Radiative Transfer Modeling with DART: An Introduction

Růžena Janoutová, Vojtěch Barták

2025-12-18

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1 Introduction to Radiative Transfer Modeling

Remote sensing captures light reflected or emitted from Earth's surface, but these spectral signals encode complex information about vegetation structure, biochemistry, and function. To unlock this information and make quantitative predictions about ecosystem properties, we need more than statistical correlations—we need physical understanding of how light interacts with plant canopies.

Physics Meets Remote Sensing

Radiative Transfer Models (RTMs) are powerful computational tools that simulate light propagation, scattering, and absorption within virtual 3D scenes using the fundamental laws of physics. Unlike empirical models that depend on site-specific calibrations, RTMs are based on physical principles that remain valid across different ecosystems, sensors, and observation conditions. This makes them invaluable for interpreting satellite and airborne imagery, designing new sensors, and retrieving vegetation properties that cannot be directly measured from space.

From Turbid Layers to 3D Forests

The evolution of RTMs parallels advances in computational power and our understanding of canopy architecture. Early 1D models treated vegetation as horizontally uniform layers—appropriate for agricultural fields but insufficient for complex forests. Modern 3D RTMs like DART (Discrete Anisotropic Radiative Transfer) can simulate detailed forest scenes with individual trees, accounting for shadows, multiple scattering between canopy elements, and the complex interplay between direct sunlight and diffuse sky radiation.

The DART Advantage

DART represents the state-of-the-art in 3D radiative transfer modeling. Developed by CESBIO (Centre d'Etudes Spatiales de la BIOsphère), it simulates the complete radiative budget of natural and urban landscapes. DART can generate synthetic remote sensing imagery—from optical reflectance to thermal emission to LiDAR waveforms—that mimics what satellites and aircraft would observe over real terrain. This capability enables researchers to test retrieval algorithms, optimize sensor designs, and understand which spectral bands contain information about specific vegetation traits.

The Challenge and Opportunity

Using RTMs requires careful parameterization: leaf optical properties, 3D canopy structure, atmospheric conditions, and sensor geometry must all be specified. This complexity creates both challenge and opportunity. The challenge lies in obtaining accurate input data through field measurements or existing databases. The opportunity lies in the unprecedented ability to link remote sensing signals to biophysical processes, enabling quantitative ecosystem monitoring from leaf to landscape scales.

2 Where to go further?

Watch the **video lecture** in which Dr. Růžena Janoutová introduces the key concepts for this lesson:

https://www.youtube.com/embed/4vr2syILgZM?si=7M6s8hLB_IyVmSvh

View and download the **presentation** from the video:

Read the **theory** to understand:

- The basic physical principles of light interaction with vegetation
- How leaf-level and canopy-level models work
- Different levels of RTM complexity (1D, 3D geometrical, 3D complex)
- RTM products (reflectance, thermal, LiDAR) and applications
- DART's capabilities and the RAMI benchmarking initiative

- Practical retrieval workflows using Look-Up Tables (LUTs)

Follow the **practical tutorial** to learn how to:

- Set up a DART forest scene simulation
- Configure optical properties using the PROSPECT model
- Import and position 3D tree models
- Define spectral bands and sensor geometry
- Run simulations and generate synthetic imagery
- Create Look-Up Tables (LUTs) for trait retrieval
