From SAIL simulations towards automated remote sensing applications: an overview of 6 years of ARTMO developments

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Since the advent of optical remote sensing (RS), physically-based radiative transfer models (RTMs) have deeply helped in understanding the radiation processes occurring on the Earth's surface and their interactions with vegetation and atmosphere. Among the most popular RTMs for vegetation applications is undoubtedly the SAIL model. SAIL provides a gentle introduction into the science of plant-light interactions to a generation of students and researchers, and has been used in all kinds of RS applications. However, when it comes to intensive use of SAIL (or similar RTMs) for mapping applications, then there is need to have these models implemented into a user-friendly framework that enables automating its running and further processing.

To facilitate the use of RTMs into RS applications, since 2010 we have been developing a Graphic User Interface (GUI) software package called 'Automated Radiative Transfer Models Operator' (ARTMO). ARTMO is a freely downloadable scientific toolbox that provides essential tools for running and inverting a suite of plant RTMs, both at the leaf and at the canopy scale (ipl.uv.es/artmo). While initially developed around PROSAIL (PROSPECT + SAIL), currently ARTMO runs about 10 RTMs. ARTMO essentially facilitates consistent and intuitive user interaction, thereby streamlining model setup, running, spectral output storing and plotting for any kind of optical sensor operating in the visible, near-infrared and shortwave infrared range (400-2500 nm). Over the past six years ARTMO has been expanded with a variety of post-processing toolboxes. This presentation will give an overview of developments in ARTMO toolboxes. They include:

Retrieval toolboxes. These toolboxes optimize and automate the retrieval of vegetation properties from RS images. They can be categorized into: (1) parametric regression methods (e.g. vegetation indices), (2) non-parametric regression methods (e.g. machine learning methods), (3) physical methods (e.g. RTM look-up table inversion ad numerical inversion) and (4) hybrid methods (RTM simulations coupled with a nonparametric regression method). Mapping examples using SAIL simulations will be given, and their pros and cons discussed.

Sensitivity analysis. Sensitivity analysis can range from local sensitivity analysis (LSA), i.e. one-factor-at-a-time, to global sensitivity analysis (GSA), where the full variable space is explored. LSA can be easily visualized into ARTMO's graphics tool, where simulations are plotted as a function of input variables. Regarding GSA, a variance-based GSA toolbox was developed based on the method of Saltelli et al., 2010. With this method the driving input variables of SAIL and other RTMs can be rapidly identified.

Emulation. Although SAIL is a relatively fast RTM, it can become time-consuming for tedious applications where many per-pixel iterations are involved such as numerical inversion. To speed up its processing, a bypass is to construct *emulators* or meta-models that approximate the functioning of an RTM through statistical learning. With the risk of losing somewhat in accuracy, emulators gain tremendously in processing speed. Examples of SAIL emulations will be presented and their pros and cons discussed.

In conclusion, ARTMO offers an assortment of toolboxes for optimized and automated processing of leaf and canopy RTMs into RS applications such as biophysical parameter mapping, sensitivity analysis and emulation.