CyanoSCape

Freshwater Phytoplankton and Floating Aquatic Vegetation Biodiversity of the South African Cape

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Abstract

In Southern Africa, the impacts of anthropogenic activities on biodiversity and ecosystem services are exacerbated by the climate crisis. Rapid land use change and the lack of emphasis on environmentally sustainable agricultural practices has hindered hydrological processes and compromised riverine and aquatic ecosystems. This poses obvious risks to natural/indigenous aquatic biodiversity and long-term ecosystem sustainability. Phytoplankton serve as the foundation of the freshwater food web. The diversity of phytoplankton includes photosynthesizing bacteria (cyanobacteria), plant-like diatoms, dinoflagellates, and green algae. Nutrient run-off from agricultural fertilizers and urban overflows, warm temperatures, abundant light availability and compromised hydrological systems provide an ideal environment for cyanobacteria to flourish and can incur significant effects on the biodiversity of the overall phytoplankton assemblage. These conditions also provide a favorable environment for the overgrowth of floating aquatic vegetation (FAV), which is often invasive and associated with reduced aquatic biodiversity.

The algal biodiversity of the GCFR's freshwater systems is not well characterized. Hyperspectral optical observations (e.g, BioSCape campaign) are expected to facilitate the improvement of current phytoplankton diversity, as the sensitivity is sufficient that the distinctive, fine spectral features of different phytoplankton groups can be detected. This will enable testing emerging algorithms and inform the development of new algorithms for use with upcoming hyperspectral satellite missions in this decade.

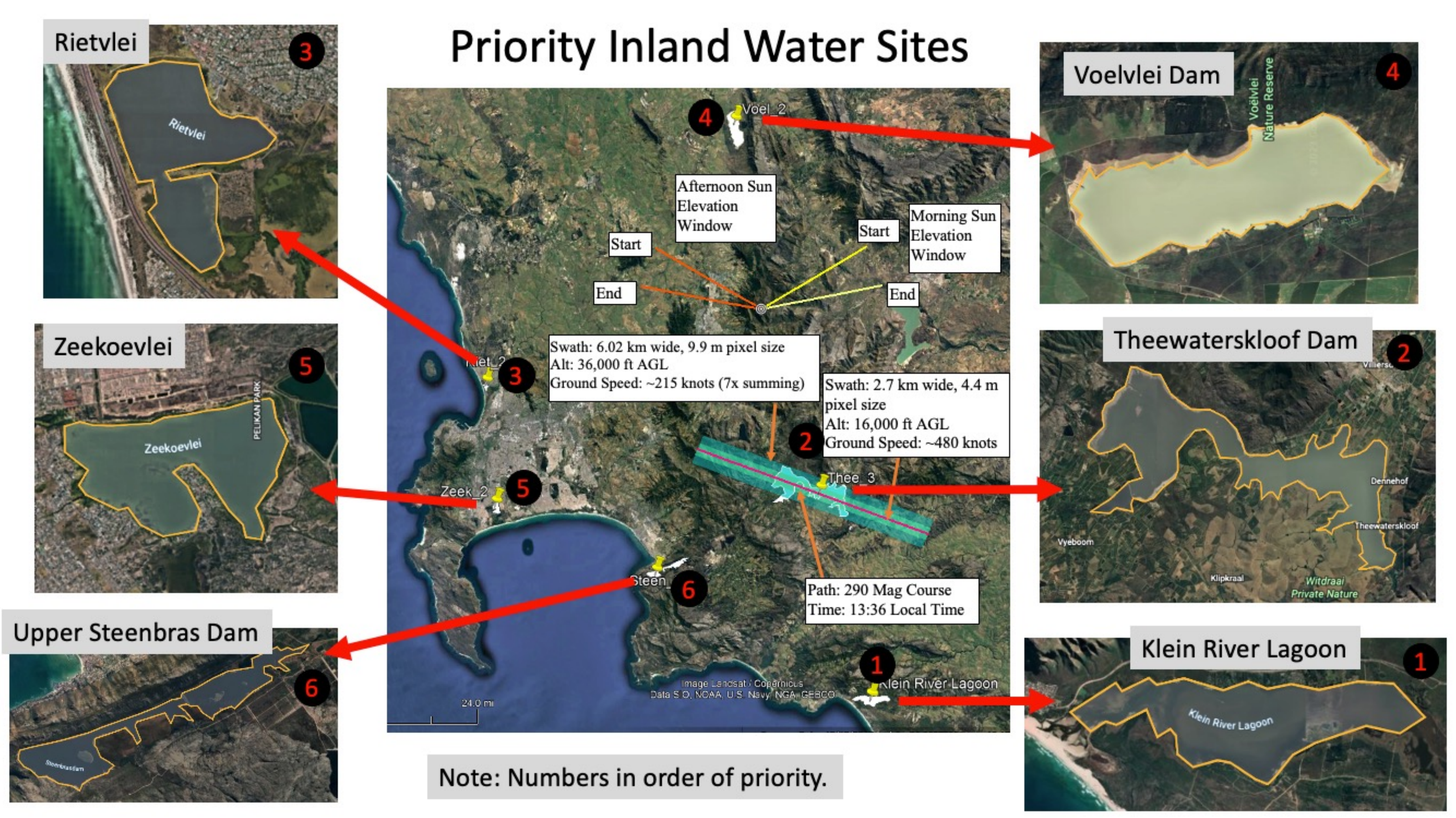
Innovations in optical sensor sensitivity and next generation machine learning capabilities considerably enhance the potential for accurate and rapid detection of phytoplankton, presence, extent, and diversity and additionally, invasive FAV.

Goal & Objectives

Utilize hyperspectral data with recently developed and next-generation algorithms to:

- **Determine the biodiversity of freshwater systems phytoplankton assemblages** with emphasis on phytoplankton functional type (PFT) level distinction, including potentially toxic cyanobacteria and…
- **Monitor the prevalence and diversity of (floating aquatic vegetation) FAV** that favor these environments.

Study Sites



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Methods

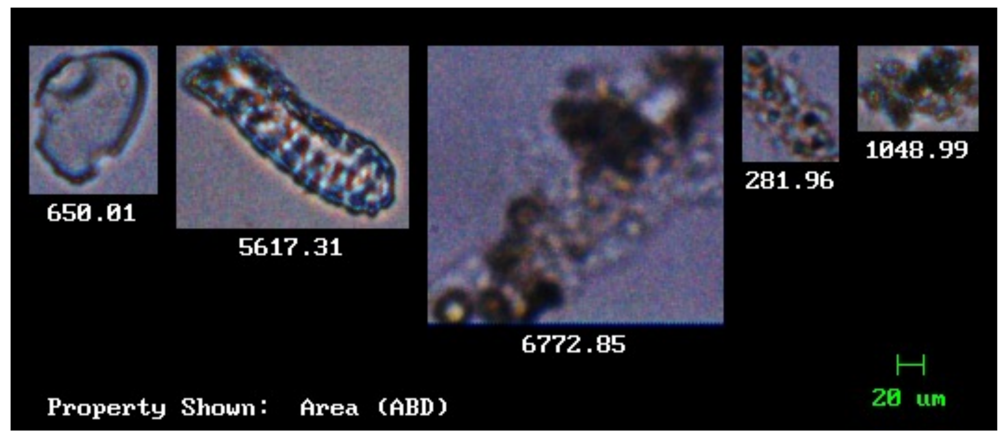
1. Community composition
Characterize phytoplankton composition and FAV diversity of example freshwater systems through aligned field spectroscopy, water sample collection, temperature, microscopy, and HPLC analysis

2. Aligned field radiometry and optics with airborne observations
Collect field radiometric and bio-optical data coincident with airborne imagery for assessment of radiometric integrity of atmospherically corrected surface reflectance over productive waters

3. Forward modeling and deep learning
Bio-optical and Radiative Transfer Modeling will produce a state-of-the-art synthetic dataset simulating diverse optical conditions of inland waters to train an emulator for high-fidelity water quality retrievals, PFT contribution, and FAV discrimination, including well calibrated uncertainties.

4. Airborne mapping
Application of published and next-generation algorithms to airborne PRISM and AVIRIS-NG for phytoplankton and FAV discrimination and spatial distribution

5. Phytoplankton phenology
Historic seasonality of phytoplankton, FAV, and meteorology with past/current multispectral observations (Landsat, Sentinel, MODIS) and opportunistic satellite matchup collection during airborne campaign



Bottom: Example invasive FAV found in Hartbeespoort Dam, SA. Top: Example phytoplankton community found in irrigation canals and farm dams of Hartbeespoort Dam. Harmful cyanobacteria can be identified using FlowCam microscopy (from left to right: *Anabaena* [650.01]; Dinoflagellate spp. [5617.31]; *Microcystis* [6772.85, 281.96, 1048.99]. Photos: Univ. of Venda.

Preliminary Testing and Modeling (Kravitz et al.)

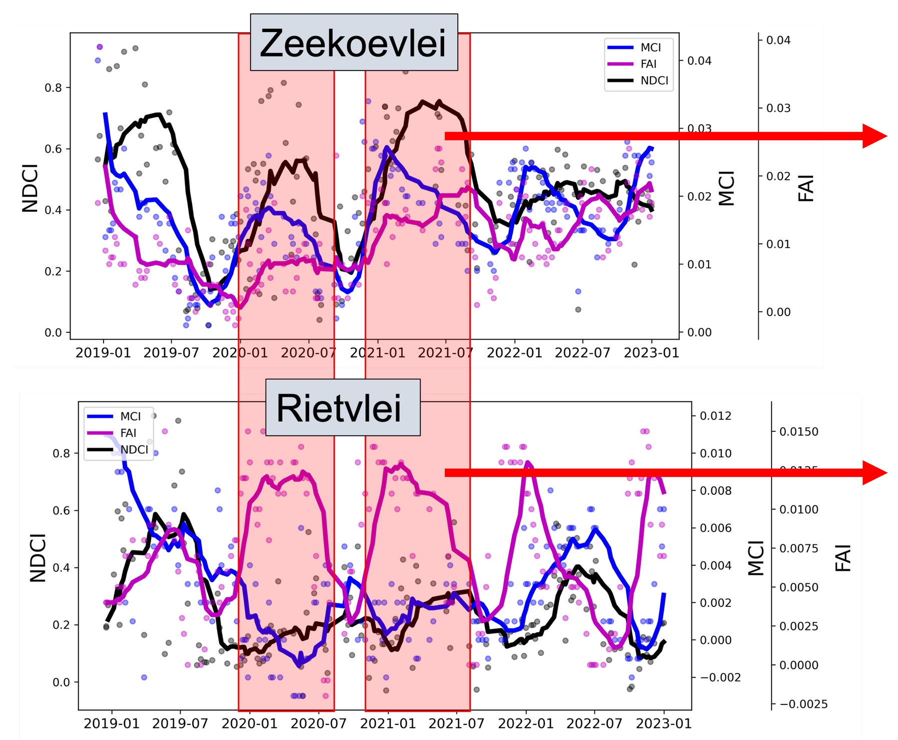
4 – Year Timeseries of SA sites

Normalized Difference Chlorophyll Index (NDCI) | Maximum Chlorophyll Index (MCI) | Floating algal Index (FAI)

$$\mathrm{NDCI} = \frac{\text{Red edge 1} - \text{Red}}{\text{Red edge 1} + \text{Red}}$$

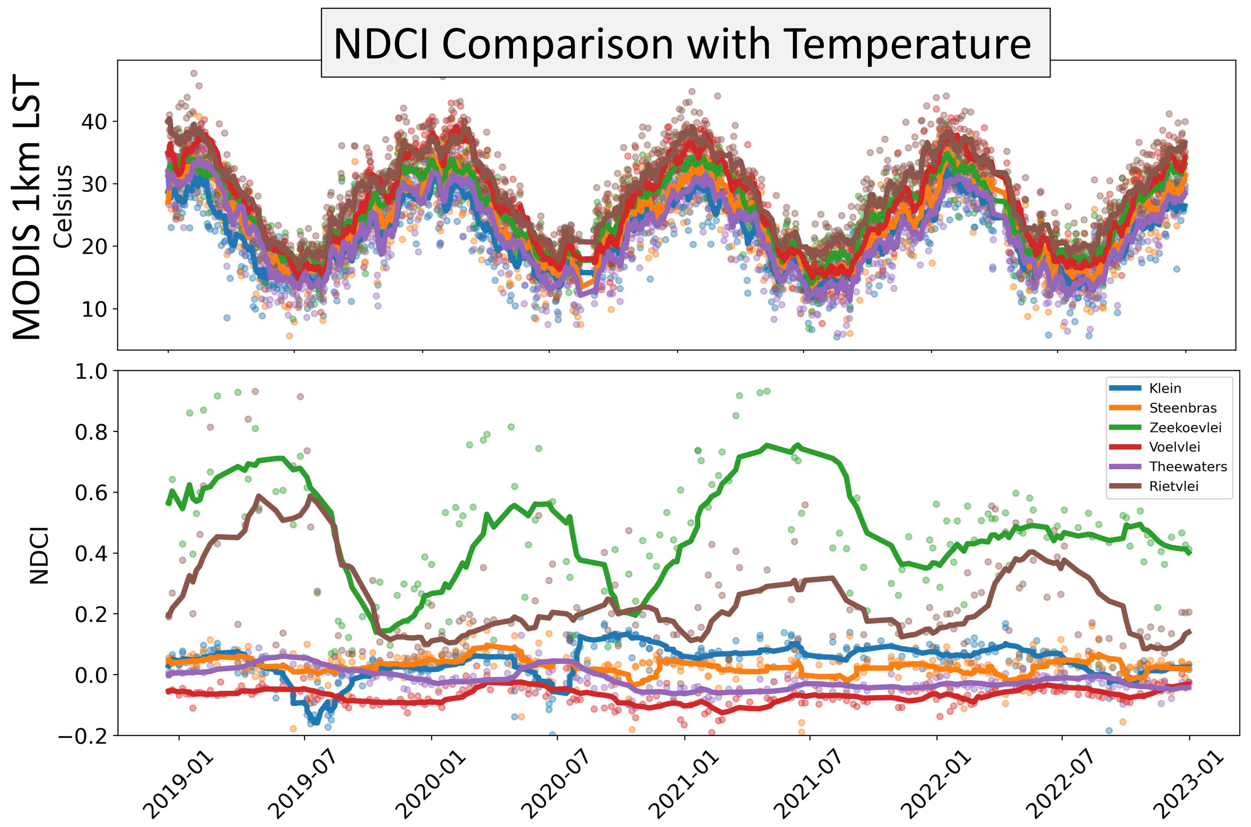
MCI bands : B4, B5, B6
FAI bands : B4, B6, B8

$$\mathrm{Chl-a} \propto R(\lambda_2) - R(\lambda_1) + \left(R(\lambda_1) - R(\lambda_3)\frac{(\lambda_2 - \lambda_1)}{(\lambda_3 - \lambda_1)}\right)$$



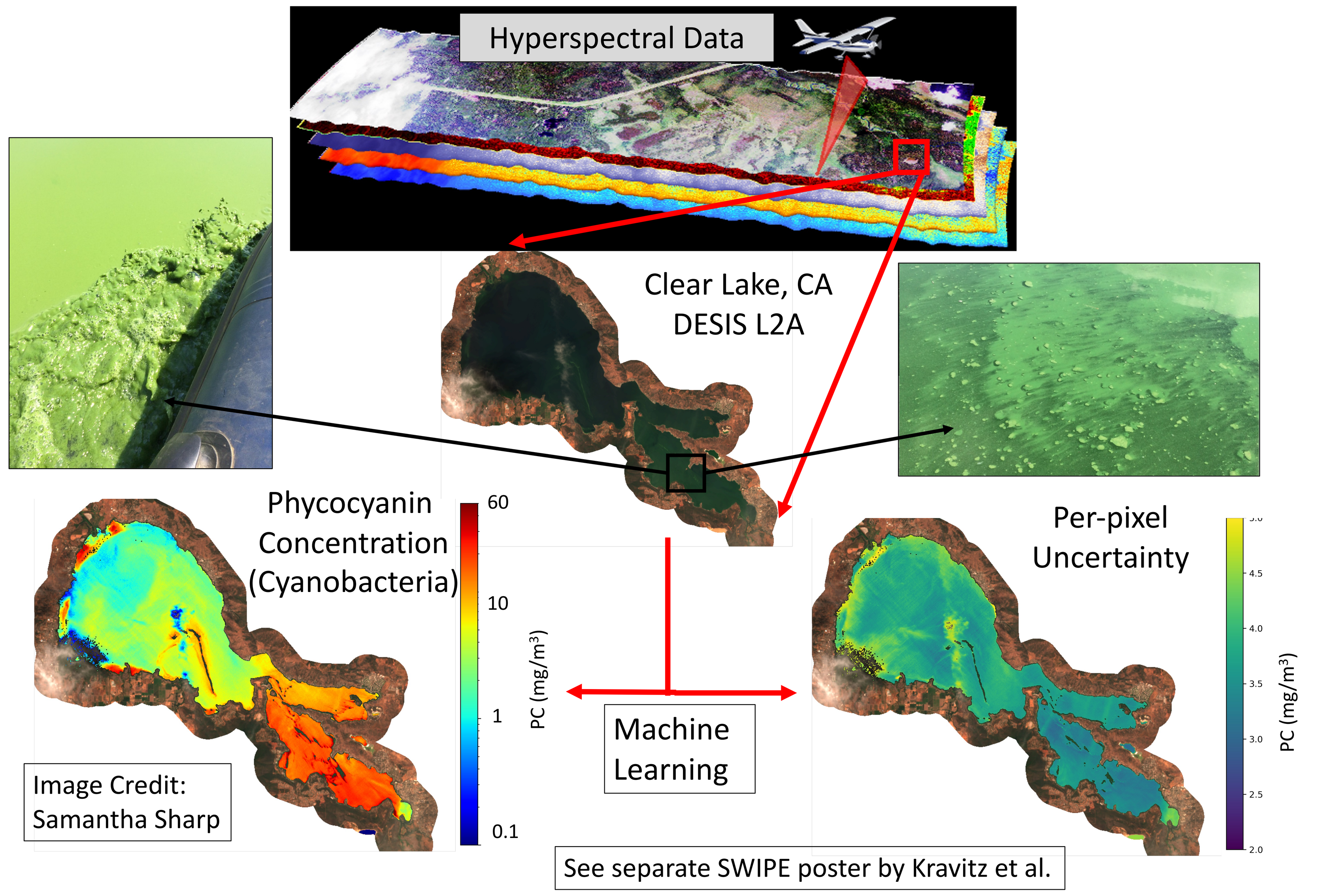
Algal blooms during and after the hot summer months and receding into the rainy winter season

FAI only bloom could imply floating vegetation or benthic influence from water level change



3-4 Month Latent effect from temp peak to bloom peak

Spectral Water Inversion Processor and Emulator (SWIPE)



- Radiative Transfer Modeling will produce a synthetic dataset to train an emulator to output Phytoplankton Functional Type (PFT) products
- Machine learning and artificial neural network will be used for Phytoplankton Class/PFT level
- Additionally mapping floating aquatic vegetation and connection with cyanobacteria blooms