

PHYSICAL MODELS IN REMOTE SENSING

CAS EE445/GRS EE645

PHYSICAL MODELS IN REMOTE SENSING

Spring 2026

Classroom: CAS 223

Tu & Th 2PM to 3:15PM

Contact Hours: Anytime (Setup via Email)

Instructor

Prof. Ranga Myneni

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<http://sites.bu.edu/cliveg>

PHYSICAL MODELS IN REMOTE SENSING

Prof. Ranga B. Myneni

PhD in Biology, University of Antwerp, Belgium (1985)

@ Boston University since 1997

@ NASA Goddard Space Flight Center (1990-1996)

Expertise: Remote Sensing of Vegetation, Climate-Vegetation Interactions

Research: 350+ Journal Articles

Academic: 27 Doctoral Students, 25 Post-docs & Visiting Scholars etc.

<https://sites.bu.edu/cliveg/people/professors/prof-ranga-b-myneni/>

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What is Remote Sensing?

The discipline of remote sensing involves measurements and interpretation of Electromagnetic radiation (EMR) emitted or scattered by targets such as water bodies, ice sheets, vegetation, atmosphere, etc.

The focus is typically on the properties of the targets, such as, aerosols in the atmosphere, leaf area of vegetation, organic matter in water bodies, etc.

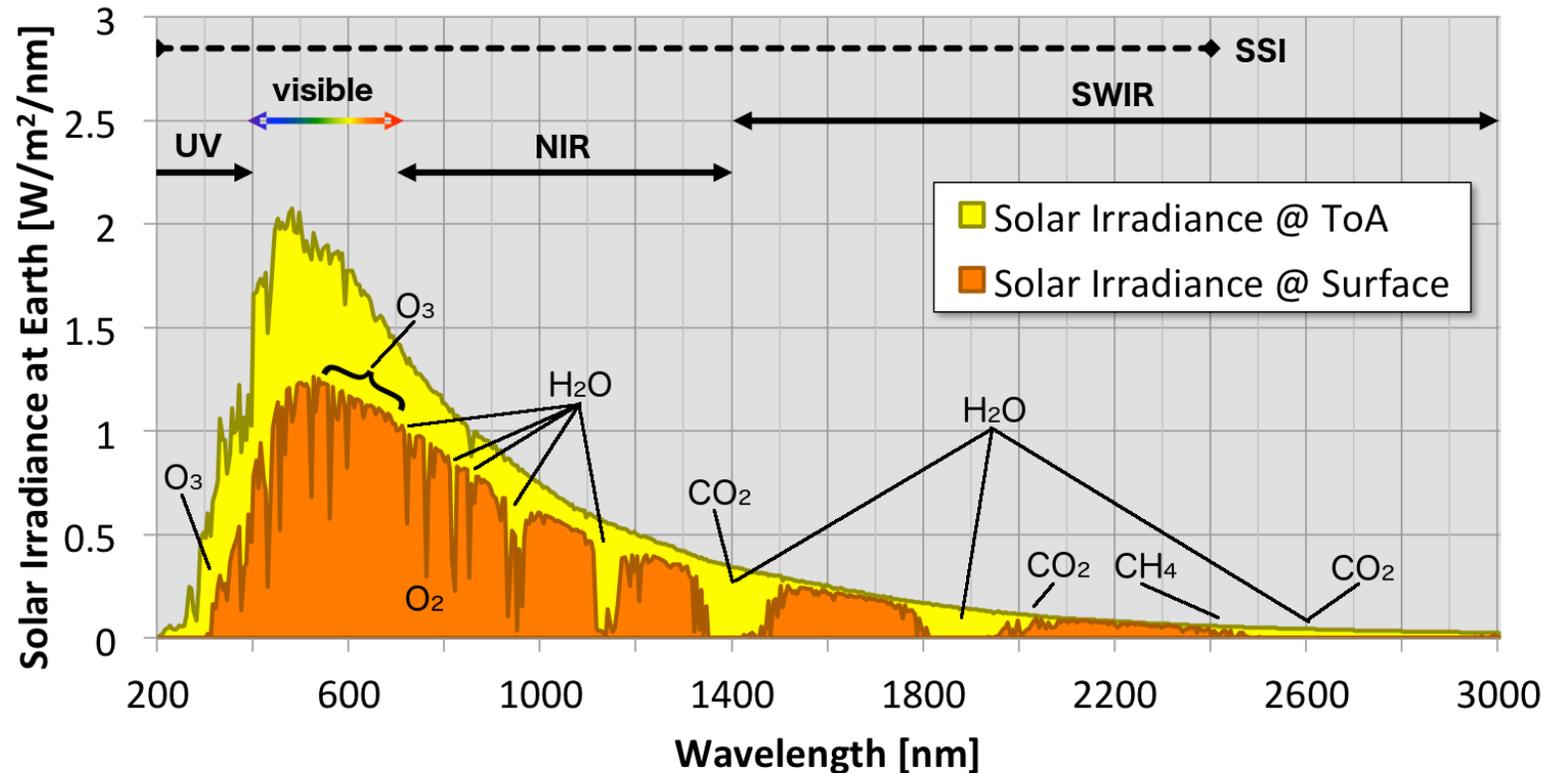
This problem is best described by invoking the wave or particle nature of EMR and mathematically characterizing the corresponding propagation and interaction physics.

Solutions to resulting equations shed light on the nature and information content of remotely measured signals.

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Simple Example of Remote Sensing

- Measuring transmission spectra to infer constituents in a medium



Credit: <https://earth.gsfc.nasa.gov/climate/projects/solar-irradiance/science>

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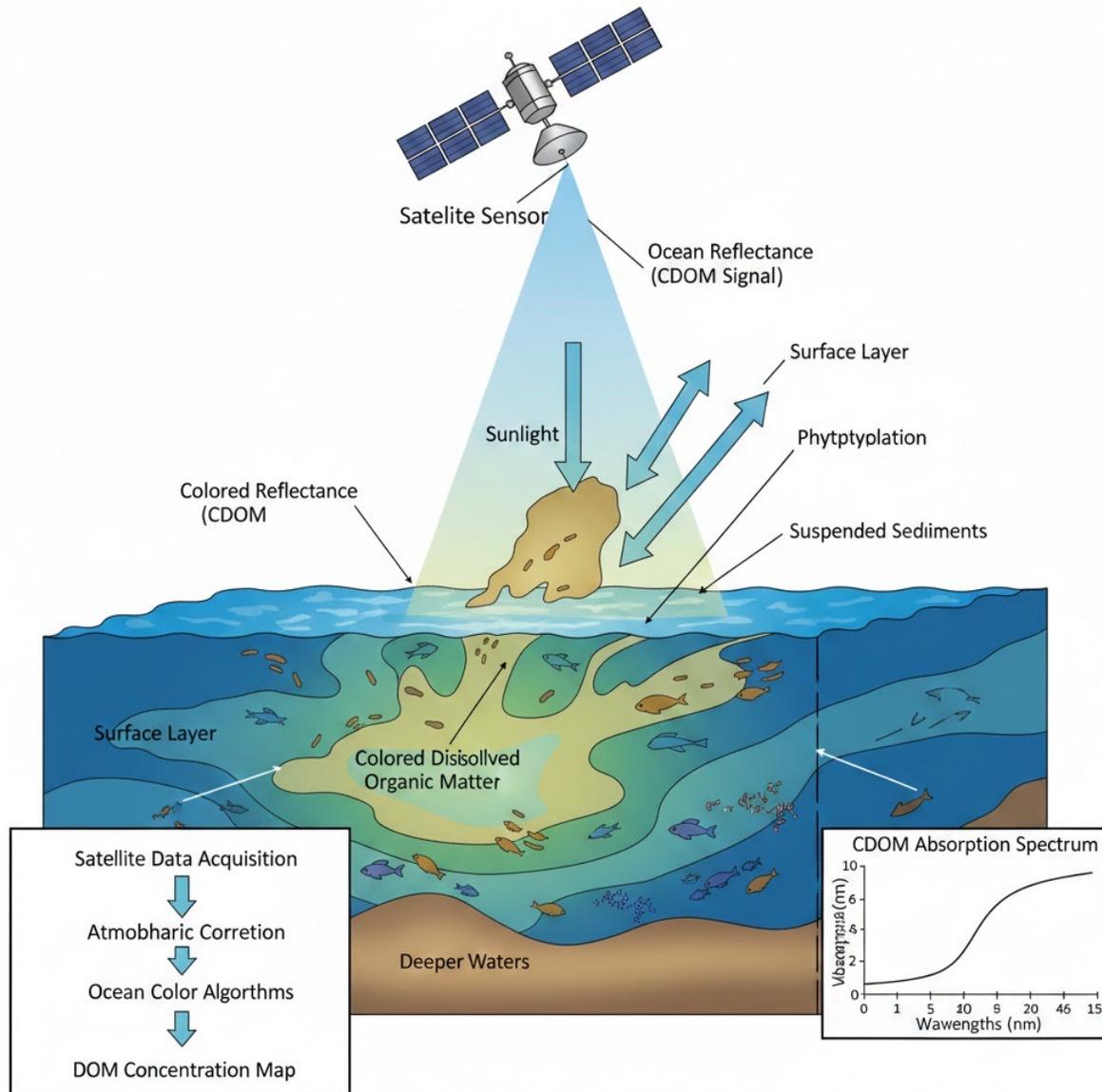
Forward & Inverse Problems?

Forward problem: The physical variables of the target are assumed known, and the solution is the remotely measured signal.

Inverse problem: The remote signal is assumed known and solved for physical properties of the target. This is the central problem in remote sensing

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Example: Remote Sensing of CDOM in Ocean Waters

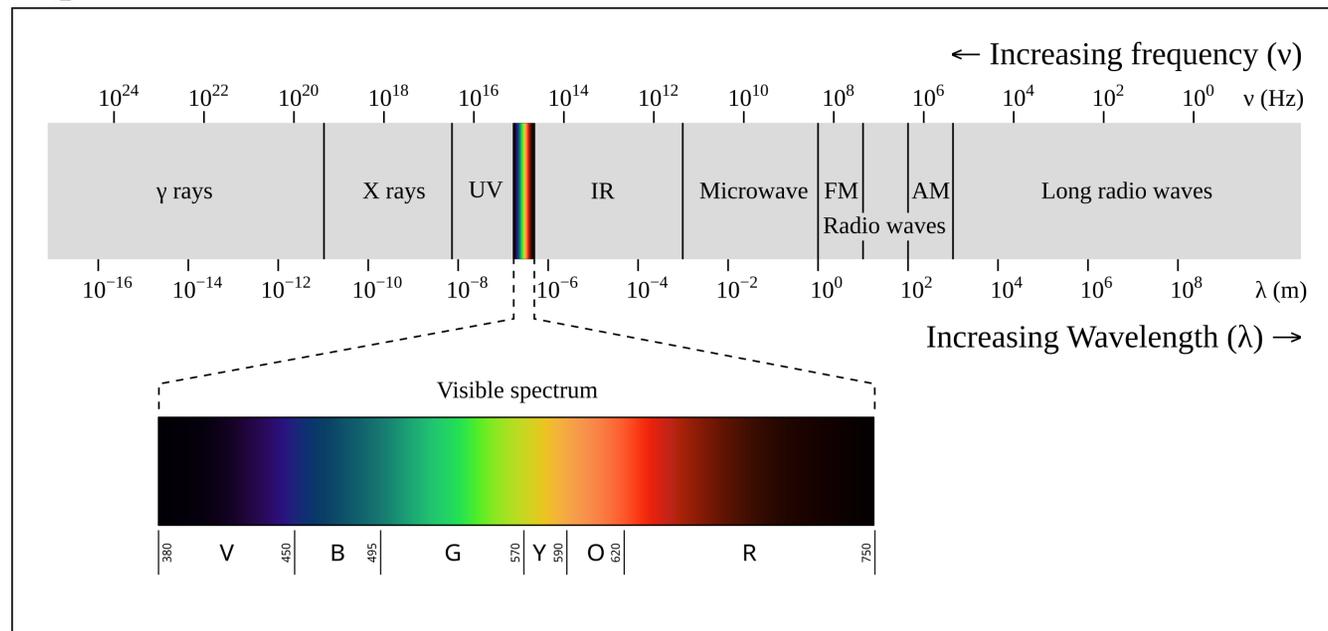
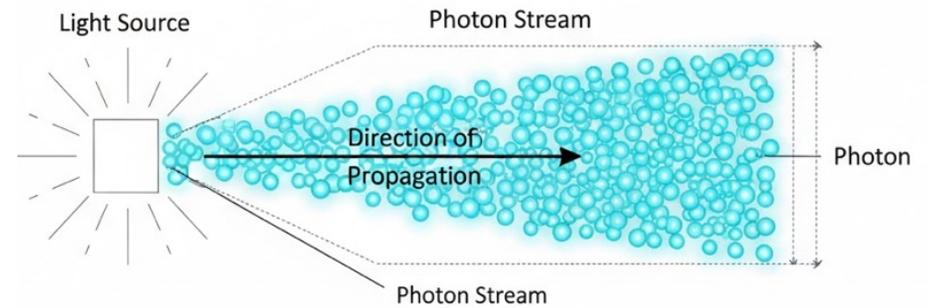
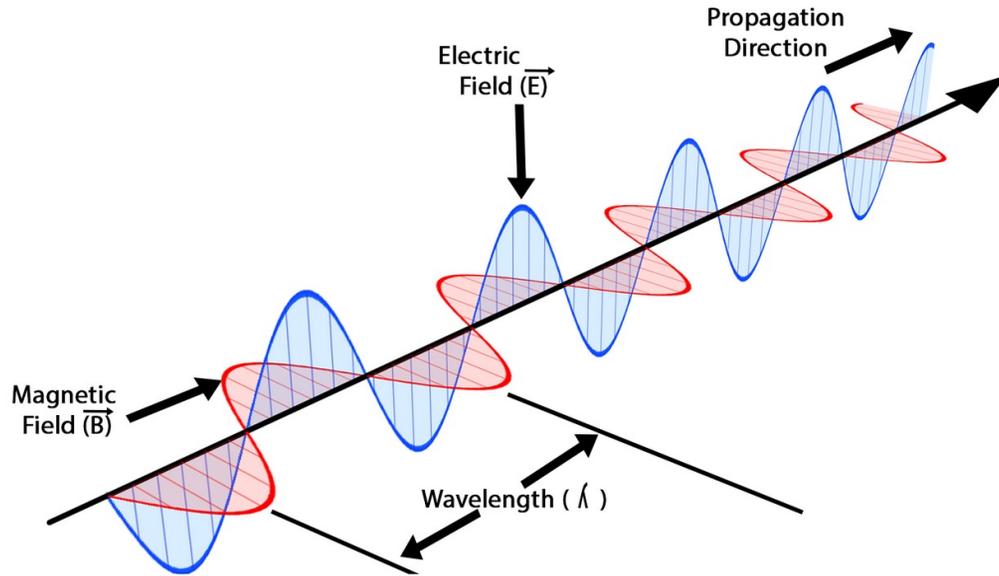


Forward problem?

Inverse problem?

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EMR: Wave-Particle Duality

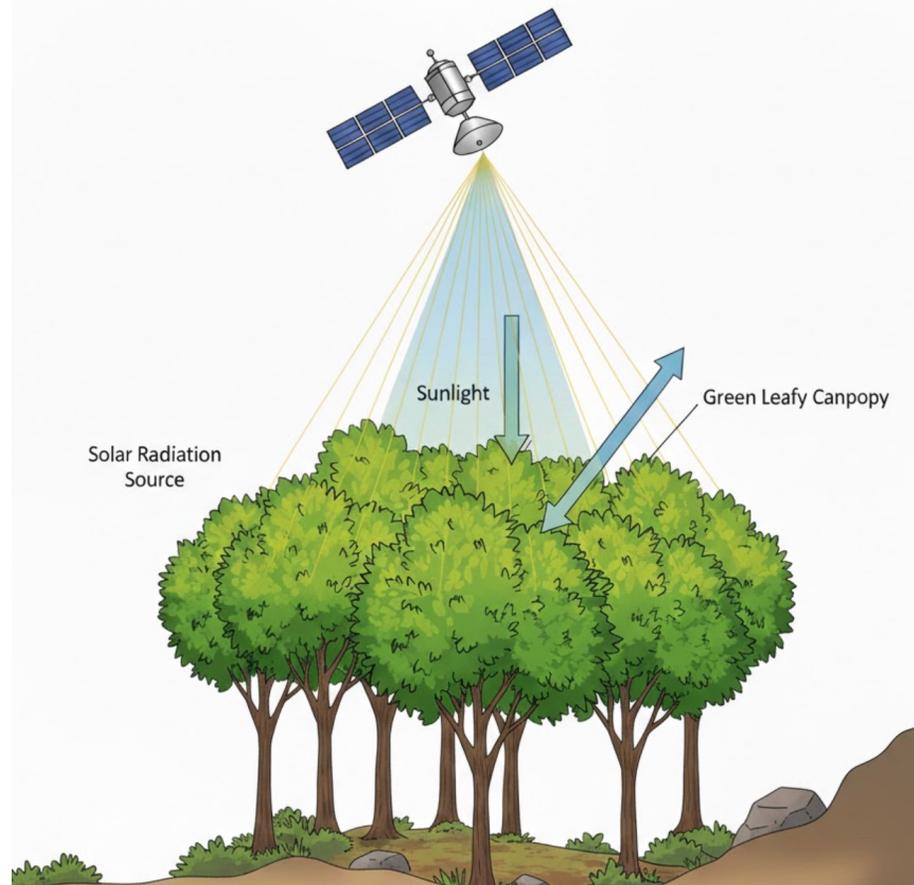


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Specific Focus in this Course

We will focus on remote sensing of green leaf area using vegetation as a target and invoking the particle nature of EMR.

Our approach shall be sufficiently generic, that mastering this topic will easily translate to skills for solving problems in remote sensing of other media.



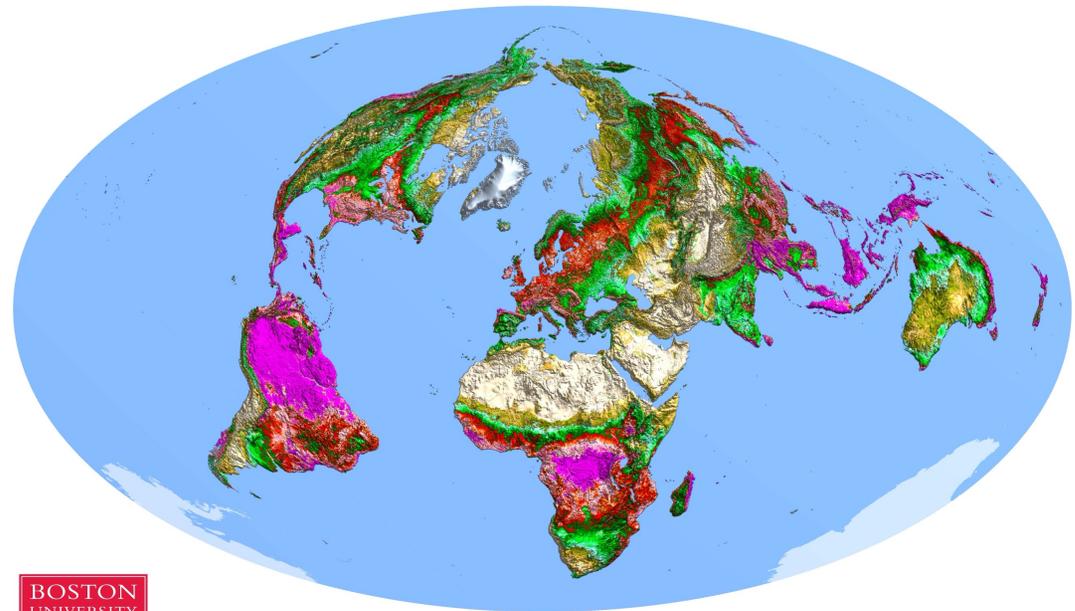
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Example Satellite Data Product

500M KM 8 DAY MODIS C6 LAI PRODUCT

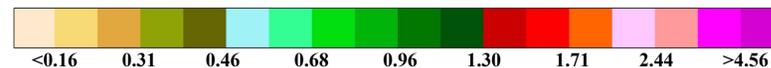
LAI
Leaf Area Index
one-sided green leaf area
per unit ground area

Useful in studies of
exchange of fluxes of
energy, mass and
momentum between the
surface and atmosphere



BOSTON
UNIVERSITY

Annual Average Green Leaf Area Index From Terra MODIS (2001 to 2010)



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Example Results from Analysis of Satellite Data Products

Year in review

Climate chronicles

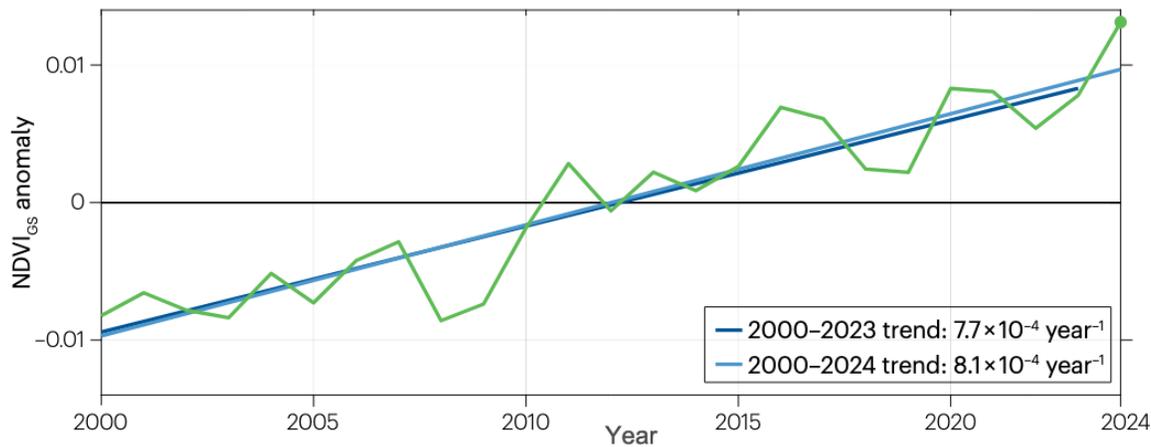
<https://doi.org/10.1038/s43017-025-00656-z>

Vegetation greenness in 2024

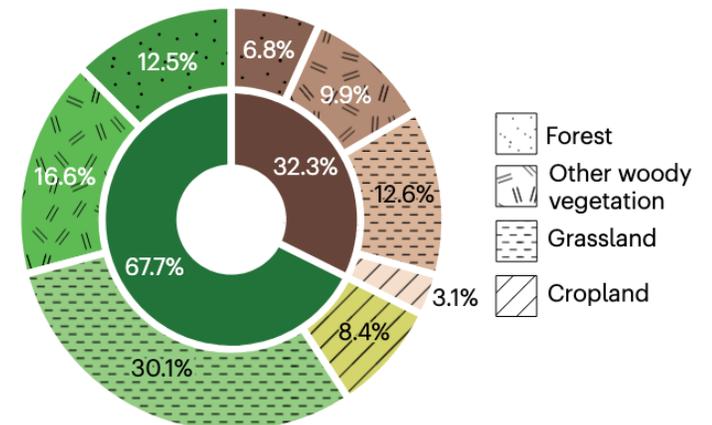
Yanchen Gui, Kai Wang, Chris Huntingford, Shankai Wei, Xiangyi Li, Ranga B. Myneni
& Shilong Piao

 Check for updates

a Global mean NDVI_{GS}



b Greening or browning by vegetation type



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Goals for this Course:

- (1) to gain a process level physics-based understanding of the measured signals, i.e., satellite data, and
- (2) master skills required to develop algorithms for remote sensing of physical traits of interest of any target.



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Outline of this Course:

The lectures will be grouped into five thematic chapters:

1. Definitions and the Radiative Transfer Equation (RTE)
 2. The RTE Problem in Vegetation Media
 3. Physics of Photon-Vegetation Interactions
 4. Numerical Solution Methods of the RTE
 5. Advanced Methods
- I will provide you lecture notes and all needed reference materials.
 - I will assume that you have some college-level background in Calculus, differential equations and numerical methods.
 - I will do my best to teach you all in a manner that shall make you the master of this material by the semester's end.

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Grading:

Course assignments will require coding and interpretation of results.

Final grade will be based on the report submitted at the semester's end.

This report shall consist of results and their interpretation from solution of the 1D radiative transfer equation for a vegetation medium idealized as a turbid medium.

I will give you example codes and assignments for your use as guides.

There are no exams in this course.

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Class Website:

<https://sites.bu.edu/cliveg/ee-445-645-spring-2026/>

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Schedule:

EE 445/645 Lecture Schedule for Spring 2026
(Jan-20-2026)

Chapter 01: Definitions & Radiative Transfer Equation		
1	Jan-20	Introduction to the Course
2	Jan-22	Basic definitions (C1-P1)
3	Jan-27	Particle Dist. Function & Radiative quantities – C1-P2)
4	Jan-29	Radiative interactions (C1-P3)
5	Feb-03	The Radiative Transfer Equation (C1-P4)
6	Feb-05	Integral form of the Radiative Transfer Equation (C1-P5)
7	Feb-10	Energy Balance & Reciprocity Principles (C1-P6)
Chapter 02: Radiative Transfer Problem in Vegetation Canopies		
8	Feb-12	RTE in Vegetation & Radiative Quantities of Interest (C2-P1)
Chapter 03: Structure, Optics and Cross Sections		
09	Feb-19	Canopy Structure (C3-P1)
10	Feb-24	Extinction Cross Section (C3-P2)
11	Feb-26	Leaf Optics (C3-P3)
12	Mar-03	Differential Scattering Cross Section (C3-P4)
Chapter 04: Numerical Solution of the Radiative Transfer Equation		
13	Mar-10	One dimensional RTE problem set-up (C4-P1)
14	Mar-12	Successive orders of scattering (C4-P2)
15	Mar-17	Start Discrete Ordinates method (C4-P3)
16	Mar-19	Finish Discrete Ordinates method (C4-P3)
17	Mar-24	Gauss-Seidel method (C4-P4) & Two Stream Method (C4-P5)
18	Mar-26	Hot Spot (C4-P6) & Model Inversion (C3-P7)
19	Mar-31	Start 3D Discrete Ordinates – 01 (C4-P8)
20	Apr-02	Finish 3D Discrete Ordinates – 02 (C4-P9)
Chapter 05: Advanced Topics		
21	Apr-07	Decomposition of RTE Solution (C5-P1)
22	Apr-09	Estimating LAI from RS data (C5-P2)
23	Apr-14	Spectral Invariants (C5-P3)
24	Apr-16	Stochastic RTE (C5-P4)
25	Apr-21	Light Quality in Vegetation Canopies (C5-P5)
26	Apr-23-30	Discussion Related to Coding of Assignment & Submission for Grading

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Policies:

Please read the [Boston University Academic Conduct Code](https://www.bu.edu/academics/policies/academic-conduct-code/), which governs all BU undergraduate students, so you understand it and its implications for your actions.

<https://www.bu.edu/academics/policies/academic-conduct-code/>

See also the [GRS Academic Conduct Code](https://www.bu.edu/cas/academics/phd-and-mfa-academics/academic-policies-and-conduct-code/), which applies to all courses and students in the Graduate School of Arts & Sciences.

<https://www.bu.edu/cas/academics/phd-and-mfa-academics/academic-policies-and-conduct-code/>