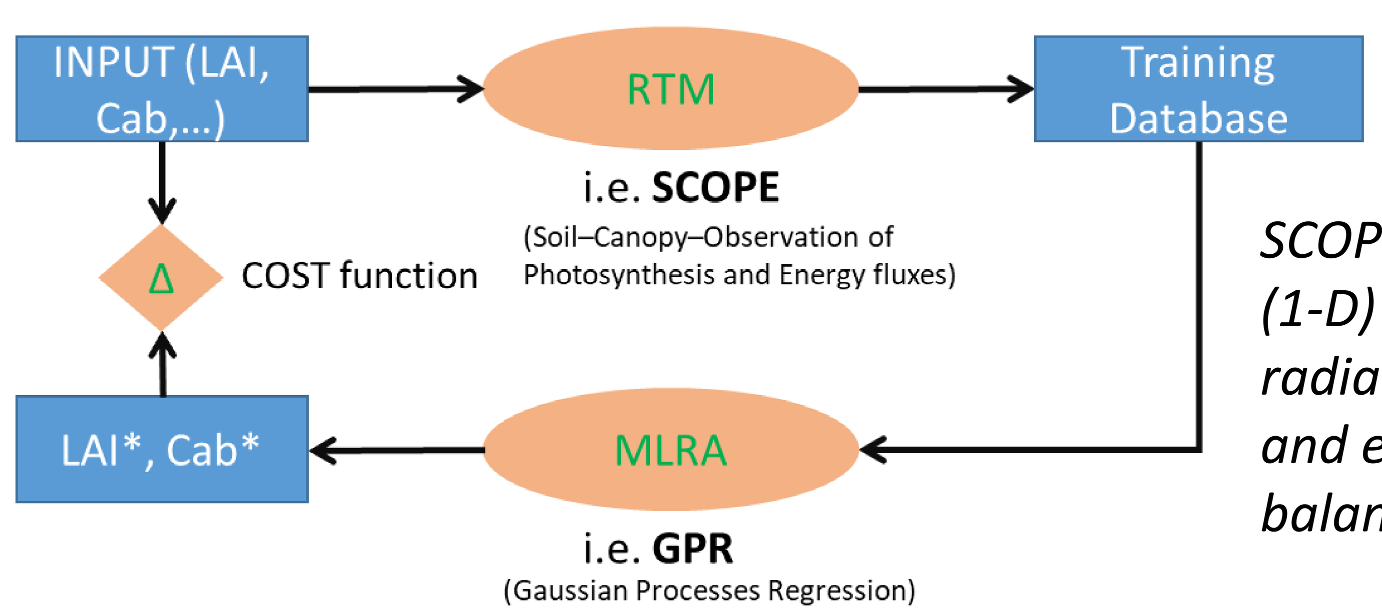
LAI and Cab retrieval from S3-OLCI TOC reflectances

Charlotte De Grave, Jochem Verrelst, Jose Moreno – Laboratory for Earth Observation, University of Valencia

What is the framework of this study?

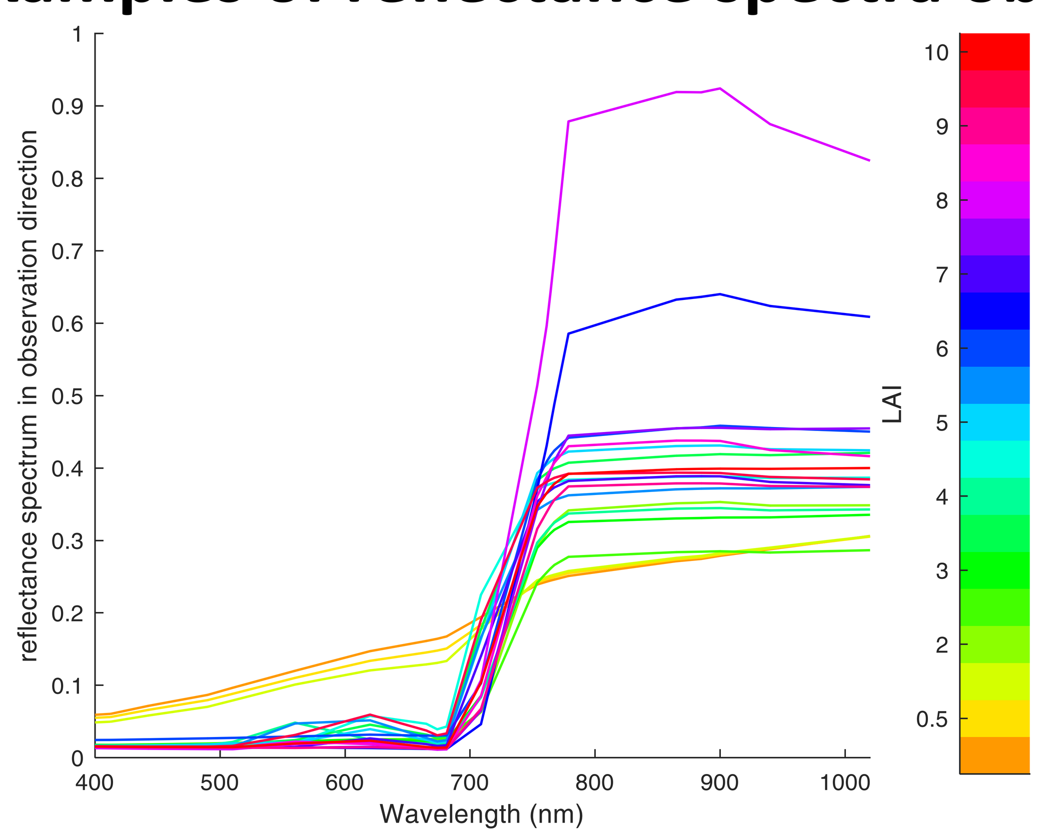
- This study is part of the **SENTIFLEX** research project, which is framed within ESA's **FLEX** (FLuorescence EXplorer) mission. FLEX will be equipped with an imaging spectrometer (FLORIS) specifically designed to capture the fluorescence emitted by vegetation. FLEX will be launched in 2022 and will fly in tandem with **Sentinel-3 (S3)**. S3 hosts a push-broom imaging spectrometer, **OLCI** (Ocean and Land Colour Imager), which is specifically designed to measure ocean colour over open ocean and coastal zones at a spatial resolution of 300m. Its spectral definition (21 bands between 400 and 1020 nm) however, also permits a fine characterization of the atmosphere (aerosol composition, water vapour and illumination conditions) and of the vegetation (biophysical variables including LAI and Cab).

Schematic diagram of the retrieval method



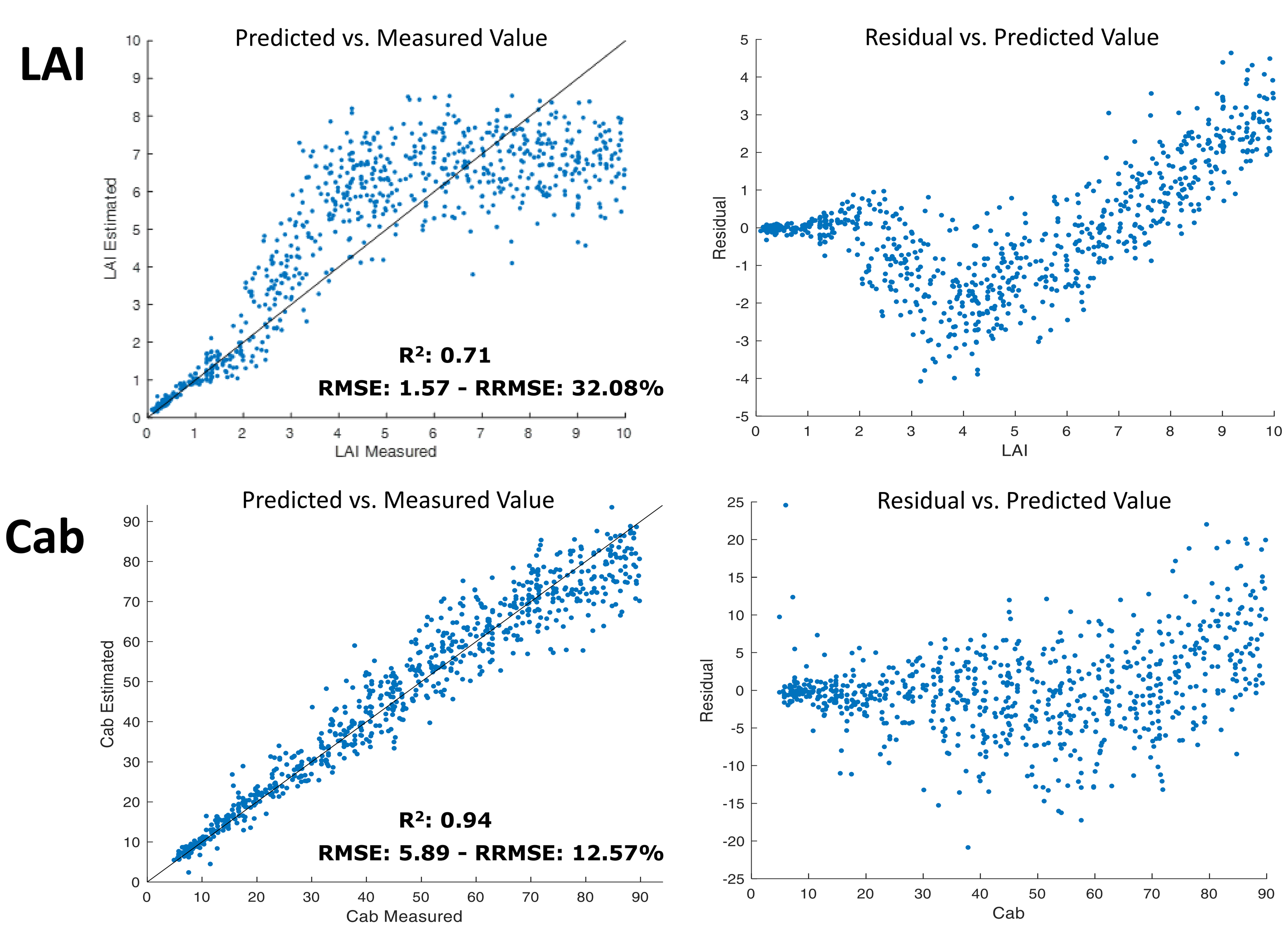
SCOPE is a vertical (1-D) integrated radiative transfer and energy balance model

Examples of reflectance spectra obtained with SCOPE



Only 20 spectra are shown but we used a training database of 3000 spectra for our analysis.

Theoretical performances of GPR models



Possible model improvements

- Optimize noise model parameters by use of the **FLEX End-to-End Mission Performance Simulator** which will soon be able to administrate "close-to-real" noise to the simulated reflectances.
- Use of filters to reduce the parameter space and enhance result accuracies.
- Add bare soil reflectance spectra.
- Use of **FLORIS** surface reflectance data. Preliminary tests suggest that it greatly improves model performances.

Why retrieve LAI and Cab?

- **LAI** or Leaf Area Index is defined as the one-sided leaf area per unit ground area. It is the primary remotely sensed descriptor of the density, the phenology and the distribution of vegetation across a landscape. In addition, it influences substantially the energy, the water vapour and the CO2 exchange between plants and the atmosphere.
- **Cab** is the content in chlorophyll (-a + -b) of the leaf. Chlorophylls are photosynthetic pigments and their concentration influence CO_2 assimilation and primary production.

How are these biophysical variables retrieved?

- By use of a hybrid regression method, which combines simulations of a **Radiative Transfer Model (RTM)** with a **Machine Learning Regression Algorithm (MLRA)**. A RTM is used to create a large database of vegetation properties and corresponding **Top-Of-Canopy (TOC) reflectances**, covering a wide range of situations and configurations. This database is then used to train a MLRA, which will generate a model composed of coefficients that are obtained by minimizing a cost function.

Input variables of the SCOPE model

Variable type	Variable	Distribution	Min	Max	Mean	SD
Weather	Rin (W.m^{-2})	Gaussian	20	1100	400	300
	Rli (W.m^{-2})	Gaussian	100	400	250	125
Leaf biochemical	Vcmax (µmol.m^{-2}.s^{-1})	Gaussian	10	180	80	40
Leaf structure	N	Gaussian	1	2.5	1.4	0.7
	Cab (µg.cm^{-2})	Uniform	5	90		
	Cdm (g.cm^{-2})	Gaussian	0.002	0.02	0.012	0.006
	Cw	Gaussian	0.0015	0.02	0.01	0.005
	Cant (µg.cm^{-2})	Gaussian	0	50	10	5
	Cs	Gaussian	0	0.05	0.001	0.01
	Cca (µg.cm^{-2})	Gaussian	0	80	20	10
Canopy structure	LAI	Uniform	0.1	10		
	LIDFa (rad)	Uniform	-1	1		
	LIDFb (rad)	Uniform	-1	1		
	VH (m)	Gaussian	0.1	20	3	8
Geometry	SZA (°)	Uniform	0	60		
	OZA (°)	Uniform	0	25		
	RAA (°)	Uniform	0	180		

Rin: Incoming shortwave radiation; Rli: Incoming longwave radiation; Vcmax: maximum carboxylation capicity;, N: Leaf mesophyll structure; Cab: Leaf chlorophyll content; Cdm: Leaf dry matter content; Cw: Leaf water thickness; Cant: Leaf anthocyanin content; Cs: Leaf senescent material content; Cca: Leaf carotenoid content; LAI: Leaf Area Index; LIDFa: Average leaf angle; LIDFb: Variation in leaf angle; VH: Vegetation Height; SZA: Solar Zenith Angle; OZA: Observer Zenith Angle; RAA: Relative Azimuth Angle

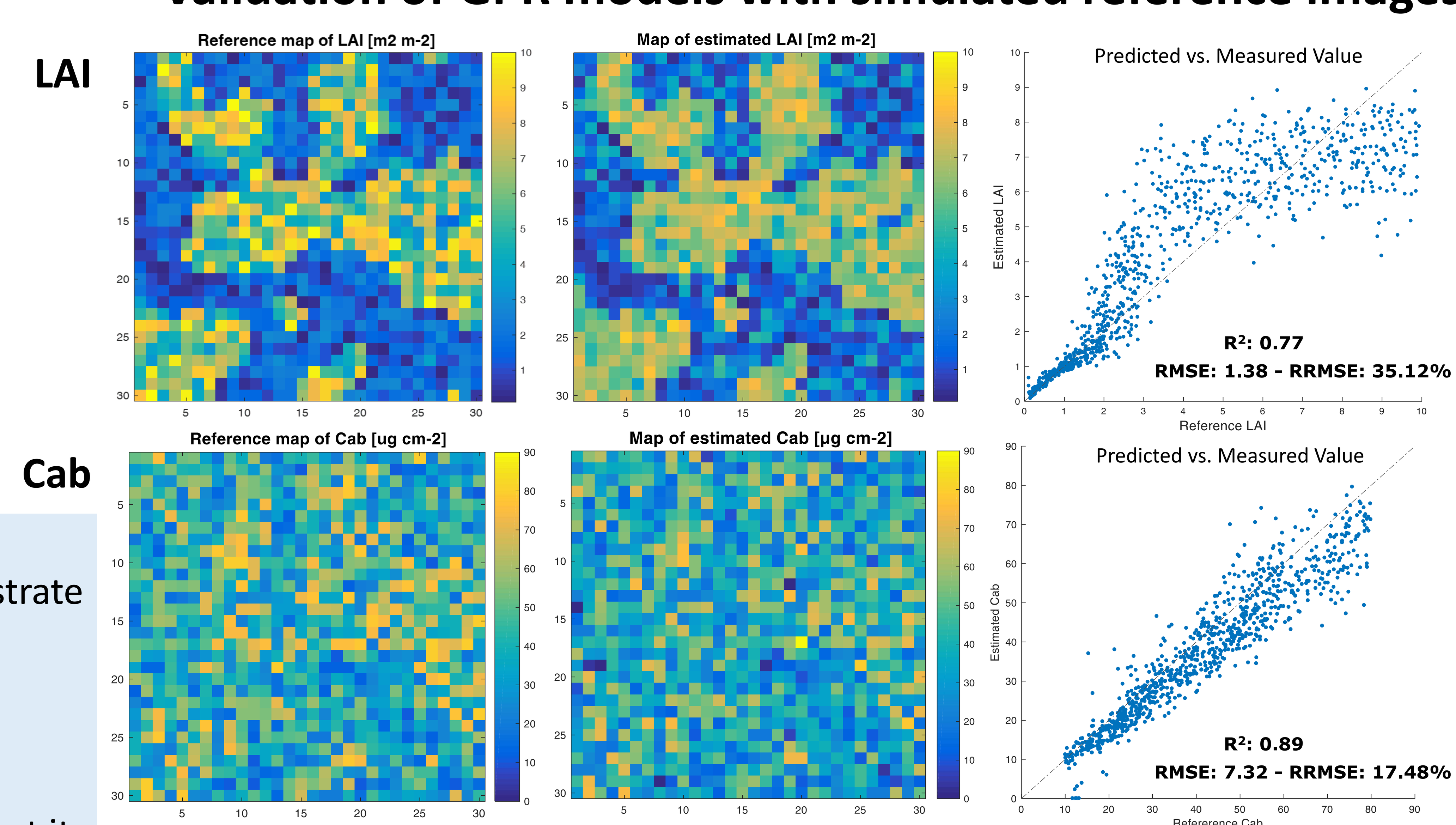
Noise model

Model used to contaminate the reflectance spectra with **noise** in order to make them more realistic (*Weiss and Baret*, 2016):

$$R^*(\lambda) = R(\lambda) * (1 + (MD(\lambda) + MI)/100) + AD(\lambda) + AI$$

where **R** is the raw simulated reflectance, **R*** is the reflectance contaminated with noise, **MD** (0.03 - 0.05) is the multiplicative wavelength dependant noise, **MI** (0.05) is the multiplicative wavelength independent noise, **AD** (0 - 0.01) is the additive wavelength independent noise, and **AI** (0.002) is the additive wavelength independent noise.

Validation of GPR models with simulated reference images



This work was supported by the European Research Council (ERC) under the ERC-2017-STG SENTIFLEX project (Grant Agreement 755617)

References:
Baret F., Buis S. (2008) Estimating Canopy Characteristics from Remote Sensing Observations: Review of Methods and Associated Problems. In: Liang S. (eds) Advances in Land Remote Sensing. Springer, Dordrecht.
Croft H., Chen J.M., Zhang Y. et al. (2015) Evaluating leaf chlorophyll content prediction from multispectral remote sensing data within a physically-based modelling framework. ISPRS Journal of Photogr. and Rem. Sens.,102, 85-95.
Houborg R., McCabe M., Cescatti A. et al. (2015) Joint leaf chlorophyll content and leaf area index retrieval from Landsat data using a regularized model inversion system (REGFLEC). Rem. Sens. of Envir., 159 , pp. 203-221.
Sentinel-3 Team, ESA (2013) Sentinel-3 User Handbook. Reference: GMES-S3OP-EOPG-TN-13-0001, https://sentinel.esa.int.
Vicent J., Sabater Medina N., Tenjo, C., et al. (2016). FLEX End-to-End Mission Performance Simulator. IEEE Transactions on Geoscience and Remote Sensing. 54. 1-9.
Weiss M., Baret F. (2013) S2ToolBox Level 2 Products: LAI, FAPAR, FCOVER. Institut National de la Recherche Agronomique (INRA), Avignon (France).