University of Victoria | Graduate Studies

# Notice of the Final Oral Examination for the Degree of Master of Science

of

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BSc (University of Victoria, 2013)
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## "Bio-optical Characterization of the Salish Sea, Canada Towards Improved Chlorophyll Algorithms for MODIS and Sentinel-3"

Department of Geography

Friday, December 11, 2015
2:00PM
David Turpin Building
Room B215

Supervisory Committee:
Dr. Maycira Costa, Department of Geography, University of Victoria (Supervisor)
Dr. David Atkinson, Department of Geography, UVic (Co-Supervisor)

External Examiner:
Dr. Eduardo Loos, ASL Environmental Sciences, Victoria, BC

Chair of Oral Examination:
Dr. Timothy Iles, Department of Pacific and Asian Studies, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

## Abstract

The goal of this research was to improve ocean colour chlorophyll *a* (Chl*a*) retrievals in the coastal Case 2 waters of the Salish Sea by characterizing the main drivers of optical variability and using this information to calibrate and validate empirical algorithms based on an optical classification. This was addressed with three specific objectives: (1) build a comprehensive spatio-temporal data set of *in situ* optical and biogeochemical parameters, (2) apply a hierarchical clustering analysis to classify above-water remote sensing reflectance (*Rrs*) and associated bio-optical regimes, (3) validate and optimize class-specific empirical algorithms for improved Chl*a* retrievals.

Measured i*n situ b*iogeochemcial and optical measurements, acquired at 145 stations, showed considerable variation; chlorophyll *a* (Chl*a*) (mean=1.64, range: 0.10 –7.20 μg□l-1), total suspended matter (TSM) (3.09, 0.82 – 20.69 mg□l-1), and absorption by chromophoric dissolved organic matter ($acd$(443)) (0.525, 0.007 – 3.072 m-1), thus representing the spatial and temporal variability of the Salish Sea. Optically, a comparable range was found; particulate scattering ((650)) (1.316, 0.250 – 7.450 m-1), particulate backscattering ($bbp$(650)) (0.022, 0.005 – 0.097 m-1), total beam attenuation coefficient ($ct$(650)) (1.675, 0.371 – 9.537 m-1) and particulate absorption coefficient ($ap$(650)) (0.345, 0.048 – 2.020 m-1). Empirical orthogonal function (EOF) analysis revealed 95% of the *Rrs* variance was highly correlated to $bp$ (r = 0.90), $bbp$ (r = 0.82) and TSM concentration (r = 0.80), emphasizing the strong influence of riverine systems in this region. Hierarchical clustering on the normalized *Rrs* revealed four spectral classes. Class 1 is defined by high overall *Rrs* magnitudes in the red, indicating more turbid waters, Class 2 showed high *Rrs* values in the red and well defined fluorescence and absorption features, indicated a high Chl*a* and TSM presence, Class 3 showed low TSM influence and more defined Chl*a* signatures and Class 4 is characterized by overall low *Rrs* values, suggesting more optically clear oceanic waters. Spectral similarities justified a simplification of this classification into two dominant water classes, (1) estuarine class (Classes 1 and 2), (2) oceanic class (Classes 3 and 4), representing the dominant influences seen here.

*In situ* Chl*a* and above-water remote sensing reflectance measurements, used to validate and parameterize the OC3M/OC3S3, two-band ratio, FLH and modified FLH (ModFLH) empirical algorithms, showed a systematic overestimation of low Chl*a* concentrations and underestimation of higher Chl*a* values for all four algorithms when tuned to regional data. FLH and ModFLH algorithms performed best for this data (*R2* ~ 0.40; *RMSE* ~ 0.32). Algorithm accuracy was significantly improved for the class-specific parametrizations with the two-band ratio showing a strong correlation to the Chl*a* concentrations in the estuarine class (*R2* ~ 0.71; *RMSE* ~ 0.33) and the ModFLH algorithm in the oceanic class (*R2* ~ 0.70; *RMSE* ~ 0.26). These results demonstrated the benefit of applying an optical classification as a necessary first step into improving Chl*a* retrievals from remotely sensed data in the contrasted coastal waters of the Salish Sea. With accurate Chl*a* information, the health of the Salish Sea can be viably monitored at spatial and temporal scales suitable for an ecosystem based approach.