Modeling reflectance and transmittance of leaves in the 0.4 - 5.7 µm domain: PROSPECT-VISIR

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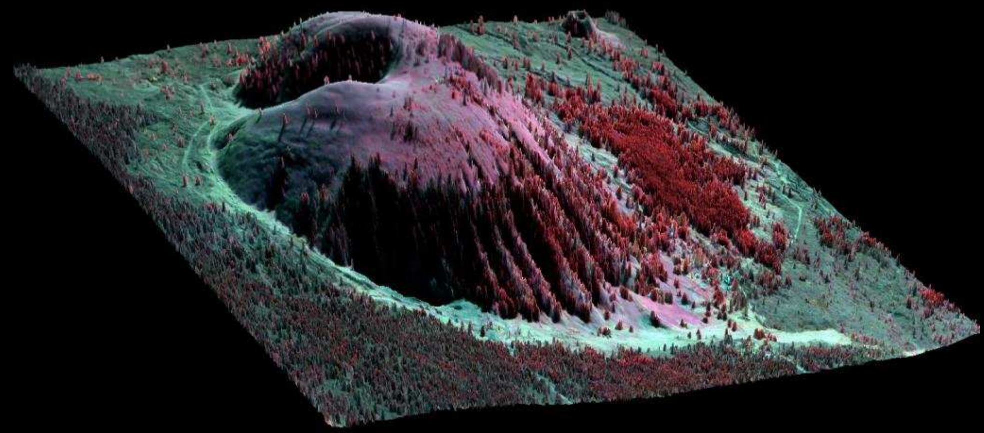
Applications of vegetation optical properties models

- agriculture,
- fire forest prevention,
- pollution,
- defense,
- ...

- climatology,
- geophysic,
- ...



Vegetation species classification on Hawaii
(green: native species – red: invasive species)
Credits: Carnergie Airbone Observatory

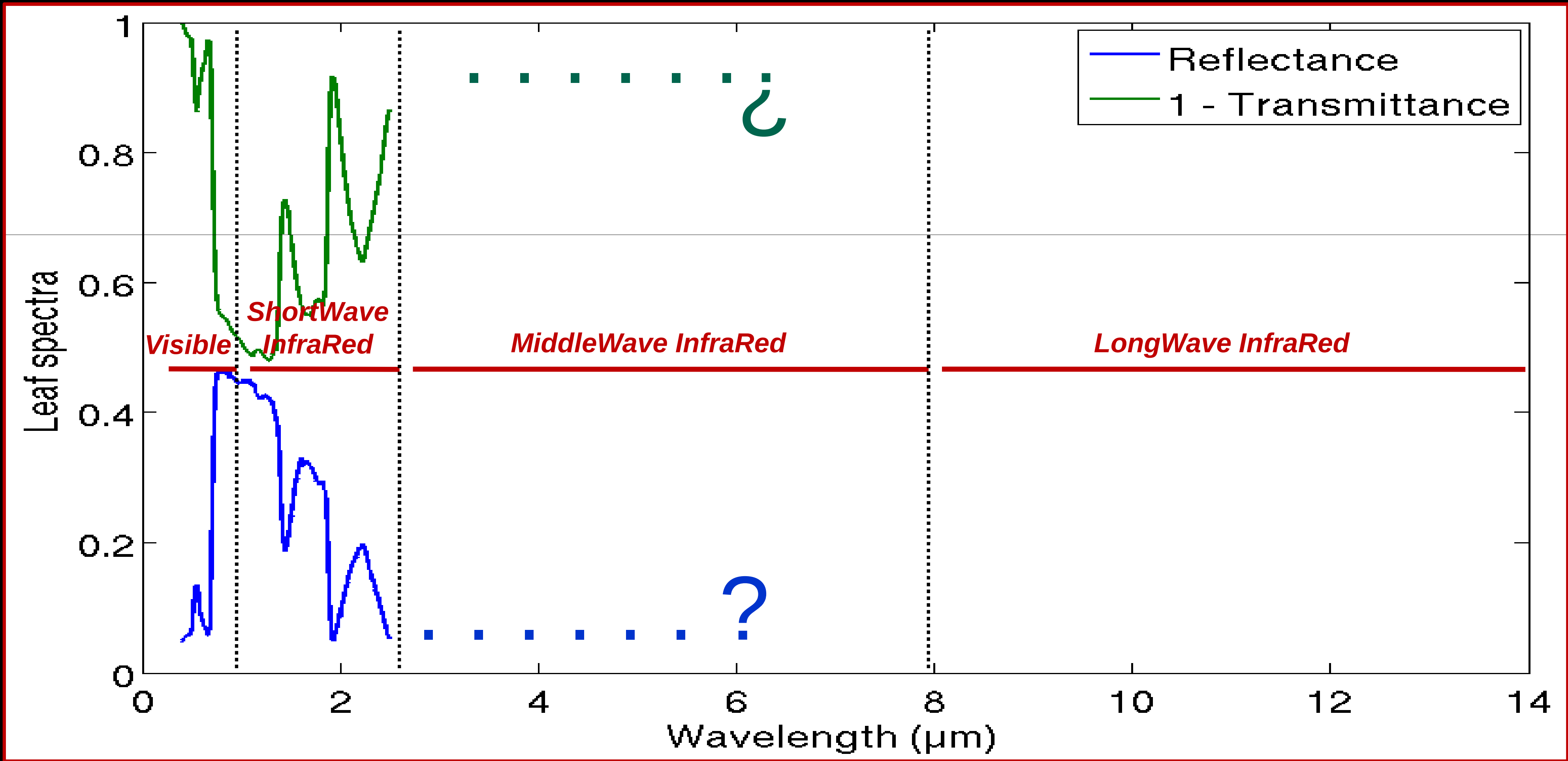
http://cao.stanford.edu/

Outline

- **Existing work and objectives**
- **The PROSPECT-VISIR model**
  - USGS & ONERA measurement campaigns
  - Design of a new leaf model
  - Validation
- **Conclusion & future work**
  - Scaling up to canopy and top-of-atmosphere levels
  - Inversion using hyperspectral remote sensing data

Existing work and objectives

- **Existing work**
  - VNIR – SWIR domain (0.4 – 2.5 µm) ⇒ widely studied (many data and models)
  - MWIR – LWIR domain (2.5 – 14 µm) ⇒ almost no data, to be exploited!



Existing work and objectives

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  - VNIR – SWIR domain (0.4 – 2.5 µm) ⇒ widely studied (many data and models)
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- **OBJECTIVES**
  - Modeling leaf optical properties in the visible-infrared domain for accurate estimation of *vegetation water content*

→ **Need to collect new data:**

leaf spectra up to 14 µm + biochemical content

USGS & ONERA datasets 1/2

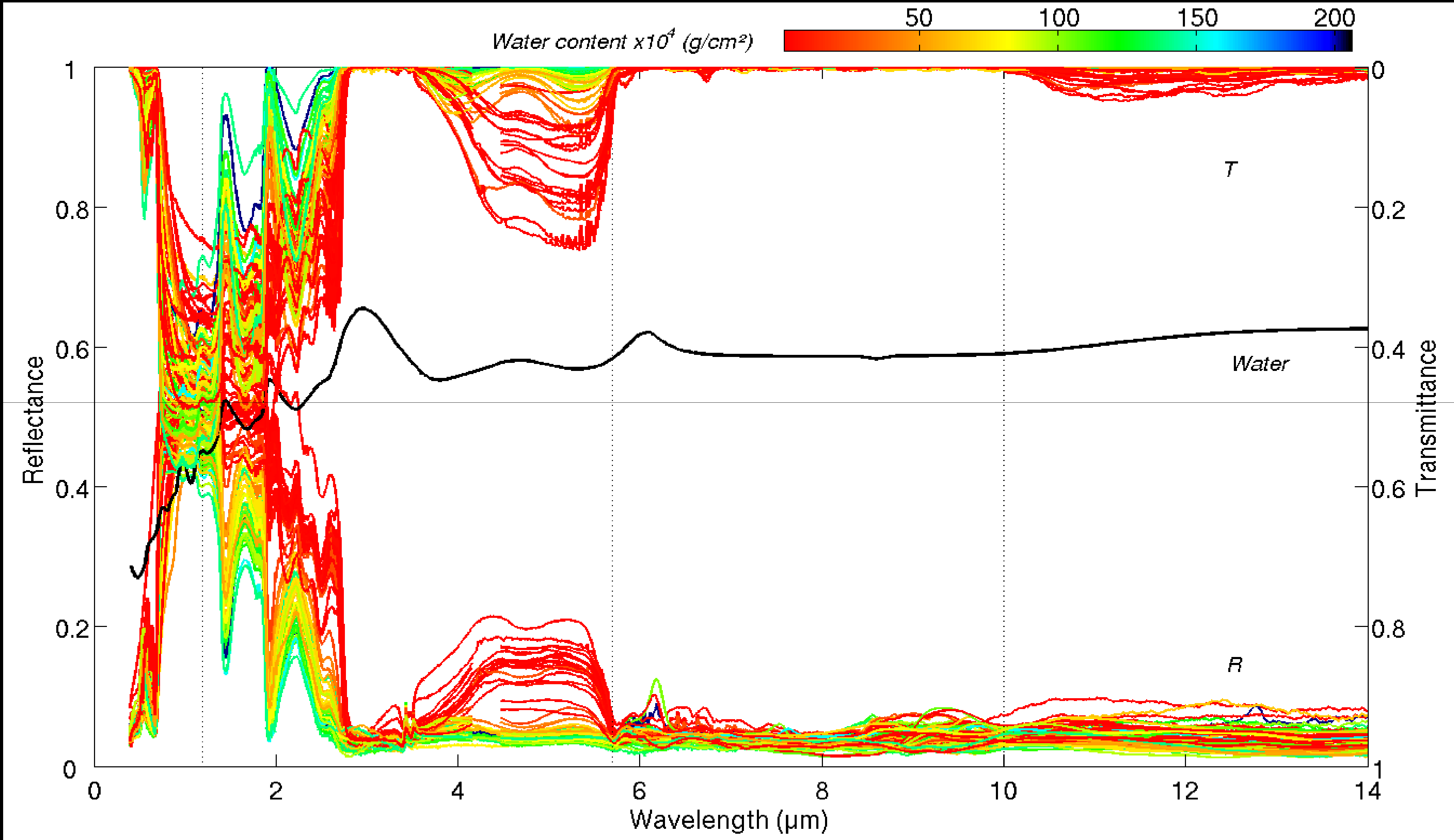
- 2 EXPERIMENTAL CAMPAIGNS
  - USGS (Reston, VA), June 08
  - ONERA (Toulouse), July 08

- 2 INDEPENDENT DATASETS
  - Important variability of water content (leaf drying,...)
  - Many leaf species (28)

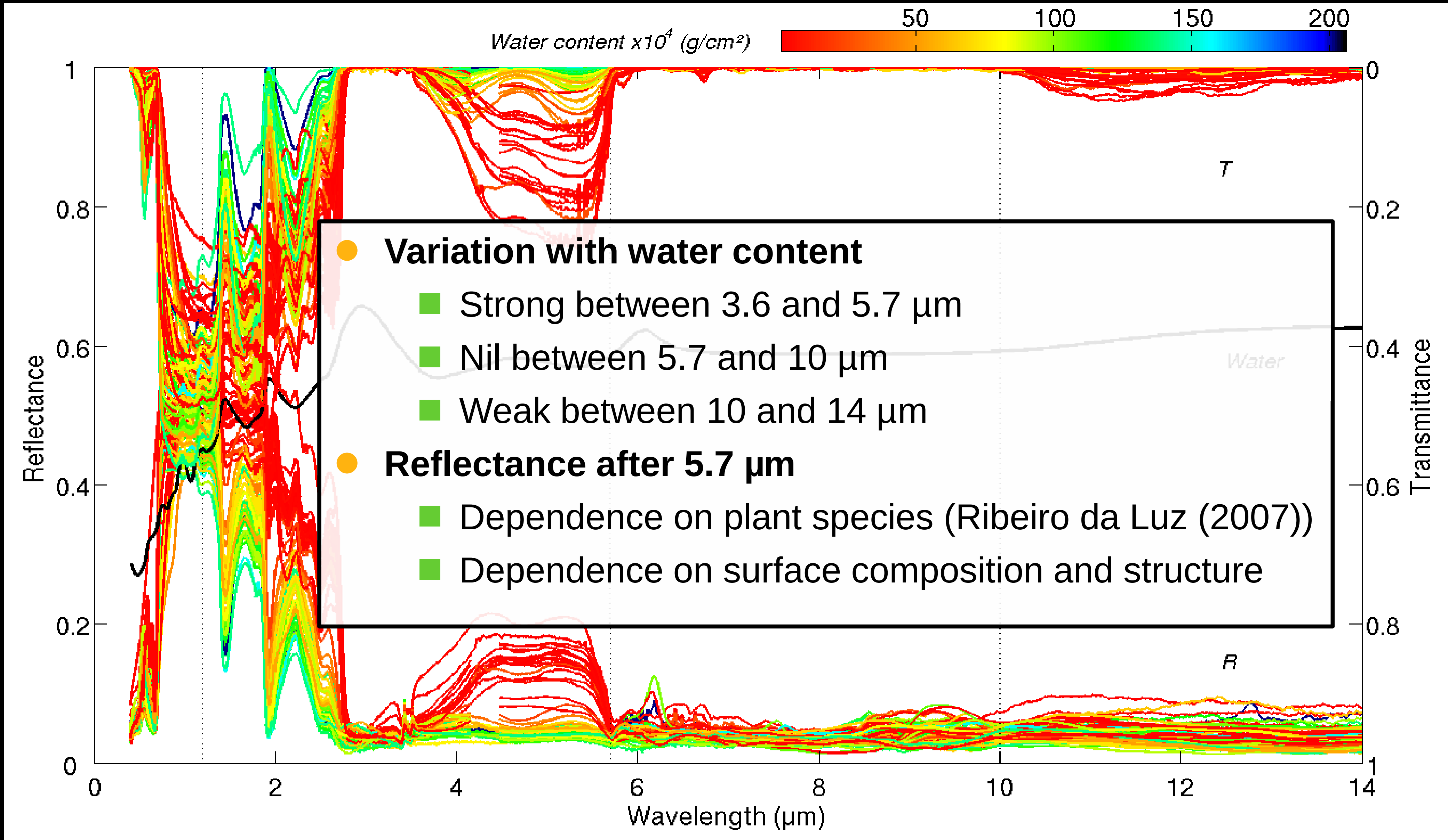
- BIOPHYSICAL AND RADIOMETRIC MEASUREMENTS
  - 64 directional - hemispheric reflectance and transmittance spectra from 0.4 to 14 µm (spectral resolution of 1 nm)
  - 64 associated water and dry matter content (g/cm²)

Nicolet Nexus 670 infrared spectrometer + integrating sphere

USGS & ONERA datasets 2/2



USGS & ONERA datasets 2/2



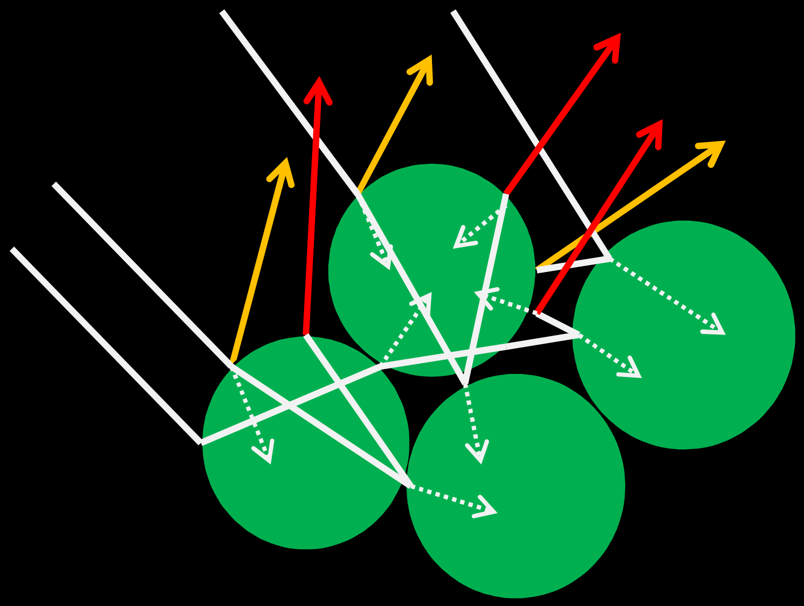
- **Variation with water content**
  - Strong between 3.6 and 5.7 µm
  - Nil between 5.7 and 10 µm
  - Weak between 10 and 14 µm
- **Reflectance after 5.7 µm**
  - Dependence on plant species (Ribeiro da Luz (2007))
  - Dependence on surface composition and structure

Ribeiro da Luz, B., & Crowley, J. (2007). Remote Sensing of Environment, 109, 393-405.

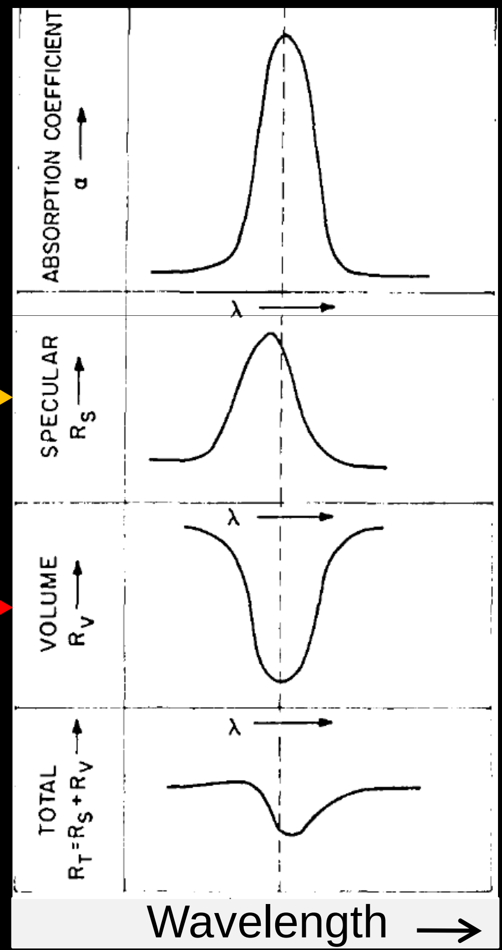
Physics basis

Reflection and transmission depend on:

- Absorption levels
- Surface and internal leaf structure
  (particule size, air spaces,...)



<u>*2 types of reflection*</u>



Absorption coefficient

Specular reflection (surface)

+

Volume reflection (internal)

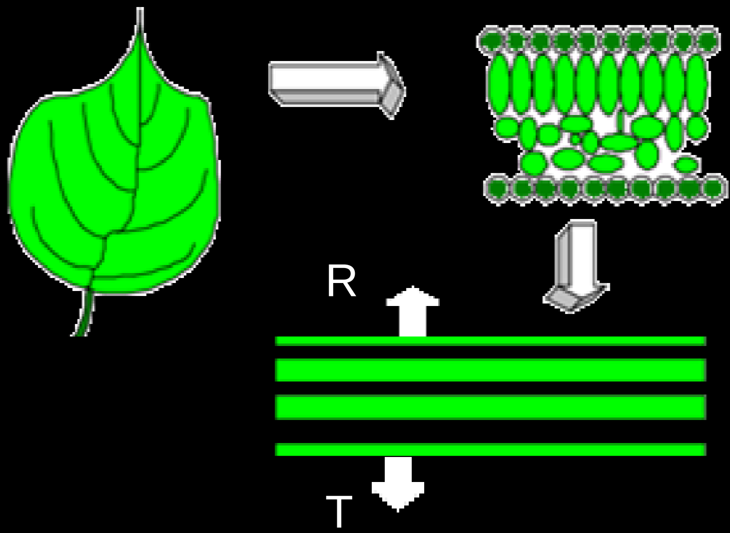
=

Total reflection

Vincent, K.V. & Hunt, R. H. (1967). Infrared reflectance from mat surfaces. Applied Optics, 7(1), 53-59

The PROSPECT radiative transfer model

Modeling of leaf R and T as a function of leaf biochemical content and anatomical structure



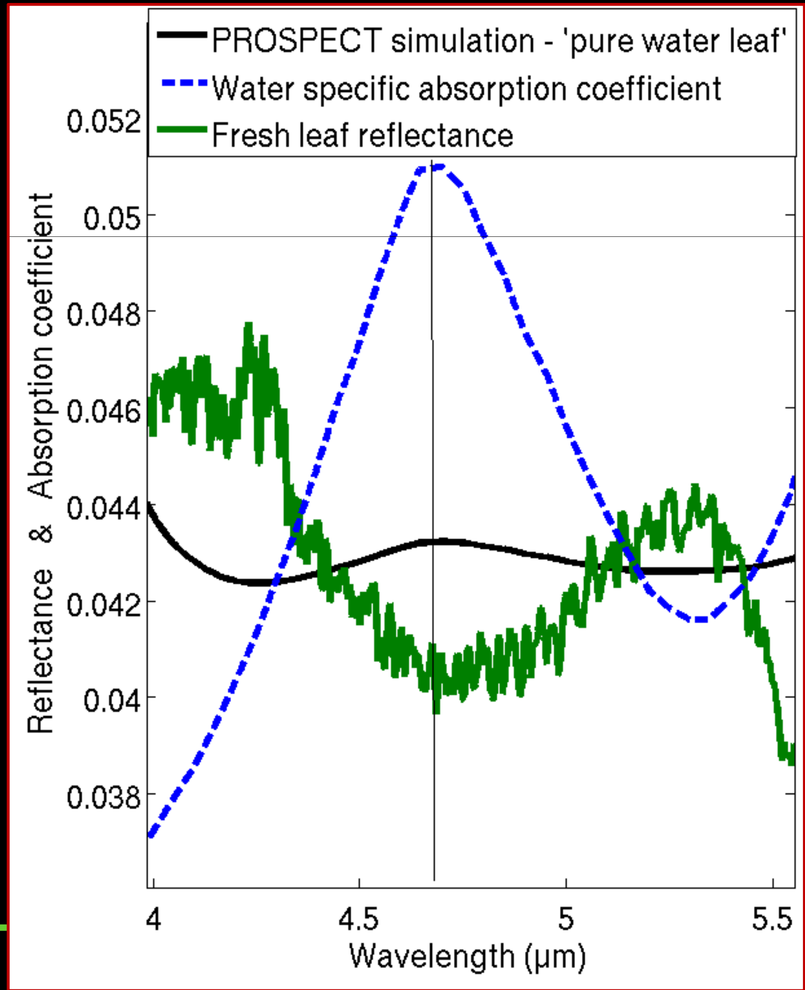
N layers characterized by an absorptance and a complex refractive index

- Specular reflection: at the surface of the layer (Fresnel coefficient)
- Volume reflection: combination of multiple reflections between the layers

Jacquemoud, S. & Baret, F. (1990). PROSPECT: a model of leaf optical properties spectra. Remote Sensing of Environment, 91, 34-75

PROSPECT → PROSPECT – VISIR

- Limits of the PROSPECT model when absorption is very high (2.9-5.7 µm)
  - *In the present version*
    → **Specular reflection** dominates
  - *But in the data,*
    → **Volume reflection** dominates



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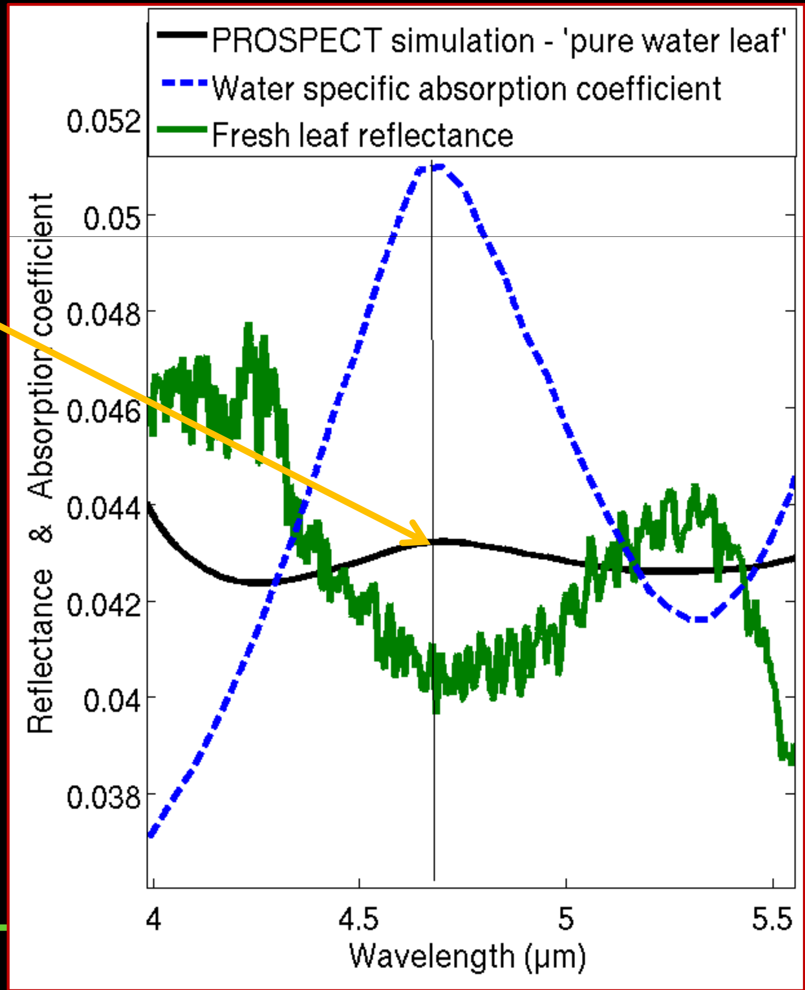

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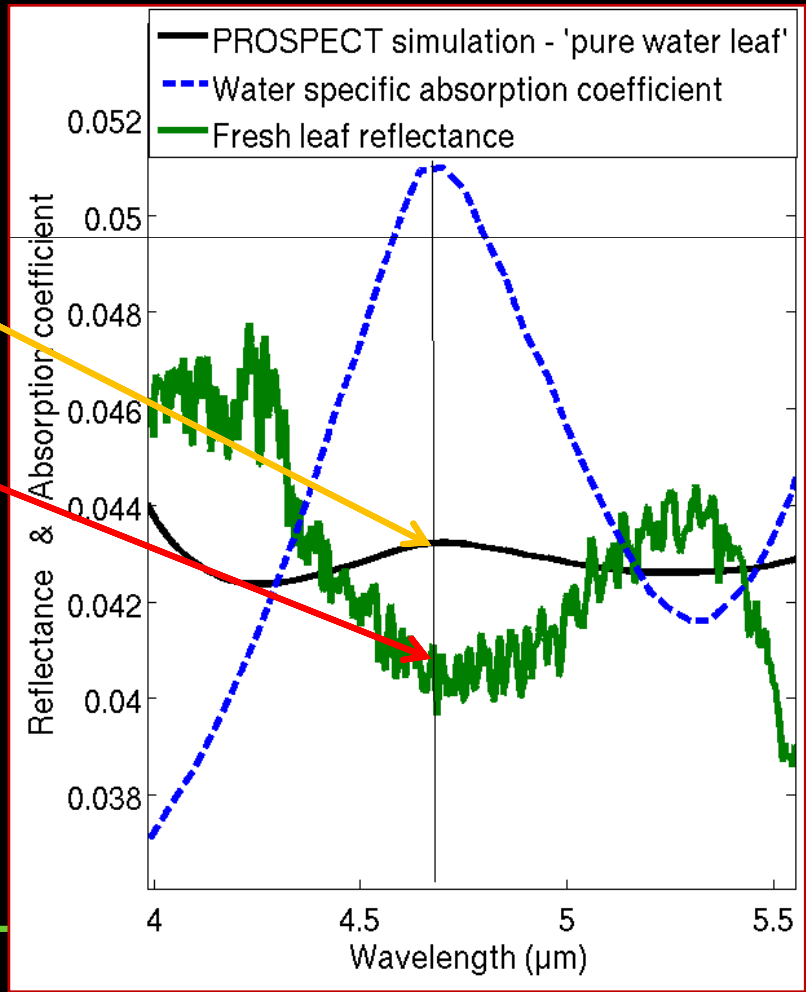

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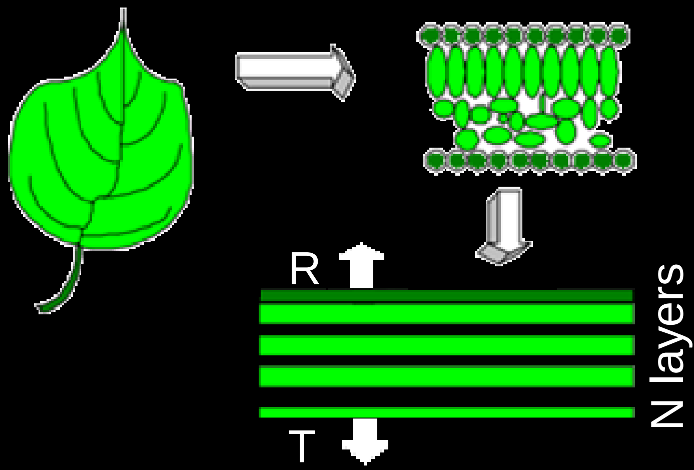
→ Need to modify PROSPECT to account for volume reflection at high absorption levels

A new leaf model: PROSPECT-VISIR (0.4 – 5.7 µm)



$$k(\lambda) = \sum_i \left(\frac{C_i}{N} . k_i(\lambda) \right)$$

Absorption of one elementary layer

R and *T* are functions of *N*, *k*, *n* and n_{surf}

<u>Parameters</u> (to calibrate)

- Water $k_w(\lambda)$
- Dry matter $k_m(\lambda)$

} *Specific absorption coefficients*

- Refractive index of the leaf interior $n(\lambda)$
- Equivalent refractive index of the leaf surface $n_{surf}(\lambda)$

<u>Variables</u>

- Water content C_w
- Dry matter content C_m
- Structure parameter *N*

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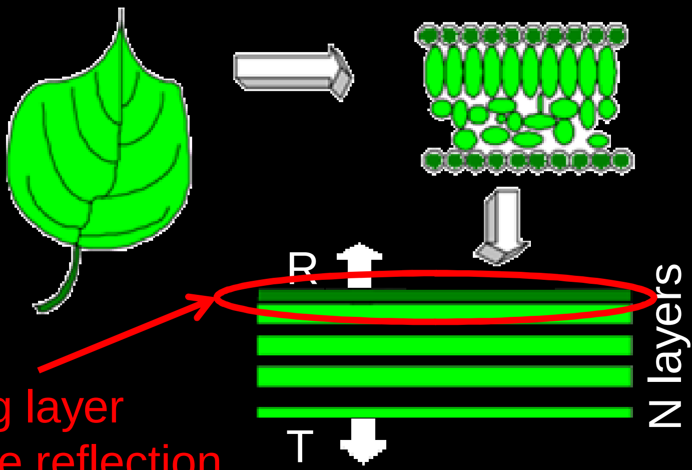

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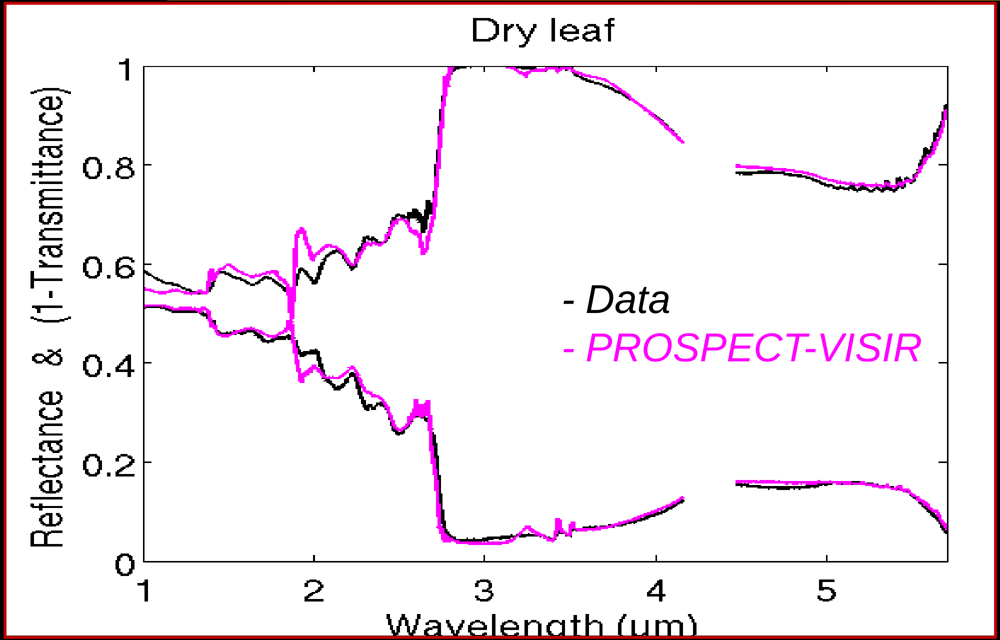
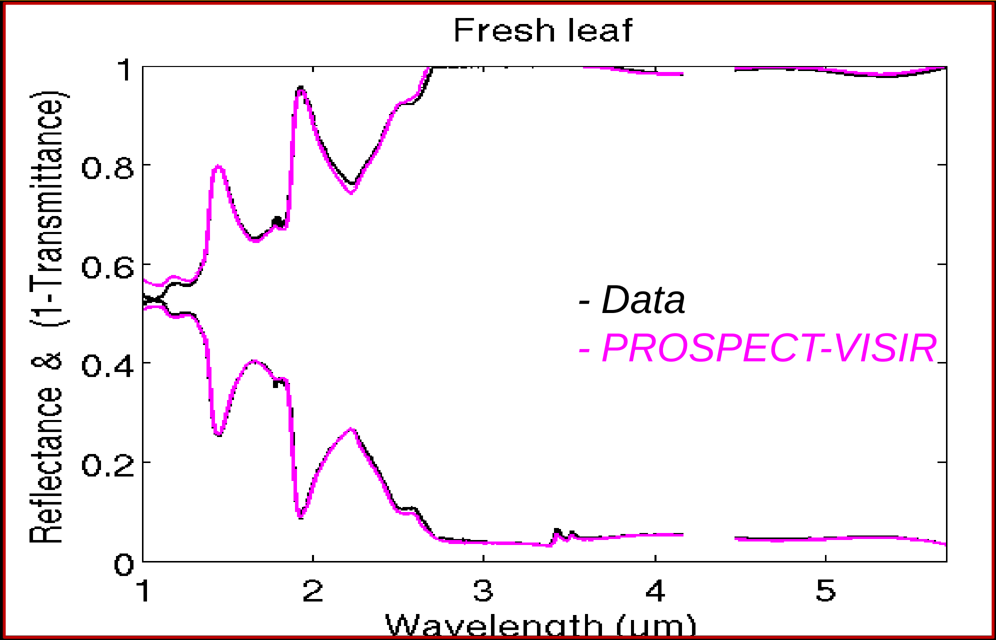
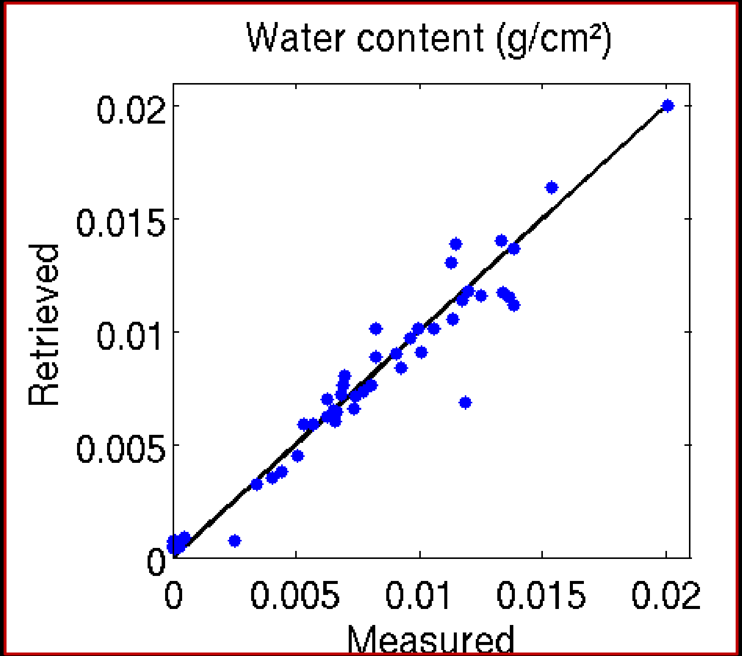
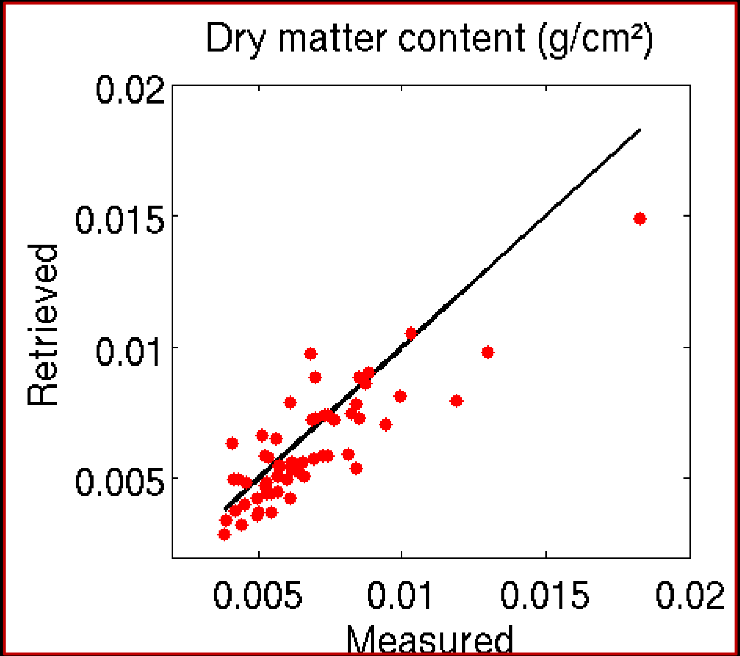
PROSPECT-VISIR: validation









RMSE(C_w)= 0.0011 g/cm²
(0.0011 with PROSPECT)

RMSE(C_m)= 0.0014 g/cm²
(0.0018 with PROSPECT)

Conclusion & future work

- **Conclusion**
  - A leaf directionnal-hemispheric reflectance and transmittance model from 0.4 to 5.7 µm has been developed
  - The knowledge of leaf spectral signatures in the infrared domain has increased
- **Next steps**
  - Coupling of PROSPECT – VISIR with 4SAIL (canopy radiative transfer model)
  - Acquisition of hyperspectral images of vegetation in the 3 – 5 µm domain

    ⇒ field campaign planed at INRA Avignon in June 2009 with an ATIS camera standing on a 20 meters high crane
  - Validation of the model at the canopy level
  - A paper in preparation...

Use of the model at the satellite level.....