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RETRIEVAL OF LEAF AREA INDEX FROM REMOTE SENSING DATA

PART V: (INVERSION OF RADIATIVE TRANSFER MODELS)

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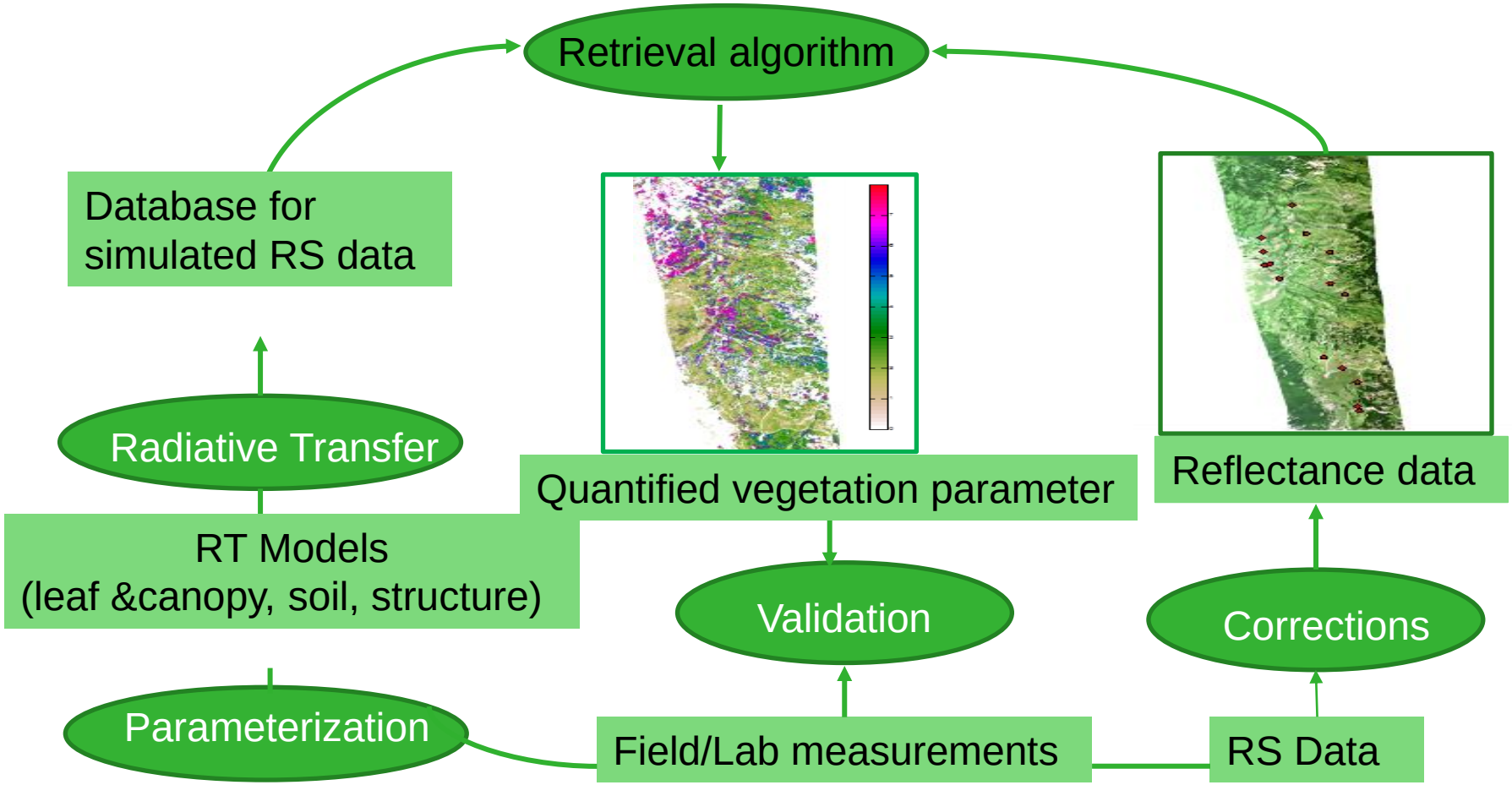
- Inversion algorithms
- Ill posed problem
- Look up table inversion

INTRODUCTION

- RTM using a number of variables as input to simulate the vegetation reflectance.
- Remote sensing reflectance data is available, vegetation variables have to be quantified.
- In order to utilize RTM for estimating a specific vegetation variable, the model has to be reversed.

AN OVERVIEW OF RETRIEVAL OF LAI THROUGH INVERSION OF RTM



INVERSION

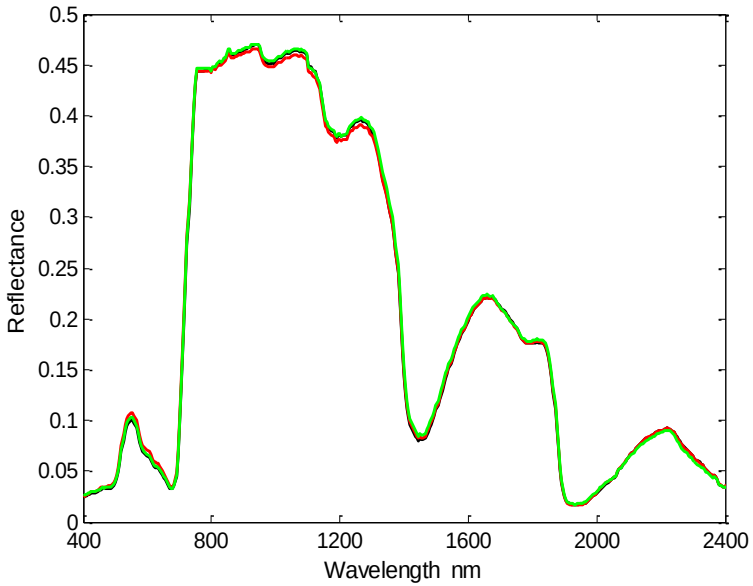
- Inverting a canopy/leaf reflectance model

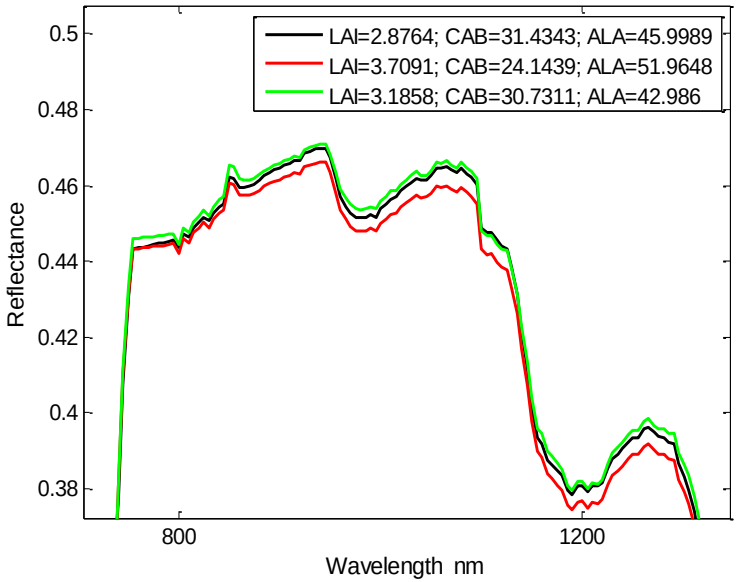
- Different inversion algorithms includes:
  - Numerical optimization methods
  - Look-up table (LUT) approach
  - Neural networks
  - Support vector machines

COMPARISON OF INVERSION METHODS

- In the iterative optimization approach, a stable and optimum inversion is not guaranteed
- LUT and neural network approaches reduce the huge computational demand
- They rely on a large database of simulated canopy reflectance spectra to achieve a high degree of accuracy.
- Refer to Kimes et al. (2000) and Liang (2004) for more detailed discussions regarding the advantages and disadvantages of the inversion methods.

ILL-POSED NATURE OF MODEL INVERSION





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SOLUTIONS TO INVERSE PROBLEM

- Use of prior knowledge about model parameters(Combal et al., 2002; Darvishzadeh et al., 2008b)
- Selection of the cost function by taking the uncertainty of the provided prior information into account (Houborg and Boegh, 2008; Jacquemoud et al., 2009)
- Use of multiple solutions (Combal et al., 2002; Darvishzadeh et al., 2011)
- Selection of the well responding wavelengths (Meroni et al., 2004; Schlerf et al., 2005)
- Spatial and temporal constraints (Atzberger, 2004; Atzberger and Richter, 2012; Lauvernet et al., 2008).

Look Up Table (LUT) inversion

1. A LUT is built in advance of the actual inversion through forward calculations
2. Compute the model spectra for a large range of model input parameter combinations and collect them in a look-up table (LUT)
3. Use a measured spectrum and search the LUT for the modeled spectrum which most resembles the measured reflectance
4. The set of model parameters associated with the “best modeled spectrum” is the result of the model inversion

A

	1	2	3	...	n
TH	5	10	15	...	30
CD	1.5	1.5	1.5	...	8.5
LAI	0.5	0.5	0.5	...	7.0
TD	200	200	200	...	3000
...	...	...	...	...	...

B

WL	1	2	3	...	n
550	0.0478	0.0450	0.0420	...	0.0573
675	0.0408	0.0382	0.0352	...	0.0174
740	0.1487	0.1418	0.1344	...	0.2526
805	0.1752	0.1675	0.1594	...	0.3042
970	0.1989	0.1902	0.1809	...	0.3176

LUT generation- e.g. PROSAIL

LUT with >100,000 entries

Parameter	Abbreviation in Model	Unit	Minimum Value	Maximum Value
Leaf area index	LAI	$m^2\ m^{-2}$	0.3	6.6
Mean leaf inclination angle	ALA	Deg	40	80
Dry matter content	C_m	$g\ cm^{-2}$	0.003	0.02
Leaf structural parameter	N	No dimension	1.5	1.9
Leaf chlorophyll content	C_{ab}	$\mu g\ cm^{-2}$	10	60
Equivalent water thickness [1]	C_w	$g\ cm^{-2}$	0.005	0.025
Hot spot size parameter	hot	$m\ m^{-1}$	0.05	0.1
Soil brightness parameter	scale	No dimension	0.5	1.5

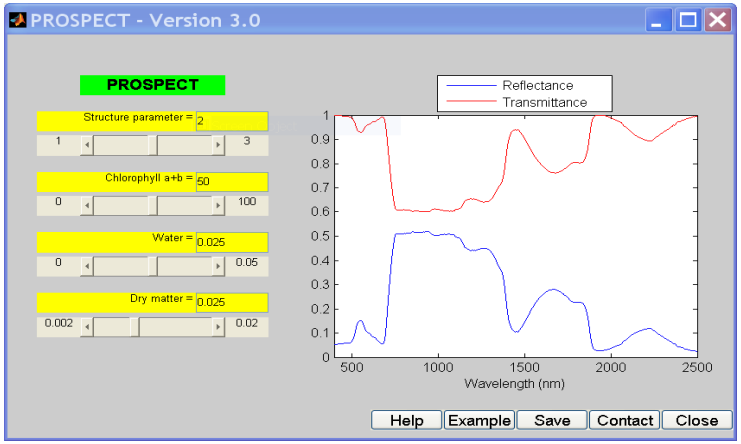
(Darvishzadeh, et al . 2019, Remote sensing (11), 6, [671]

LUT inversion

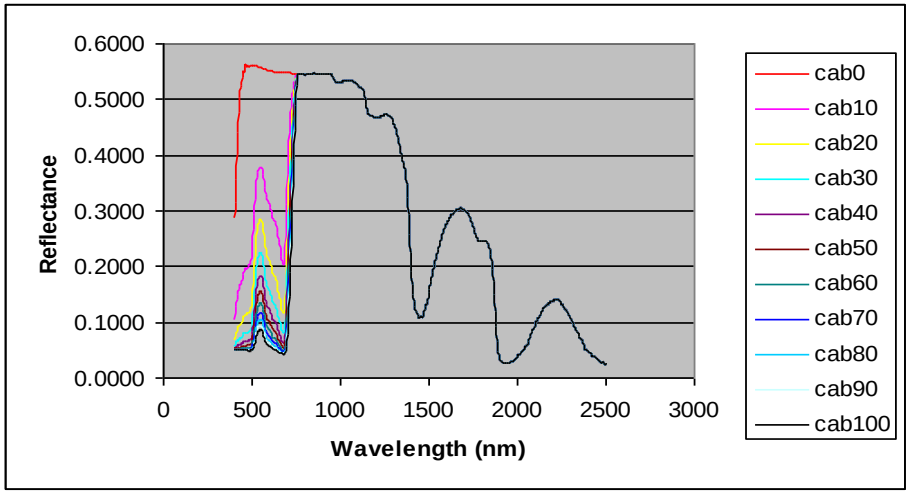
- The use of RMSE to identify “best spectrum”
- Median of 100 “best spectra” in LUT
  - Identify 100 “best spectra”
  - Compute median of the 100 associated parameter values

PROSPECT model in Forward mode

PROSPECT GUI in Matlab



Modeling results



Modeling Heterogeneity

The effect of species heterogeneity

Species heterogeneity limits the accuracy of the method.

LAI	1 species (n=32)	2 species (n=75)	3 species (n=59)	4 species (n=19)
R2	0.85	0.69	0.55	0.38
RMSE	0.7	1.1	1.2	1.3

(Darvishzadeh, R., Skidmore, A.K., Schlerf, M. et al 2008 RSE 112)

1-D turbid medium model can not fully account for heterogeneities in the canopy (e.g. multiple leaf types with different optical properties and canopy structure).

Conclusions/further research

- RTMs allow the possibility of generating large, “full spectrum” simulated datasets
- They can be used to retrieve multiple plant traits
- Their robustness and transferability in comparison to statistical models make them a proper alternatives to these models.
- They are computationally demanding and usually require information about a large number of input variables.
- Their limitations on the number of retrievable plant traits.
- It is argued that only the state variables could be retrieved from remote sensing measurements