



Inversion of PROSPECT-D

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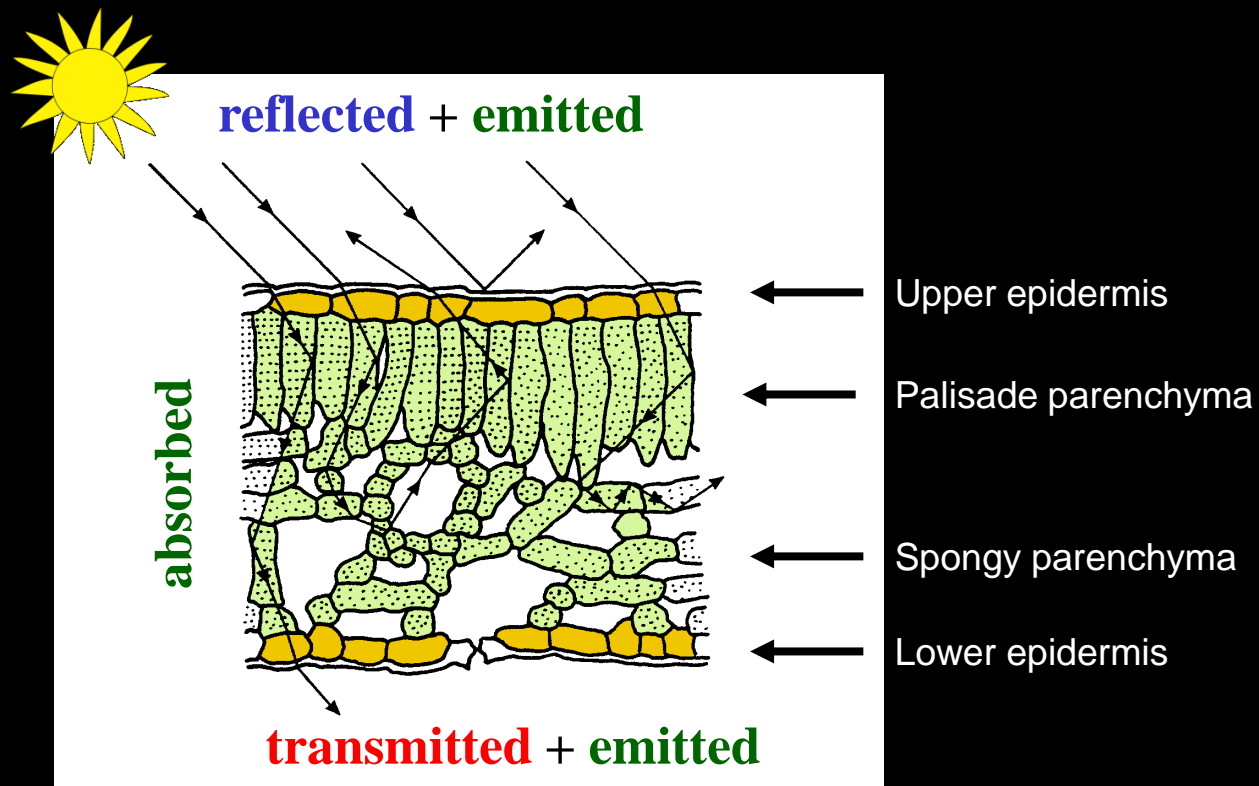
September 7, 2022

With contributions from:

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Leaf optical properties in the solar domain

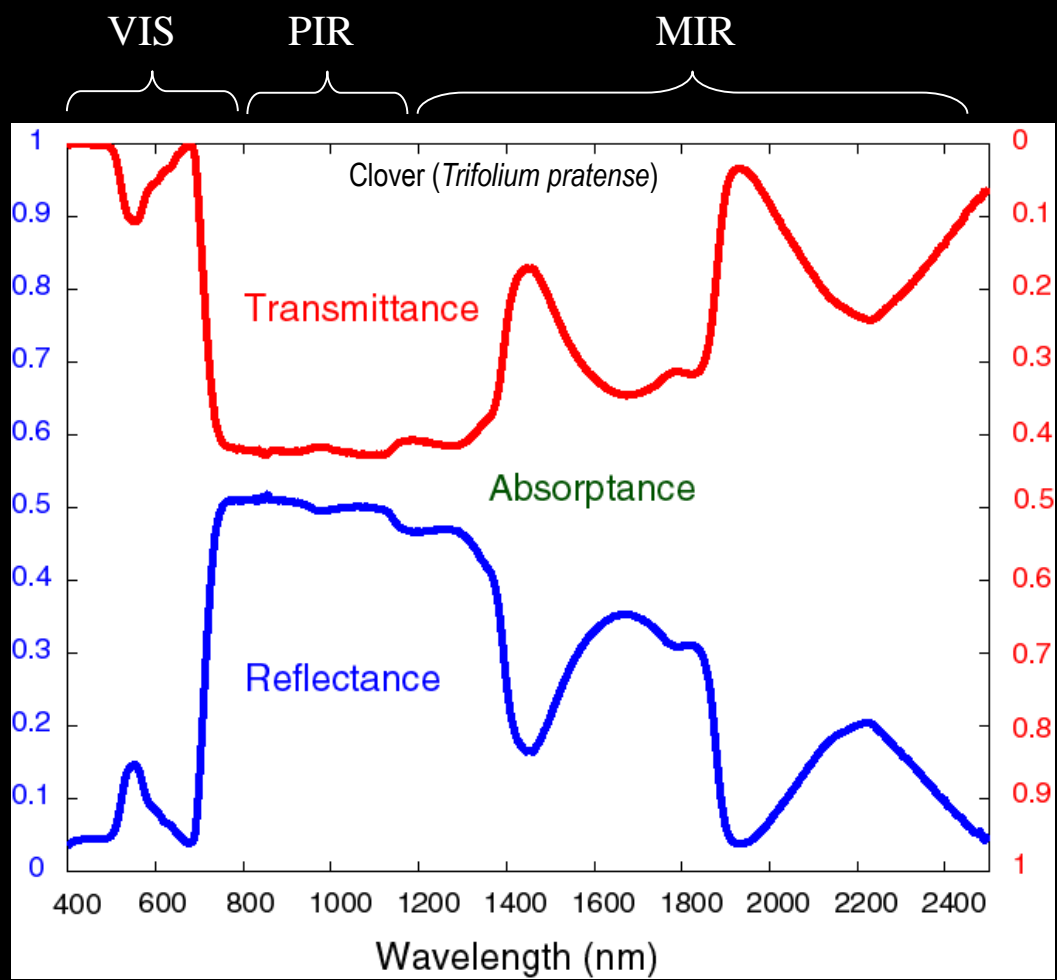
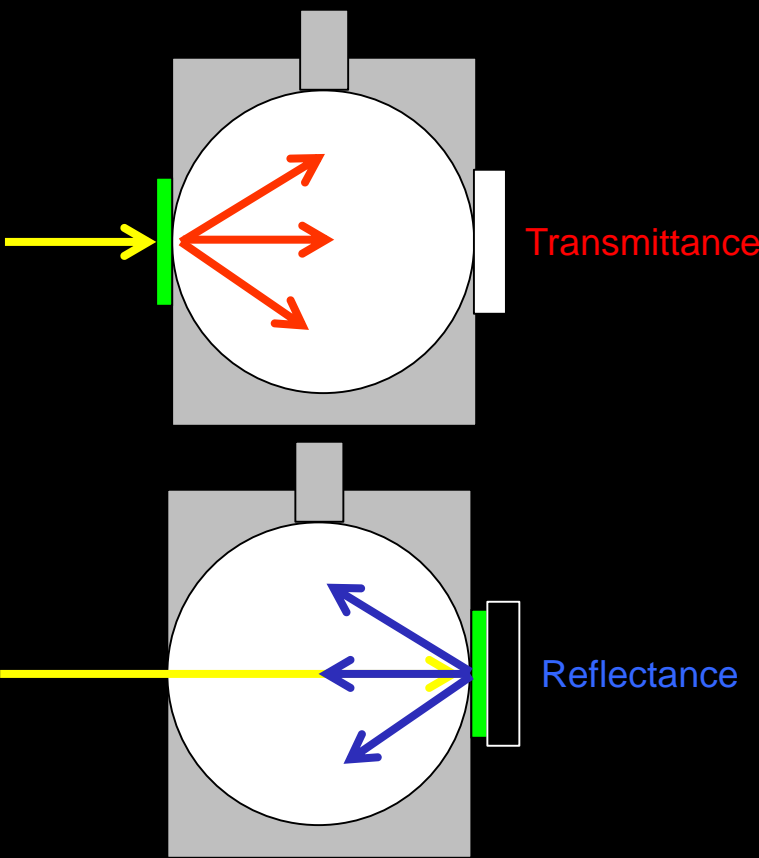
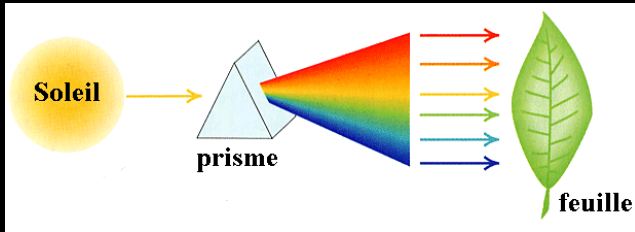


Surface/diffuse reflectance: $R = R_s + R_d$

Kirchhoff's law: $A = \varepsilon$

Conservation of energy: $R + A + T = 1$

Leaf optical properties in the solar domain



OPTICLEAF The database on leaf optical properties



07-09-2022

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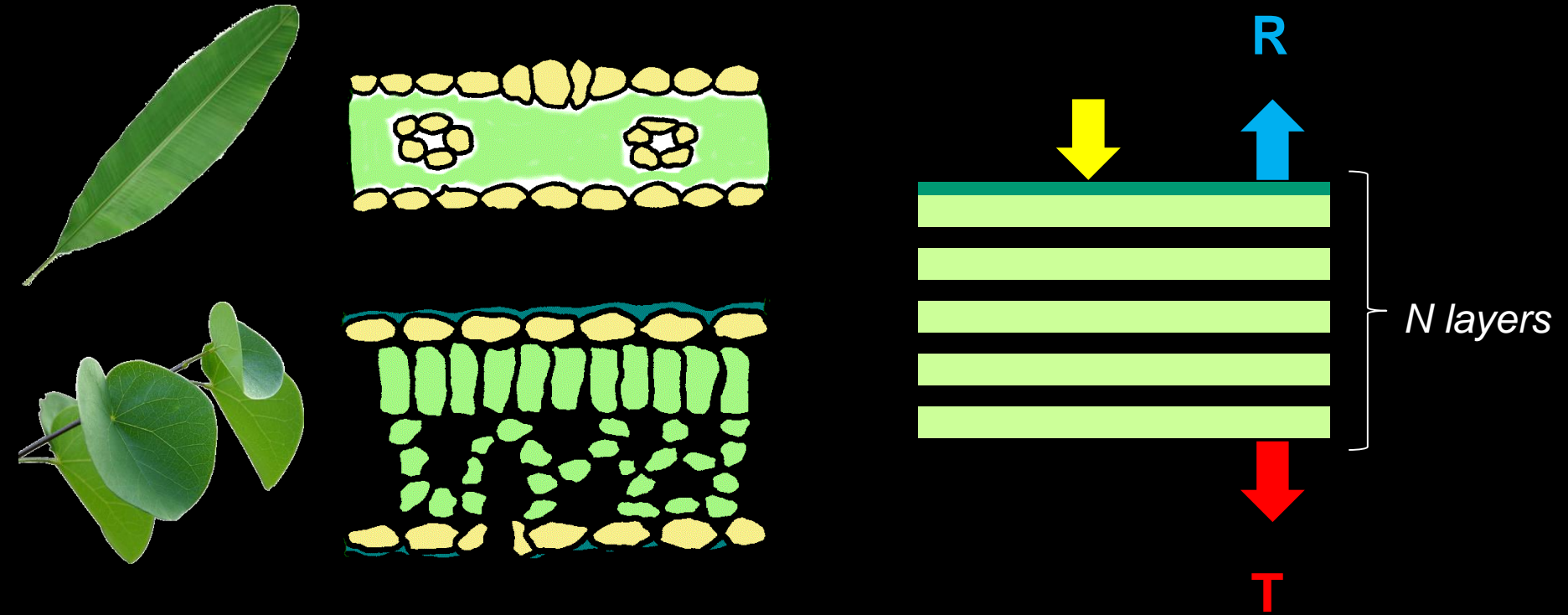
select references where auteur content 'FÉRET' and auteur content " sort by auteur

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1. Cheng T., Rivard B., Sánchez-Azofeifa A.G., Féret J.B., Jacquemoud S. and Ustin S.L. (2014), **Deriving leaf mass per area (LMA) from foliar reflectance across a variety of plant species using continuous wavelet analysis** , *ISPRS Journal of Photogrammetry and Remote Sensing* , 87: 28-38 . ✓
2. Cheng T., Rivard B., Sánchez-Azofeifa G.A., Féret J.B., Jacquemoud S. and Ustin S.L. (2012), **Predicting leaf gravimetric water content from foliar reflectance across a range of plant species using continuous wavelet analysis** , *Journal of Plant Physiology* , 169(12) : 1134-1142 . ✓
3. de Boissieu F., Lenco D. and Féret J.B. (2018), **Mise au point de méthodes hybrides combinant apprentissage machine et modélisation physique pour l'estimation de traits foliaires par spectroscopie** , *Conférence Française de Photogrammétrie et de Télédétection, Marne-la-Vallée (France)* , pp. 26-27 juin 2018 . ✓
4. Féret J.B. (2009), **Apport de la modélisation pour l'estimation de la teneur en pigments foliaires par télédétection** , *Université Pierre & Marie Curie (Paris (France))* , PhD Thesis : 200 pages . ✓
5. Féret J.B. and Asner G.P. (2011), **Spectroscopic classification of tropical forest species using radiative transfer modeling** , *Remote Sensing of Environment* , 115(9) : 2415-2422 . ✓
6. Féret J.B., Asner G.P., François C., Martin R., Ustin S.L. and Jacquemoud S. (2007), **An advanced leaf optical properties model including photosynthetic pigments** , *10th International Symposium on Physical Measurements and Signatures in Remote Sensing (M. Schaepman, S. Liang, N. Groot and M. Kneubühler, eds), Davos (Switzerland), 12-14 March 2007, ISPRS* , pp. 6 . ✓
7. Féret J.B., François C., Asner G.P., Gitelson A.A., Martin R.E., Bidet L.P.R., Ustin S.L., le Maire G. and Jacquemoud S. (2008), **PROSPECT-4 and 5: advances in the leaf optical properties model separating photosynthetic pigments** , *Remote Sensing of Environment* , 112(6) : 3030-3043 . ✓
8. Féret J.B., François C., Gitelson A., Asner G.P., Barry K.M., Panigada C., Richardson A.D. and Jacquemoud S. (2011), **Optimizing spectral indices and chemometric analysis of leaf chemical properties using radiative transfer modeling** , *Remote Sensing of Environment* , 115(10) : 2742-2750 . ✓

PROSPECT: physical basis



Modeling leaf diffuse/directional reflectance/transmittance as a function of biochemical content and anatomical structure

- Surface optical properties: interface between two dielectrics (Fresnel equations)
- Volume optical properties: transmission through an elementary layer (Beer-Lambert law) and multiple reflections between N layers (Stokes system)

PROSPECT: 30 years old


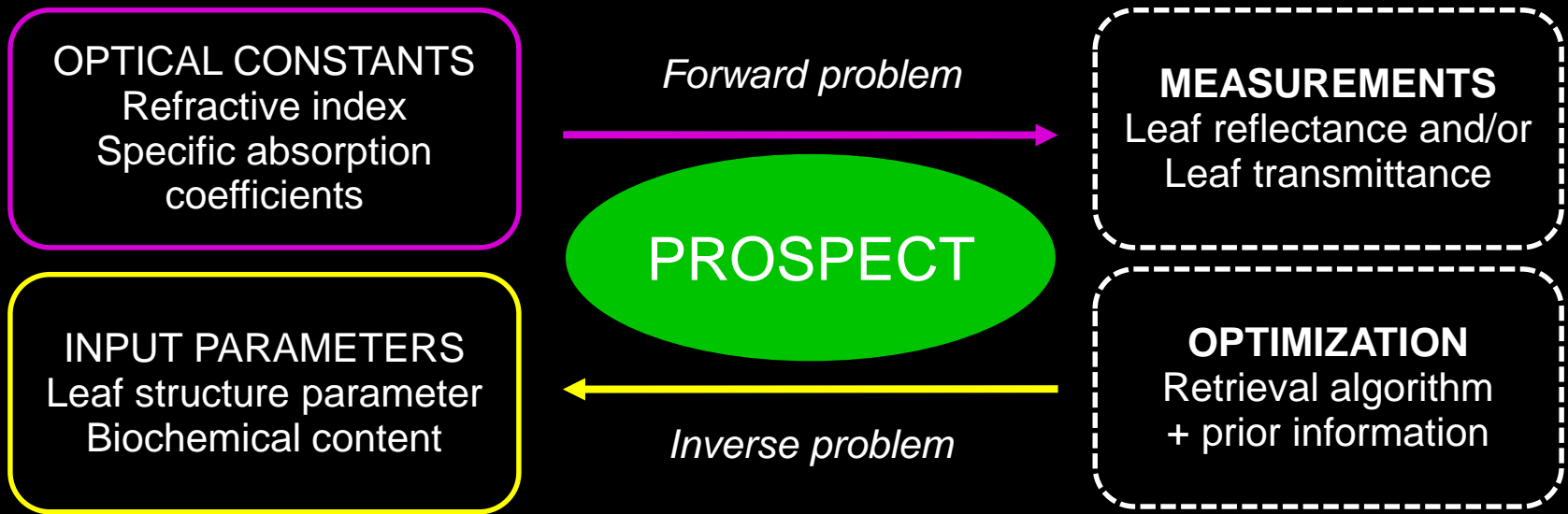


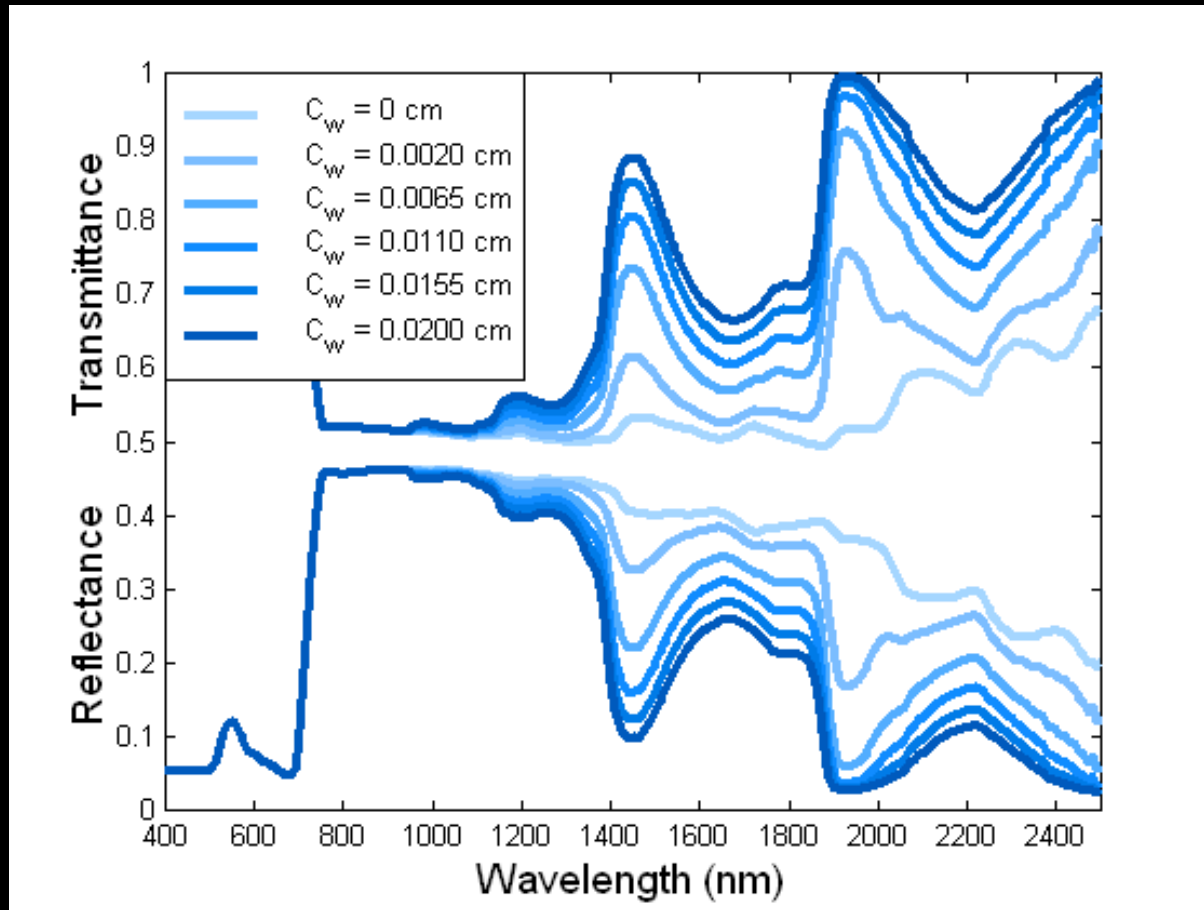
Plate model	1 layer (Allen et al., 1969)
Generalized plate model	N layers (Allen et al., 1970)
PROSPECT-3	N, C_{ab}, C_w (Jacquemoud & Baret, 1990) cellulose, hemicellulose, lignin, protein, starch (Fourty et al., 1996; Wang et al., 2015)
PROSPECT-4	N, C_{ab}, C_w, C_{dm} (Baret & Fourty, 1997) + brown pigments (Baret) improved specific absorption coefficients (Jacquemoud et al., 2005) adaptation to conifer needles (Zarco-Tejada et al., 2004; Malenovský et al., 2006) leaf BRDF/BTDF (Bousquet et al., 2005)
QSPECT	dorsiventral leaf (Ma et al., 2007)
DLM	dorsiventral leaf + epidermis (Stuckens et al., 2009)
PROSPECT-5	$N, C_{ab}, C_{car}, C_w, C_{dm}$ (Féret et al., 2008)
FluorMODleaf	Chl fluorescence (Pedrós et al., 2010; Zhao et al., 2015)
PROSPECT-VISIR	extension to the SWIR (Gerber et al., 2011)
FLUSPECT	Chl fluorescence (Verhoef, 2011; Verrelst et al., 2015) extension to Cu absorption (Zhu et al., 2014)
PROCOSINE	PROSPECT-5 + leaf BRDF (Jay et al., 2016)
PROSPECT-D	$N, C_{ab}, C_{car}, C_{anth}, C_w, C_{dm}$ (Féret et al., 2017)
PROSPECT-MP	$N, C_a, C_b, C_{car}, C_{anth}, C_w, C_{dm}$ (Zhang et al., 2017)
PROSPECT-PRO	$N, C_{ab}, C_{car}, C_{anth}, C_w, C_{pro}, C_{cbc}$ (Féret et al., 2021)

PROSPECT: direct vs inverse mode

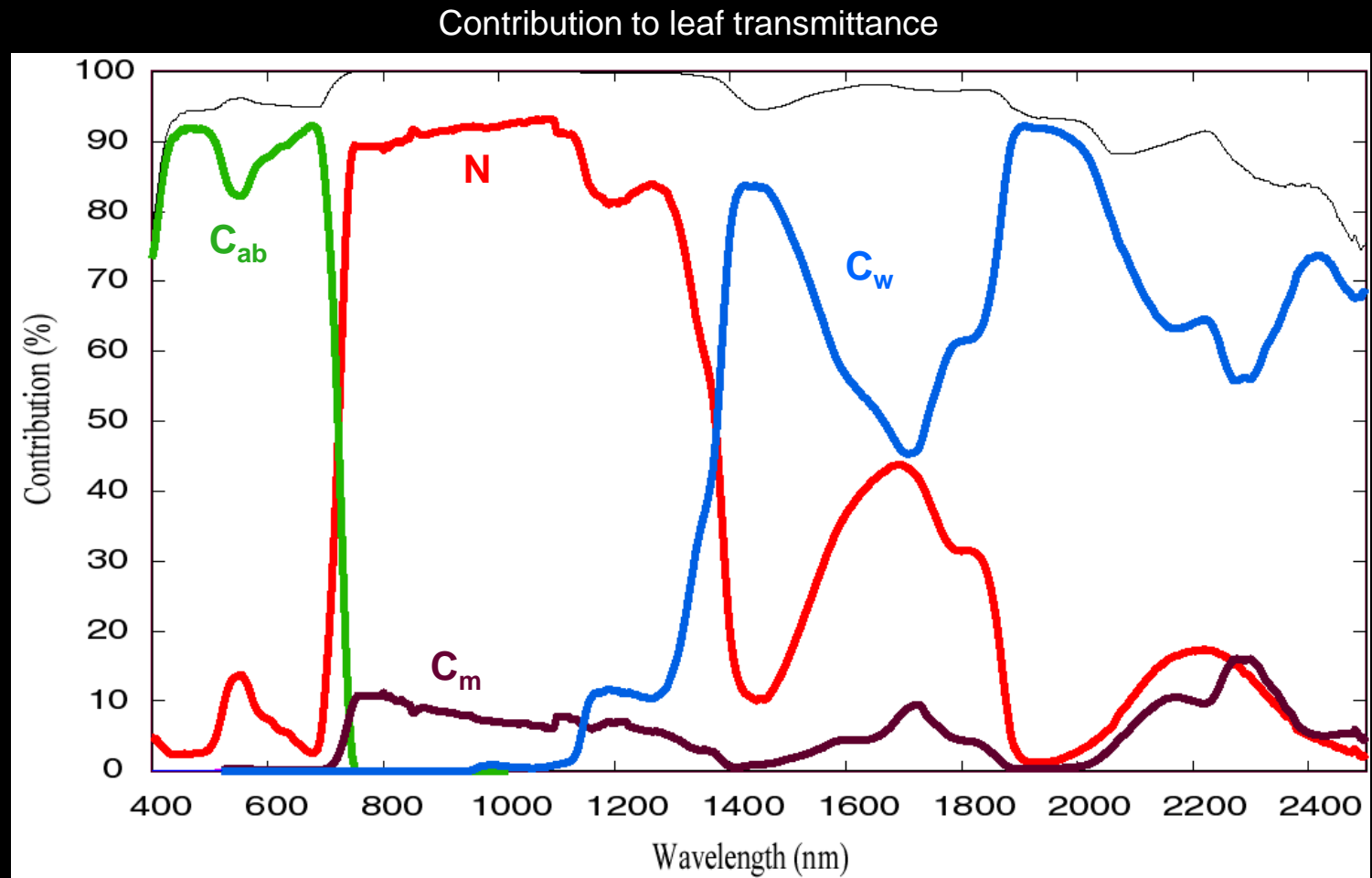


PROSPECT-4: one-factor-at-a-time sensitivity analysis

$N = 1.5$, $C_{ab} = 50 \mu\text{g}\cdot\text{cm}^{-2}$, $C_m = 0.005 \text{ g}\cdot\text{cm}^{-2}$



PROSPECT-4: global sensitivity analysis



<http://teledetection.ipgp.fr/prosail/>

PROSPECT, SAIL, and other RT models

Page updated on September 6, 2022

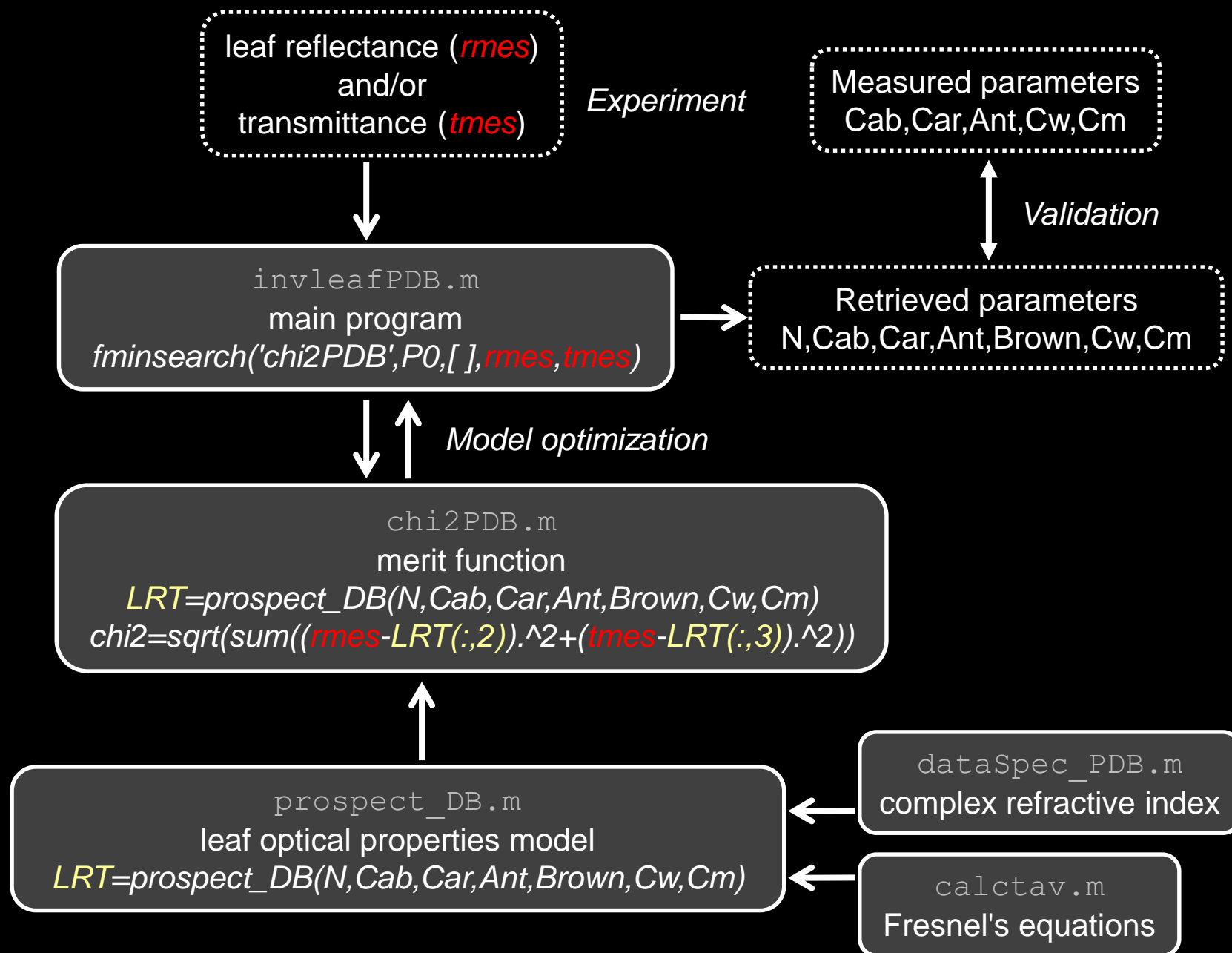
The PROSAIL model, a fusion of PROSPECT (leaf reflectance and transmittance) and SAIL (plant canopy reflectance), has been used for the last thirty years to simulate the spectral and directional reflectance of plant canopies in the solar domain. It links the spectral dimension of the reflectance, which is mainly related to the biochemical content of the leaves, to the directional dimension, which is mainly related to the architecture of the canopy. PROSAIL has been widely used to develop new methods to retrieve biophysical properties of vegetation and to prepare new space missions. Applications are numerous in agriculture, forestry, ecology, climatology, exobiology, etc. Because of its ease of use, robustness and regular updates, PROSAIL has become one of the most popular tools for radiative transfer in vegetation.

Version	Matlab	Fortran	IDL	Python	R	Web interface	GUI
PROSPECT-4	PROSPECT4_Matlab.rar	PROSPECT4_Fortran.rar					
+ SAIL							ARTMO
PROSPECT-5 *	PROSPECT5_Matlab.rar	PROSPECT5_Fortran.rar				PROSPECT5	
+ 4SAIL *	PROSAIL_5B_Matlab.rar	PROSAIL_5B_Fortran.rar	PROSAIL_5B_IDL.zip	PyProSAIL	HSDAR		ARTMO
PROCOSINE	Toolbox_Cosine.rar						
PROSPECT-D	PROSPECT-D_Matlab.rar	PROSPECT-D_Fortran.rar			GITLAB		
+ 4SAIL	PROSAIL_D_Matlab.rar	PROSAIL_D_Fortran.zip		PROSAIL-2.0.alpha	GITLAB		ARTMO
PROSPECT-PRO	GITLAB				GITLAB		
+ 4SAIL					GITLAB		ARTMO

* It is recommended to use PROSPECT-D (with zero anthocyanin concentration) rather than PROSPECT-5.

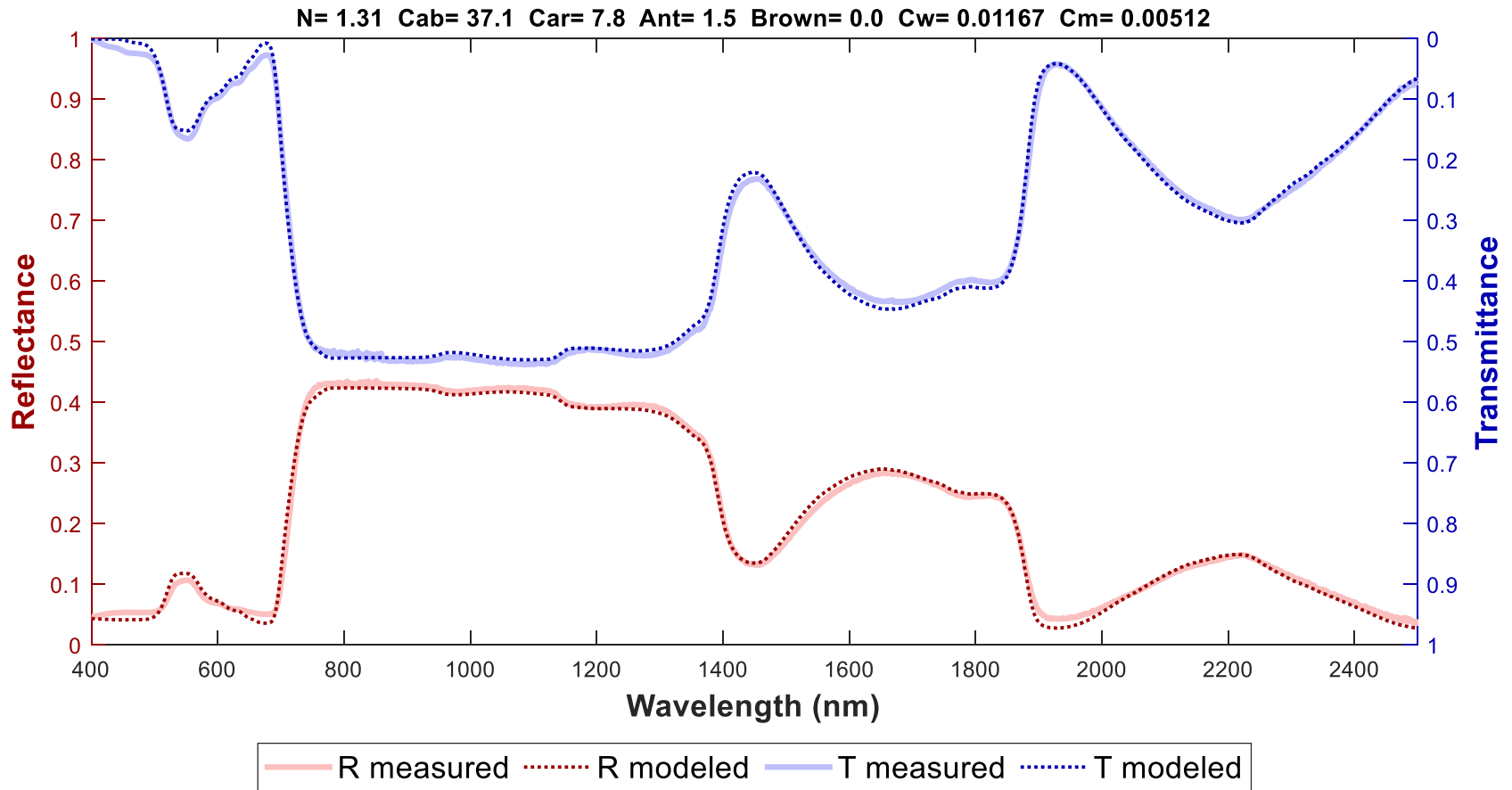
Download the Matlab files at http://teledetection.ipgp.fr/prosail/PROSPECTD_Matlab_inversion.rar

PROSPECT-D: inverse mode



PROSPECT: leaf reflectance/transmittance reconstruction

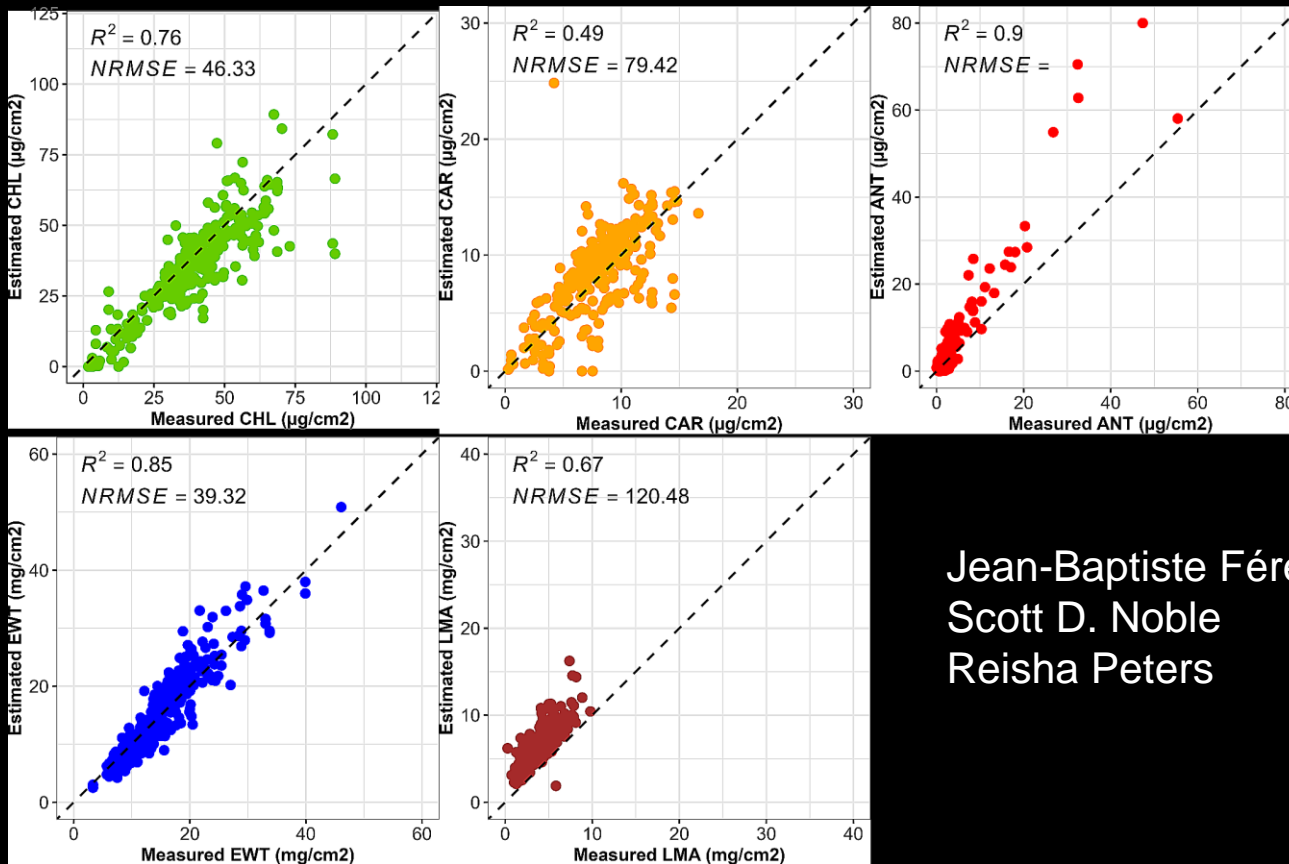
Poplar (*Liriodendron tulipifera*)



PROSPECT-D: leaf parameter retrieval

Thousands of leaf samples belonging to more than 100 plant species and corresponding to independent data sets acquired under various environmental conditions:

- ☐ climate: temperate, tropical
- ☐ ecosystem: forest, crops



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