

# Special Topics: Introduction to Bio-optics Syllabus

Department of Oceanography  
OCEA 4301/5421, Winter 2026

*Dalhousie University acknowledges that we are in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq People and pays respect to the Indigenous knowledges held by the Mi'kmaq People, and to the wisdom of their Elders past and present. The Mi'kmaq People signed Peace and Friendship Treaties with the Crown, and section 35 of the Constitution Act, 1982 recognizes and affirms Aboriginal and Treaty rights. We are all Treaty people.*

*Dalhousie University also acknowledges the histories, contributions, and legacies of African Nova Scotians, who have been here for over 400 years.*

## Course Instructor(s)

Name	Email	Office Hours
Hugh MacIntyre	<a href="mailto:hugh.macintyre@dal.ca">hugh.macintyre@dal.ca</a>	Ad hoc

## Course Description

This is an upper-division/graduate course on applications of imaging and reflectance, absorption, and fluorescence spectroscopy to estimate the abundance, community composition, and productivity of marine phytoplankton.

### *Course Prerequisites*

Permission of instructor.

### *Course Exclusions*

N/A.

## Student Resources

Lectures, which include citations, will be posted prior to each lecture.

## Course Structure

### *Course Delivery*

Delivery is in-person; students are required to attend all class meetings. Missed lectures will be reviewed one-on-one.

### *Lectures*

One 90-min lecture per week, time & place TBD. All students will take Units 1-8; students in 5421 will also attend two additional lectures in Unit 9.

### *Laboratories*

No labs are involved but some experience of spectrophotometry, transmissometry, single-channel and spectral fluorometry, chlorophyll variable fluorescence, flow cytometry, and microscopy is required.

### *Tutorials*

One 90-min discussion based on an assigned reading per week, time & place TBD.

## Course Materials

The course is taught from the primary literature. No textbook is required.

## Assessment

### *Assignments*

Assessment in the undergraduate section (OCEA 4301) is through 5 equally-weighted assignments based on analysis and interpretation of field and lab data.

Students enrolled in the graduate section (OCEA 5421) will also complete an additional (6<sup>th</sup>) set of analyses on Unit 9, equally weighted with the assignments common to both sections.

Ungraded 3-question quizzes on the materials covered in the previous class are included with each lecture to help students to assess their understanding of the material. These

### *Other course requirements*

N/A.

Conversion of numerical grades to final letter grades follows the

Dalhousie Grade Scale

A+ (90-100)	B+ (77-79)	C+ (65-69)	D (50-54)
A (85-89)	B (73-76)	C (60-64)	F (0-49)
A- (80-84)	B- (70-72)	C- (55-59)	

### **Course Policies on Missed or Late Academic Requirements**

Assignments will not be accepted after the submission deadline. However, final assessment will be based on the highest-scoring 5 (of 6) assessments.

Students should file a Student Declaration of Absence form for missed lectures (maximum 2) to avoid penalty for the engagement grade.

### **Course Policies related to Academic Integrity**

Students are encouraged to work collaboratively in completing the assignments but all work submitted for evaluation must be done by the student[s] submitting it. For jointly submitted work, students will be required to submit an assessment of the contributions of each that will be used to weight the grade each receives.

Students are encourage to use AI, for writing any code required for data analysis. Publicly available code is available for specific analyses and students are encourage to test it. Use should be declared in submitting the assignments.

### **Learning Objectives**

On completion of the course, students should be able to provide critical assessments of temporal and spatial patterns of phytoplankton distributions, community composition, and productivity derived from satellite-, drone- or lab-based reflectance measurements; absorption, forward- or back-scattering, or transmission spectroscopy; single- channel, multiple-channel or hyperspectral fluorescence; flow cytometry; classified image analysis; and chlorophyll variable fluorescence.

## Course Content

Week	Unit	Topics	Assessments
1	1	<u>Introduction</u> Light properties (intensity, wavelength, polarization); UV-VIS-IR spectrum; energy- vs quantum-based measures of irradiance ( $E$ ) and radiance ( $L$ ); reflection & refraction (Snell's Law). Inherent and apparent optical properties (IOPs, AOPs; absorption, elastic and inelastic scattering, attenuation, reflectance)	
2	2	<u>Absorption</u> Spectral absorption by water, phytoplankton, non-algal particles, CDOM; optical density (OD), absorption coefficients, and specific absorption. Measurement techniques: dual-beam spectrophotometry, integrating spheres, absorption-tube instruments; measurements on dissolved vs particulate materials (pathlength enhancement, resorption, the filter-pad technique and beta correction.	1. Estimating and partitioning absorption in field samples (filter pad method and corrections)  Due Jan 20
3	3	<u>Elastic Scattering</u> Rayleigh vs Mie scattering; volume scattering function ( $b_b$ vs $b_r$ ); measuring total and angular scattering. Beam attenuation and van Hulst approximation of $Q_c$ : particle size estimation from LISST and $b_b$ ). Upwelling radiance and reflectance ( $R$ & $R_{rs}$ ) for material properties. Ocean colour: Forel-Ule and Jerlov classifications; multichannel and hyperspectral satellite remote sensing. Measurement techniques: Gershun tube and absorption-tube instruments; VSF detection ( $b_r$ and $b_b$ : LISST & back-scatter sensors.	
4	4	<u>Inelastic scattering</u> Raman scattering vs fluorescence; excitation and emission wavelengths & electron energy levels; Stokes and anti-Stokes shifts. Quantitation from fluorescence in silico: non-linearity in fluorescence vs concentration; solvent interactions and differences in specific absorption and emission; correction for interfering fluorophores; the internal filter effect; excitation/emission matrices (EEMs). Measurement techniques: Raman spectrometers; single-channel and hyperspectral fluorometers; fixed wavelength measurements vs excitation-emission matrices. Correcting Raman interference in fluorescence measurements; emission resorption and fluorescence quenching.	2. Particle size spectra (LISST); vertical profiles of $b_b$ ; spectral reflectance.  Due Feb 3

5	5	<p><u>Attenuation and the Submarine Light Environment</u>          Down-welling, up-welling, and diffuse radiance, irradiance, and attenuation.          Incident irradiance: insolation; direct and diffuse components of incident irradiance; zenith angle and atmospheric path length; spectral dependence of absorption (O<sub>3</sub>, O<sub>2</sub>, H<sub>2</sub>O) and Rayleigh scattering; Mie scattering; specular and diffuse reflection.          Modeling the attenuation coefficient: Lambert-Beer Law; zenith angle and refraction; spectral dependence of absorption in Case I and Case II waters (water, CDOM, phytoplankton, non-algal particles); accounting for magnitude of scattering, VSF, and Raman.          Proxies for [components of] attenuation: turbidity, CDOM fluorescence.          Measurement: Secchi discs; cosine vs 4π PAR sensors; spectroradiometers; reflectance-based [satellite] estimates; energy- vs quantum-based units.</p>	
6	6.1	<p><u>Biological Determinants of Bio-optical Signatures: Phytoplankton Fluorescence</u>          First-principles definition of spectral emission intensity: spectral absorption efficiency, quantum yield, and absorption and scattering by co-occurring optically active materials.          Co-operativity between fluorophores (Förster resonance energy transfer; FRET); photosynthetic and photoprotective accessory pigments (chlorophylls, carotenes, xanthophylls, phycobilins).          Acclimative pigment regulation in response to irradiance, temperature, and nutrient availability; pigment packaging effects on photosynthetic cross-sections and specific absorption; allometric relationships in specific absorption and back-scatter cross-sections.</p>	<p>3. Fluorometer calibration (acidification and non-acidification methods): quantifying standard concentration from specific absorption; defining limit of detection</p> <p>Due Feb 17</p>
7	6.2	<p><u>Biological Determinants of Bio-optical Signatures: Variations in Spectral Fluorescence</u>          Structure and diversity of photosynthetic units; genotypic vs phenotypic variation in photosystem architecture (phycobilisome vs LHC) and pigment composition.          Classification based on EEMs vs reduced (multichannel) excitation and/or emission; irradiance- and nutrient-dependence of pigment ratios and misclassification.</p>	
8	6.3	<p><u>Biological Determinants of Bio-optical Signatures: Variations in Quantum Yield 1</u>          Stern-Vollmer equation (photochemistry vs thermal dissipation vs fluorescence). Reaction centre closure as the basis of variable fluorescence; DCMU- vs E-based measurements; the OJIP transient and its interpretation.</p>	<p>4. Spectral attenuation coefficients; calculating PUR vs PAR. Rate constants for photodamage vs photorepair; calculating</p>

		D1 protein integrity and PSII functionality; kinetics of photodamage vs photorepair; Fv/Fm as a diagnostic of stress (critical role of blank selection at low biomass).	the depth-dependance of net damage.  Due Mar 10
9	6.4	<u>Biological Determinants of Bio-optical Signatures: Variations in Quantum Yields 2</u> Thermal dissipation as a protective mechanism (non-photochemical energy dissipation, NPQ); irradiance-dependence and balance between absorption and photochemistry. Definitions: NPQ vs qE, qI, qN etc. Direct dissipation: VAZ vs DD-DT xanthophyll cycles; de-epoxidation state; induction by lumen pH. Futile cycles: state transitions and the water-water cycle. <u>NPQ in darkness: chlororespiration and state transitions in cyanobacteria.</u>	
10	7	<u>Particle analysis</u> Transmission and interference imaging: brightfield, phase contrast, Normarski (differential interference contrast, DIC), and fluorescence microscopy; holographic microscopy. Autofluorescence and stains: metabolic and structural markers (FDA, SYBR, Nile Red, BODIPY). In situ particle imaging: silhouette (optical plankton counter, OPC); holographic microscopy; imaging cytometry and analogs (Flow Cytobot, Cytobuoy, FlowCam and Planktoscope).	5. Classifying cytometric data based on FALS, SS, F[λ]  Due Mar 24
11	8	<u>Data handling</u> Rate constants and attenuation coefficients: linear vs non-linear estimation and S:N Model fit and optimization for OJIP curves: model structure and evaluation (e.g. cooperativity in fluorescence induction curves – puddle vs lake models); bi- vs tri-linear fitting for relaxation kinetics Signature matching (absorption and fluorescence excitation or emission): 1 <sup>st</sup> -4 <sup>th</sup> -derivative analysis of peaks; Gaussian deconvolution; PARAFAC with EEMs; guided feature selection for discrimination Ordination and supervised vs unsupervised classification of multivariate data (cytometry and image analysis); Random Forest algorithm in feature selection and optimization	
OCEA 5421 only			
12	9	<u>Productivity modelling 1. The photosynthesis-irradiance-time response curve</u> Measurement techniques: O <sub>2</sub> exchange, <sup>18</sup> C/ <sup>16</sup> O exchange (MIMS), <sup>14</sup> C labelling; in situ, simulated in situ (deck-box and wheel) incubations; active fluorescence-based approaches	

		<p>The time-dependence of response: photosynthetic induction, xanthophyll cycle kinetics (inter-conversion and de novo synthesis); photoinhibition and photorepair kinetics</p> <p>Effect of acclimation to irradiance and temperature and nutrient stress on parameterization</p> <p>PvsE models: accounting for curvature at light saturation, accounting for rate reduction at supersaturating irradiance, biological weighting functions; intercept parameterization and the irradiance-dependence of respiration rates</p>	
12		<p><u>Productivity modelling 2: Time- and depth-dependance of productivity</u></p> <p>Vertical profiles of PUR: modelled as vertical attenuation of <math>E[\lambda]</math> via spectral <math>a[\lambda]</math> and <math>b[\lambda]</math>, with PUR as the convolution of <math>E[\lambda]</math> and <math>a[\lambda]</math>.</p> <p>Modeling vertical profiles of quantum yield from PvsE response curves and <math>a^{Chl}</math>.</p> <p>Modeling areal productivity from vertical profiles of net <math>P[z]</math>; Sverdrup revisited — compensation and critical depths integration over depth.</p> <p>Reduced models based on satellite- and in-water-based proxies for PvsE and <math>k</math>: Talling, Rodhe, and BZI models; semi-analytical models.</p>	<p>6. Modelling productivity in situ from measured and modelled incident irradiance via vertical profiles of PUR and quantum yield</p> <p>Due Apr 10</p>

## University Policies and Statements

### **Recognition of Mi'kmaq Territory**

Dalhousie University would like to acknowledge that the University is on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit or e-mail the Indigenous Student Centre at 1321 Edward St or [elders@dal.ca](mailto:elders@dal.ca). Additional information regarding the Indigenous Student Centre can be found at: [https://www.dal.ca/campus\\_life/communities/indigenous.html](https://www.dal.ca/campus_life/communities/indigenous.html)

### **Internationalization**

At Dalhousie, 'thinking and acting globally' enhances the quality and impact of education, supporting learning that is "interdisciplinary, cross-cultural, global in reach, and orientated toward solving problems that extend across national borders." Additional internationalization information can be found at: <https://www.dal.ca/about-dal/internationalization.html>

### **Academic Integrity**

At Dalhousie University, we are guided in all our work by the values of academic integrity: honesty, trust, fairness, responsibility, and respect. As a student, you are required to demonstrate these values in all the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity. Additional academic integrity information can be found at: [https://www.dal.ca/dept/university\\_secretariat/academic-integrity.html](https://www.dal.ca/dept/university_secretariat/academic-integrity.html)

### **Accessibility**

The Student Accessibility Centre is Dalhousie's centre of expertise for matters related to student accessibility and accommodation. If there are aspects of the design, instruction, and/or experiences within this course (online or in-person) that result in barriers to your inclusion, please contact the Student Accessibility Centre ([https://www.dal.ca/campus\\_life/academic-support/accessibility.html](https://www.dal.ca/campus_life/academic-support/accessibility.html)) for all courses offered by Dalhousie with the exception of Truro. For courses offered by the Faculty of Agriculture, please contact the Student Success Centre in Truro (<https://www.dal.ca/about-dal/agricultural-campus/student-success-centre.html>)

### **Conduct in the Classroom – Culture of Respect**

Substantial and constructive dialogue on challenging issues is an important part of academic inquiry and exchange. It requires willingness to listen and tolerance of opposing points of view. Consideration of individual differences and alternative viewpoints is required of all class members, towards each other, towards instructors, and towards guest speakers. While expressions of differing perspectives are welcome and encouraged, the words and language used should remain within acceptable bounds of civility and respect.

### **Diversity and Inclusion – Culture of Respect**

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness (Strategic Priority 5.2). Additional diversity and inclusion information can be found at: <http://www.dal.ca/cultureofrespect.html>

### **Student Code of Conduct**

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner - perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. The full Code of Student Conduct can be found at: [https://www.dal.ca/dept/university\\_secretariat/policies/student-life/code-of-student-conduct.html](https://www.dal.ca/dept/university_secretariat/policies/student-life/code-of-student-conduct.html)

### **Fair Dealing Policy**

The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie. Additional information regarding the Fair Dealing Policy can be found at: [https://www.dal.ca/dept/university\\_secretariat/policies/academic/fair-dealing-policy-.html](https://www.dal.ca/dept/university_secretariat/policies/academic/fair-dealing-policy-.html)

### **Originality Checking Software**

The course instructor may use Dalhousie's approved originality checking software and Google to check the originality of any work submitted for credit, in accordance with the Student Submission of Assignments and Use of Originality Checking Software Policy. Students are free, without penalty of grade, to choose an alternative method of attesting to the authenticity of their work and must inform the instructor no later than the last day to add/drop classes of their intent to choose an alternate method. Additional information regarding Originality Checking Software can be found at: <https://www.dal.ca/about/leadership-governance/academic-integrity/faculty-resources/original-plagiarism-detection.html>

### **Student Use of Course Materials**

Course materials are designed for use as part of this course at Dalhousie University and are the property of the instructor unless otherwise stated. Third party copyrighted materials (such as books, journal articles, music, videos, etc.) have either been licensed for use in this course or fall under an exception or limitation in Canadian Copyright law. Copying this course material for distribution (e.g. uploading to a commercial third-party website) may lead to a violation of Copyright law.