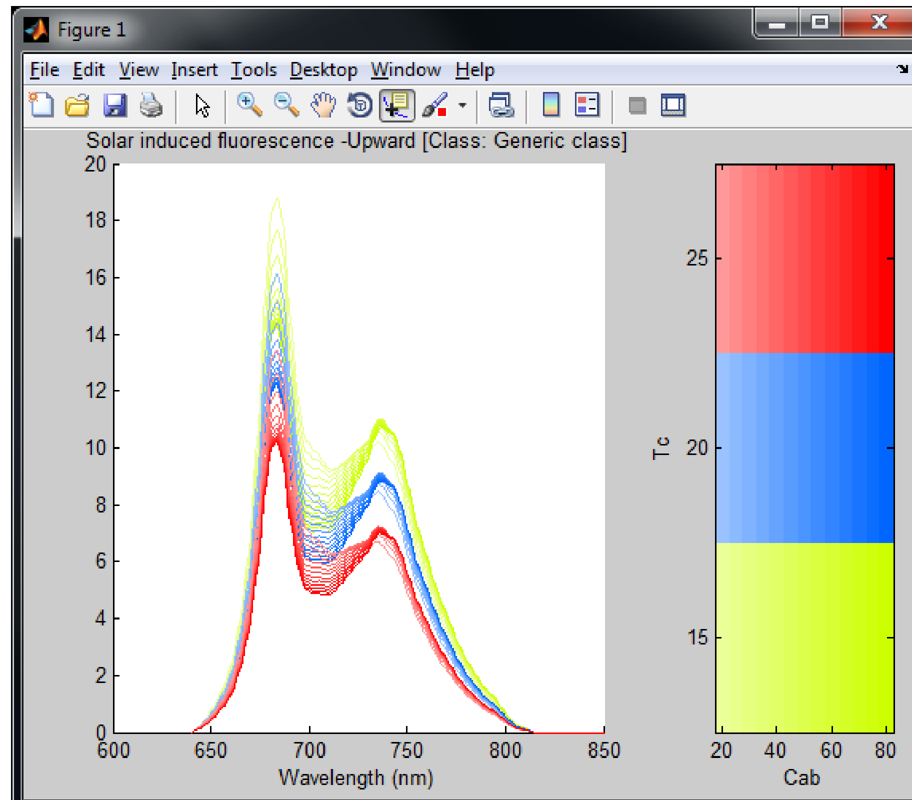



Select modelation
Select Project
Change DB
ID_PROJECT NAME DATE SENSOR # BAN... # CLASS # SIM
1 1 project_Erika_nadir 2010-12-07 CHRIS MODE 3 - LAND CHA... 18 15 29090
2 2 Erika plus36 2010-12-12 CHRIS MODE 3 - LAND CHA... 18 11 20542
3 3 Erika min36 2010-12-15 CHRIS MODE 3 - LAND CHA... 18 12 25982
4 4 Sample PROSPECT 4 + 4SAIL 2011-03-29 CHRIS MODE 3 - LAND CHA... 18 2 12
Select Class Simulation
ID_ ID_PY DATE MODELS CLASS # SIM
9 31 1 2011-01-22 FLIGTH shrubs nadir nadir 1 2196
10 32 1 2011-01-22 FLIGTH forest nadir 1D normal final 1 2196
11 33 1 2011-01-22 FLIGTH forest nadir bg-25% 1D 1098
12 47 1 2011-01-25 FLIGTH forest nadir final 3D normal 1792
13 51 1 2011-02-01 FLIGTH forest_nadir_3D_bg-25_wide_fco... 5440
14 57 1 2011-02-03 FLIGTH forest 3D bg-25 fcover widened 5440
15 65 1 2011-03-30 PROSPECT VER 4 + 4SAIL Generic class 48
OK
Leaf Model
Item Value
1 MODELO Prospect4
2 ID_MLT 6
3 ID_CLASE 1
4 N 1.250,2.500,0.000
5 Cab 20.000,45.000,0.000
Canopy Model
Item Value
1 MODE r
2 ONED_FLAG 3
3 SOLAR_ZENITH 46
4 VIEW_ZENITH 8.6700
5 SOLAR_AZIM... 170
gui_slider
LAI: Leaf area index
min.
0
max.
5
OK
gui_grafica2
Graphic Module
Select Project
LEAF PARAMETERS
Figure 1 Leaf Reflectance
Figure 2 Empty
PARAMETER MIN MAX # STEP
1 N: Internal structure 1.2500 2.5000 30 NaN
2 Cab: Chlorophyll a+b 20 100 40 NaN
3 Cw: Leaf water content 0.0020 0.0400 20 NaN
4 Cm: Dyr matter content 0.0120 0.0300 20 NaN
Parameter 1 (Hue)
Cab: Chlorophyll a+b
Parameter 2 (Saturation)
N: Internal structure
CANOPY PARAMATERS
Figure 1 Canopy Reflectance
Figure 2 Empty
PARAMETER MIN MAX # STEP
1 lai: Leaf area index 1 10 20 NaN
2 hspot: Hot spot 0 1 20 NaN
3 psoil: Soil coefficient 0 1 20 NaN
Parameter 1 (Hue)
lai: Leaf area index
Parameter 2 (Saturation)
Cab: Chlorophyll a+b
ADD
GROUP DATA SELECT
Draw Description Class #Sim... #Sim... Color
1 N: [1.25-2.5] Cab: [20-45] Cw: ... Generic class 16 0 [1.0000...
2 N: [1.25-2.5] Cab: [20-45] Cw: ... Generic class 16 0 [0.0000...
3 N: [1.25-2.5] Cab: [20-45] Cw: ... Generic class 16 0 [0.0431...
4 User spectral curve Leaf Reflectance
Add Signature for file
OK

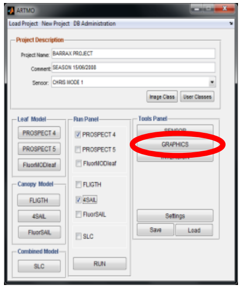
Graphics



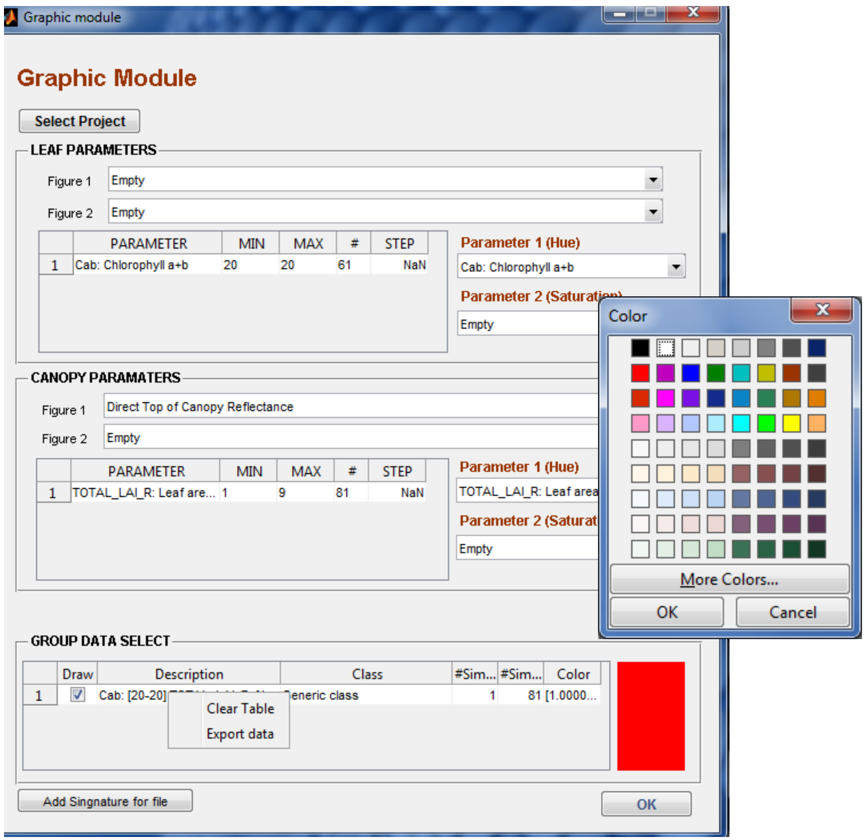


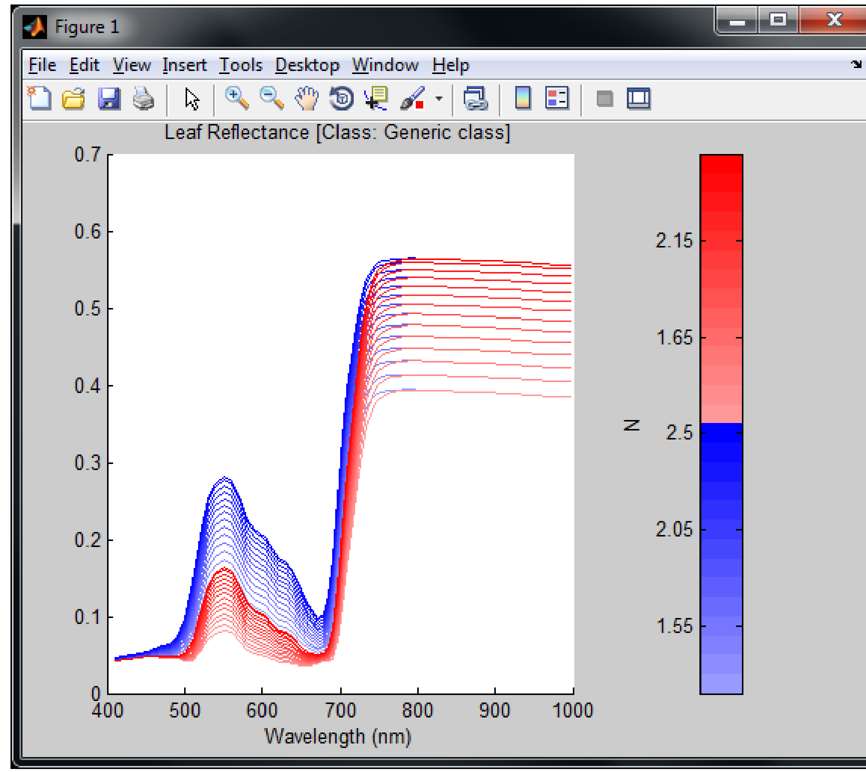


Plottings of 2 variables by color and color intensity

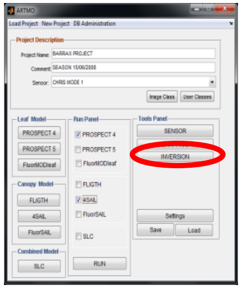


Graphics

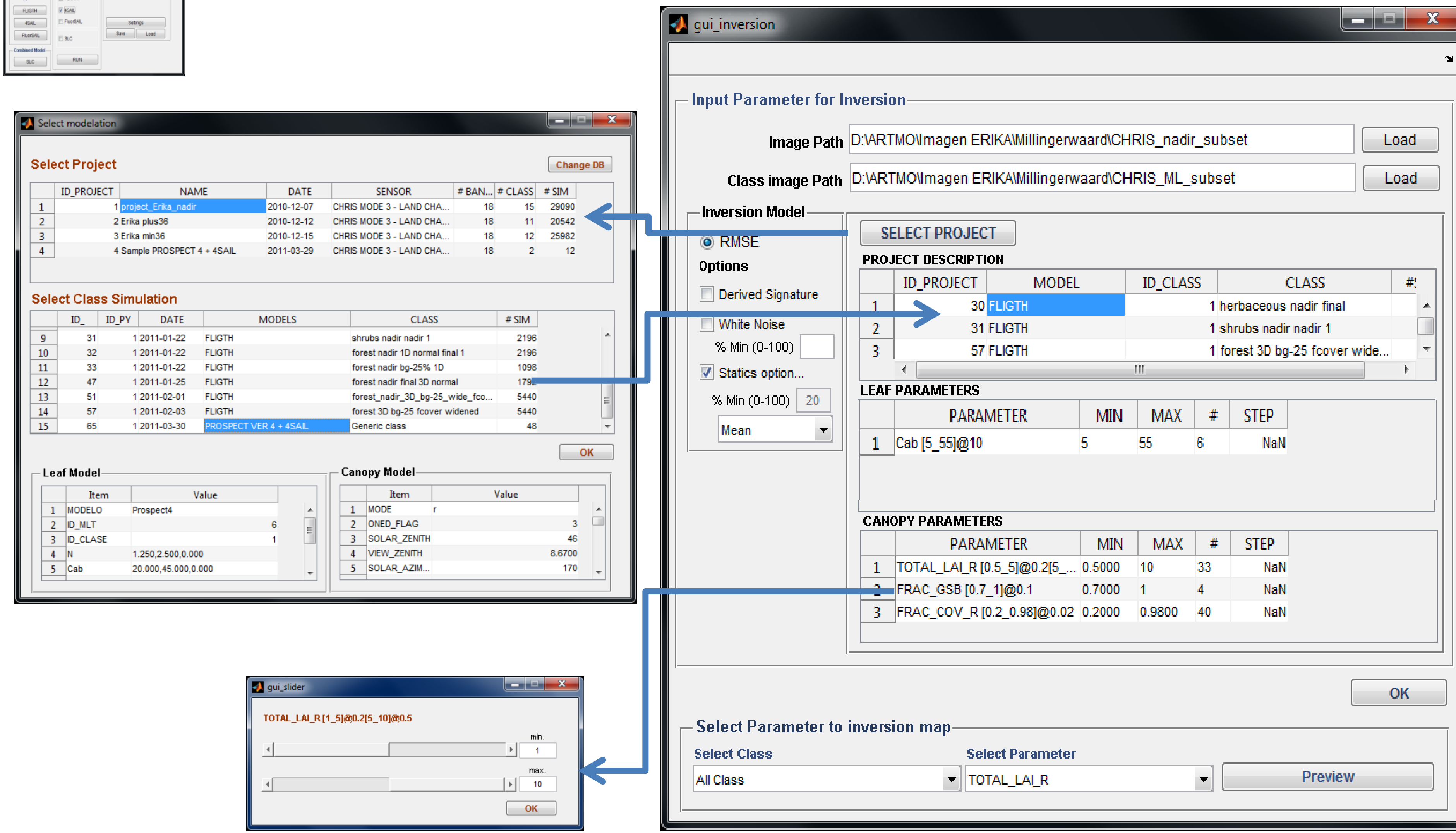




Plotting of 1 variable with an assigned color. Multiple classes can be added.



Inversion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Input Parameter for Inversion
Image Path
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Load
Class image Path
D:\ARTMO\Imagen ERIKA\Millingerwaard\CHRIS_ML_subset
Load
Inversion Model
RMSE
Options
Derived Signature
White Noise
% Min (0-100)
Statics option...
% Min (0-100)
20
Mean
SELECT PROJECT
PROJECT DESCRIPTION
ID_PROJECT MODEL ID_CLASS CLASS
1 30 FLIGTH 1 herbaceous nadir final
2 31 FLIGTH 1 shrubs nadir nadir 1
3 57 FLIGTH 1 forest 3D bg-25 fcover wide...
LEAF PARAMETERS
PARAMETER MIN MAX # STEP
1 Cab [5_55]@10 5 55 6 NaN
CANOPY PARAMETERS
PARAMETER MIN MAX # STEP
1 TOTAL_LAI_R [0.5_5]@0.2[5_... 0.5000 10 33 NaN
2 FRAC_GSB [0.7_1]@0.1 0.7000 1 4 NaN
3 FRAC_COV_R [0.2_0.98]@0.02 0.2000 0.9800 40 NaN
OK
Select Parameter to inversion map
Select Class
All Class
Select Parameter
TOTAL_LAI_R
Preview
Select modelation
Select Project
Change DB
ID_PROJECT NAME DATE SENSOR # BAN... # CLASS # SIM
1 1 project_Erika_nadir 2010-12-07 CHRIS MODE 3 - LAND CHA... 18 15 29090
2 2 Erika plus36 2010-12-12 CHRIS MODE 3 - LAND CHA... 18 11 20542
3 3 Erika min36 2010-12-15 CHRIS MODE 3 - LAND CHA... 18 12 25982
4 4 Sample PROSPECT 4 + 4SAIL 2011-03-29 CHRIS MODE 3 - LAND CHA... 18 2 12
Select Class Simulation
ID_ ID_PY DATE MODELS CLASS # SIM
9 31 1 2011-01-22 FLIGTH shrubs nadir nadir 1 2196
10 32 1 2011-01-22 FLIGTH forest nadir 1D normal final 1 2196
11 33 1 2011-01-22 FLIGTH forest nadir bg-25% 1D 1098
12 47 1 2011-01-25 FLIGTH forest nadir final 3D normal
13 51 1 2011-02-01 FLIGTH forest_nadir_3D_bg-25_wide_fco... 5440
14 57 1 2011-02-03 FLIGTH forest 3D bg-25 fcover widened 5440
15 65 1 2011-03-30 PROSPECT VER 4 + 4SAIL Generic class 48
OK
Leaf Model
Item Value
1 MODELO Prospect4
2 ID_MLT 6
3 ID_CLASE 1
4 N 1.250,2.500,0.000
5 Cab 20.000,45.000,0.000
Canopy Model
Item Value
1 MODE r
2 ONED_FLAG 3
3 SOLAR_ZENITH 46
4 VIEW_ZENITH 8.6700
5 SOLAR_AZIM... 170
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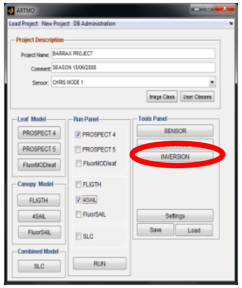
TOTAL_LAI_R [1_5]@0.2[5_10]@0.5
min.
1
max.
10
OK

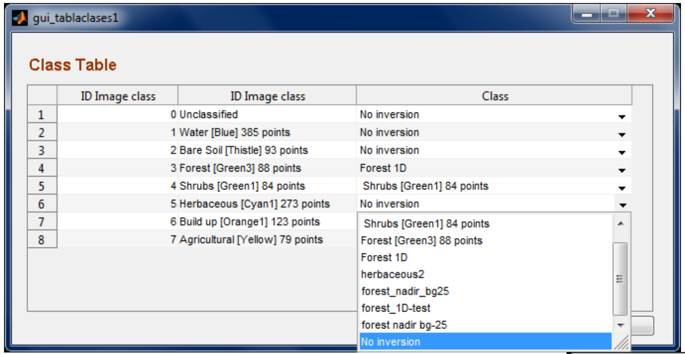


Inversion

Case study

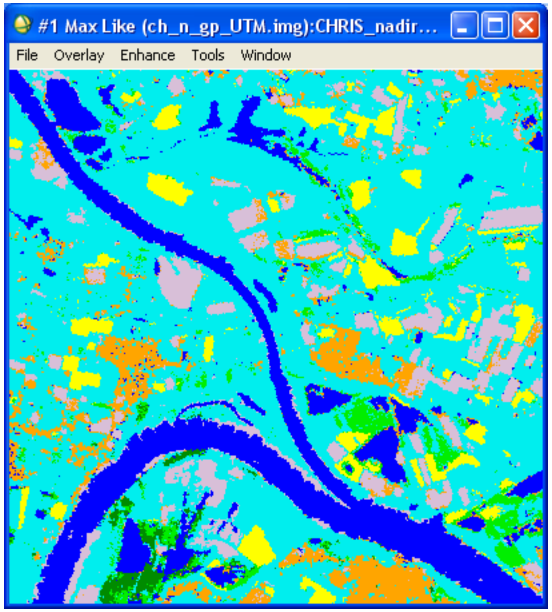
A floodplain with natural vegetation in the Netherlands.

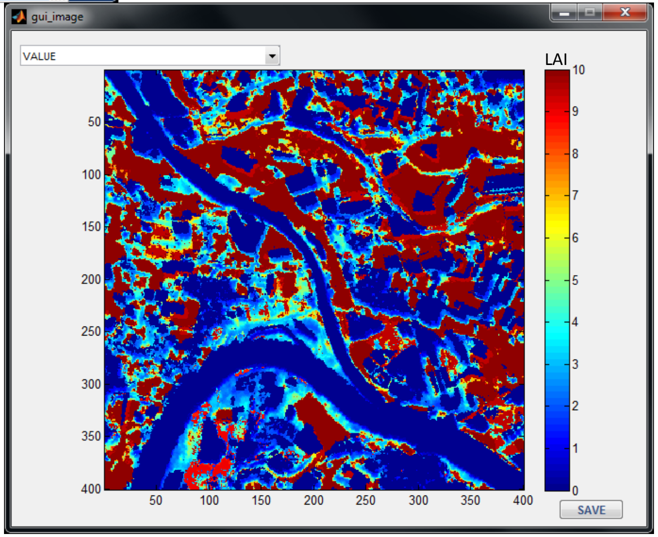
CHRIS data. (Mode 1: pixel size ~17 m, 18 bands. 400-1050 nm)

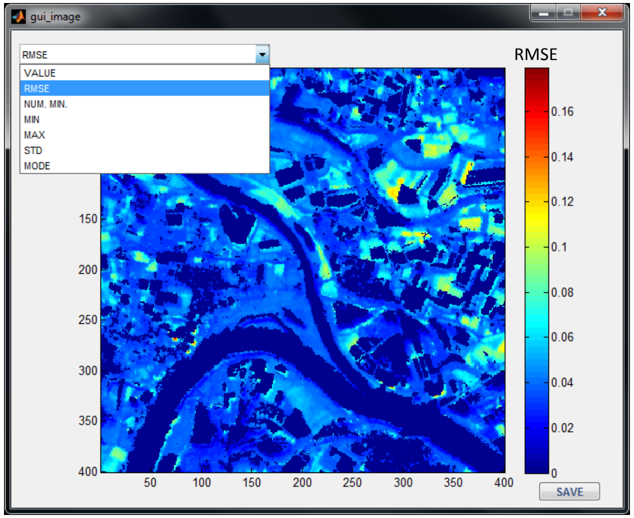

gui_tablaclases1

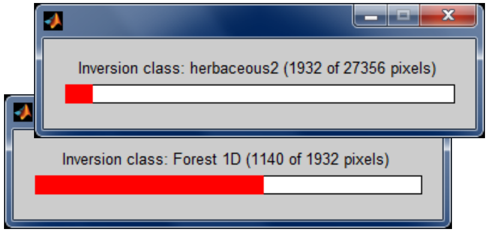
Class Table

	ID Image class	ID Image class	Class
1		0 Unclassified	No inversion
2		1 Water [Blue] 385 points	No inversion
3		2 Bare Soil [Thistle] 93 points	No inversion
4		3 Forest [Green3] 88 points	Forest 1D
5		4 Shrubs [Green1] 84 points	Shrubs [Green1] 84 points
6		5 Herbaceous [Cyan1] 273 points	No inversion
7		6 Build up [Orange1] 123 points	
8		7 Agricultural [Yellow] 79 points	



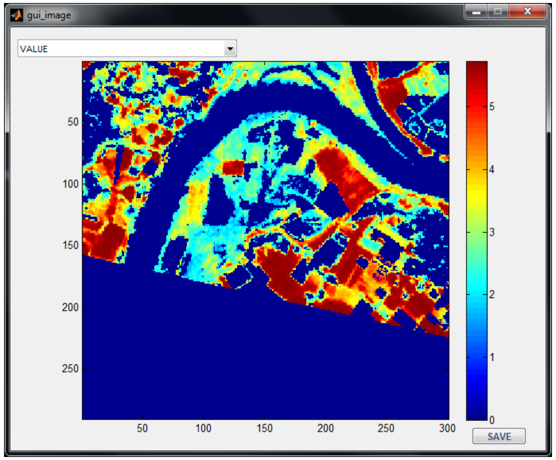


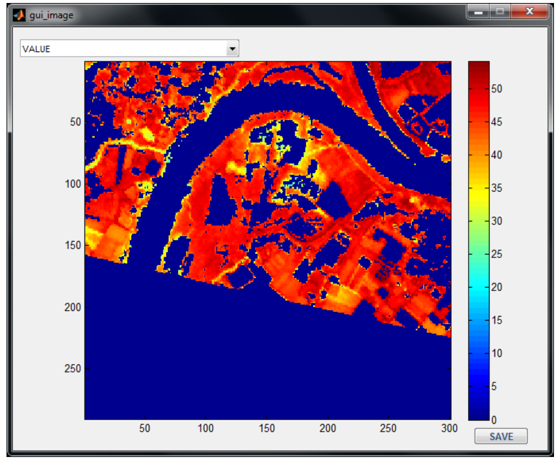


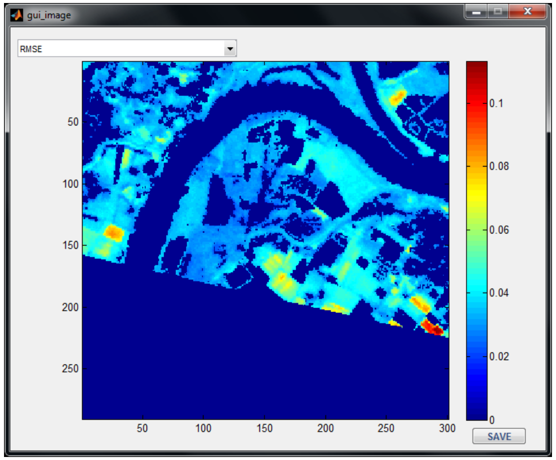


4SAIL

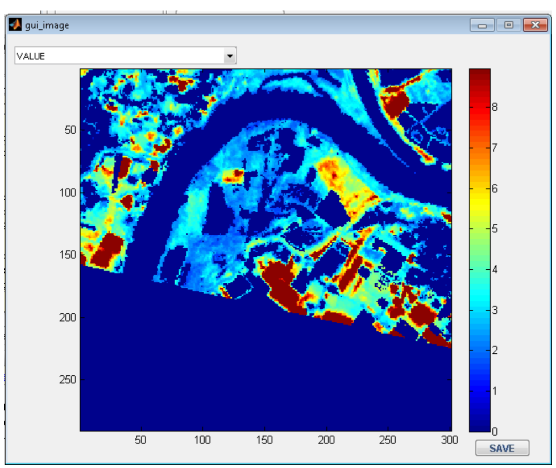
LAI **Chl** **RMSE**

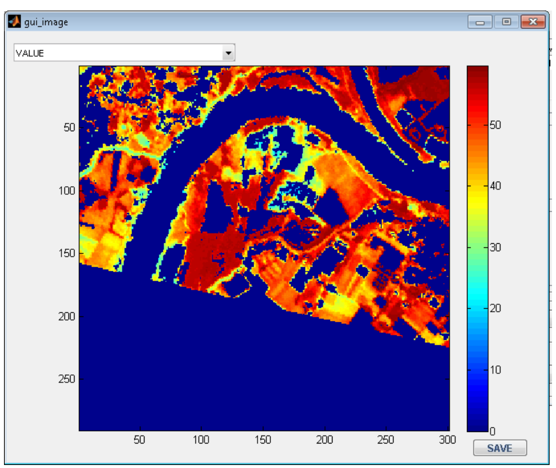


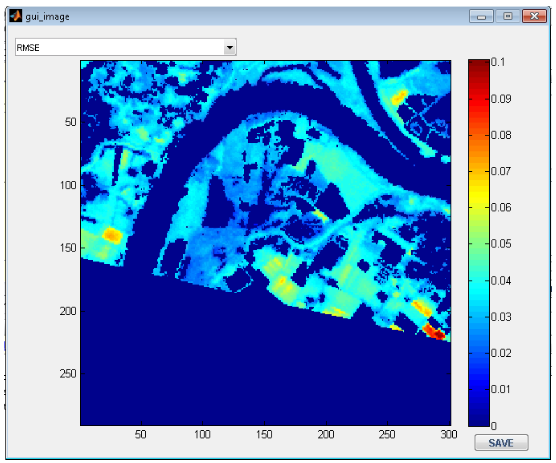




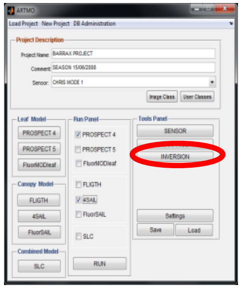
SLC



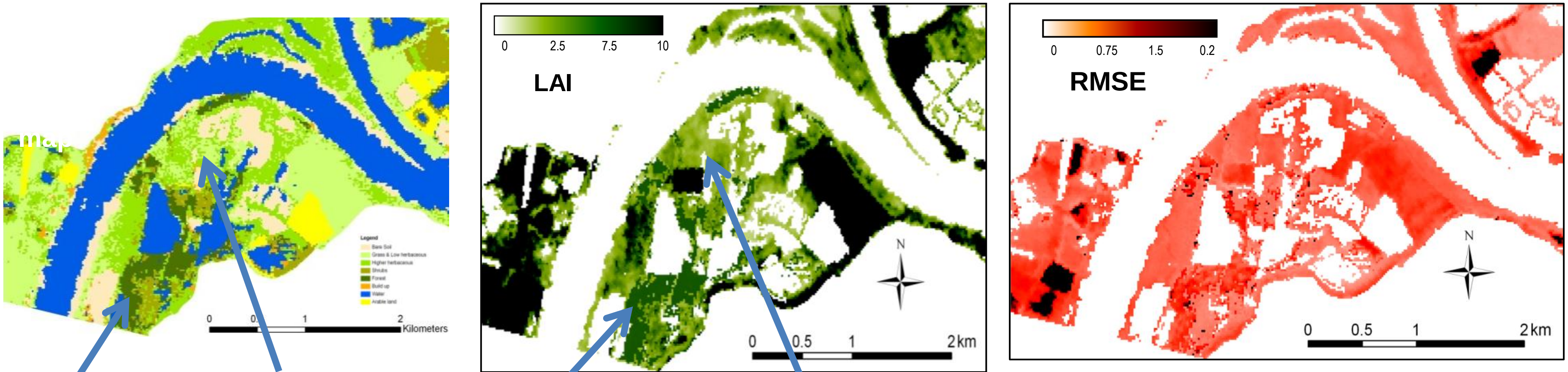




- End-to-end process flow fast: < 1h



1D + 3D combination



Trees

Grassland

3D model (FLIGHT)

1D model (4SAIL)

Models can be combined. As such more realistic representations of patchy landscapes can be achieved

Further work

- We are working on implementing more advanced cost functions
- Compatibility of ARTMO to other platforms and resolving memory issues
- Adding more models
- Coupling ARTMO with MODTRAN for simulating at-sensor radiance
- Building a scene simulation module

Conclusions

ARTMO aims to implement all the necessary models and features required for terrestrial vegetation EO applications in a GUI. ARTMO allows the user:

i) To choose between spectral band settings of various sensors, or to define own band settings

ii) To choose between various leaf-level and canopy-level RT models

iii) To simulate a massive amount of spectra based on a LUT approach and storing it in a spectral database

iv) To plot simulated spectra of multiple models and e.g. to compare it with measured spectra

v) To run model inversion against RS imagery given land cover classes, several cost options and accuracy estimates.