CyanoSCape Freshwater Phytoplankton Biodiversity

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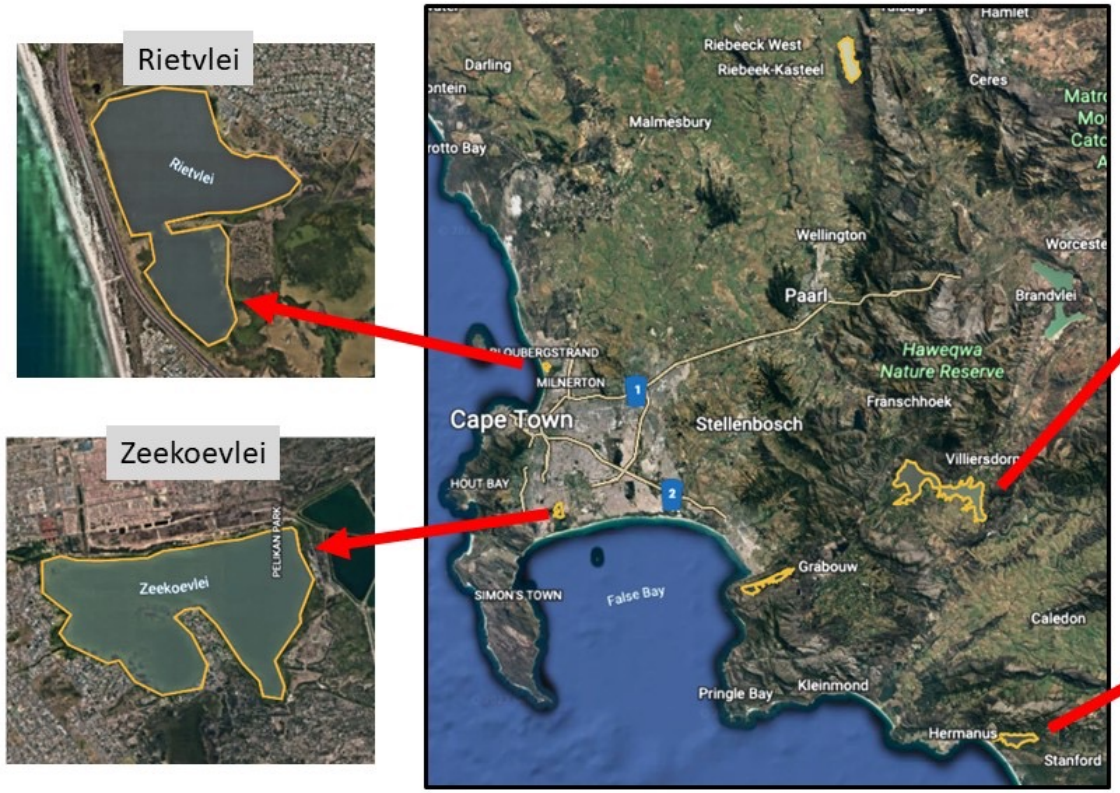
Goal: Utilize hyperspectral data with recently developed and next-generation algorithms to: Determine the biodiversity of freshwater systems phytoplankton assemblages with emphasis on phytoplankton functional type (PFT) level distinction, including potentially toxic cyanobacteria.



NASA Ames Research Center

CSIR Touching lives through innovation

University of Venda Creating Future Leaders

BioSCape Biodiversity Survey of the Cape

CyanoSCape Freshwater Phytoplankton Biodiversity

Challenges:

- The **phytoplankton biodiversity of SA freshwater systems is not well characterized**.
- Anthropogenic practices have hindered hydrological processes and **compromised riverine and aquatic ecosystems**.
- These impacts are compounded by the effects of **increasingly variable rainfall and temperature fluctuations** associated with climate change.
- The biodiversity of **freshwater phytoplankton includes cyanobacteria, some that are harmful**.
- The increased incidence of cyanobacteria and harmful bloom conditions is related to **nutrient over-enrichment from agriculture, urban, and industrial practices and climate change**.
- **Harmful cyanobacteria can produce toxins** (e.g., Microsystin) that cause hepatoxic (liver disease) and neurotoxic effects in humans and animals and can lead to mortality.

CyanoSCape Goal, Objectives/Methods

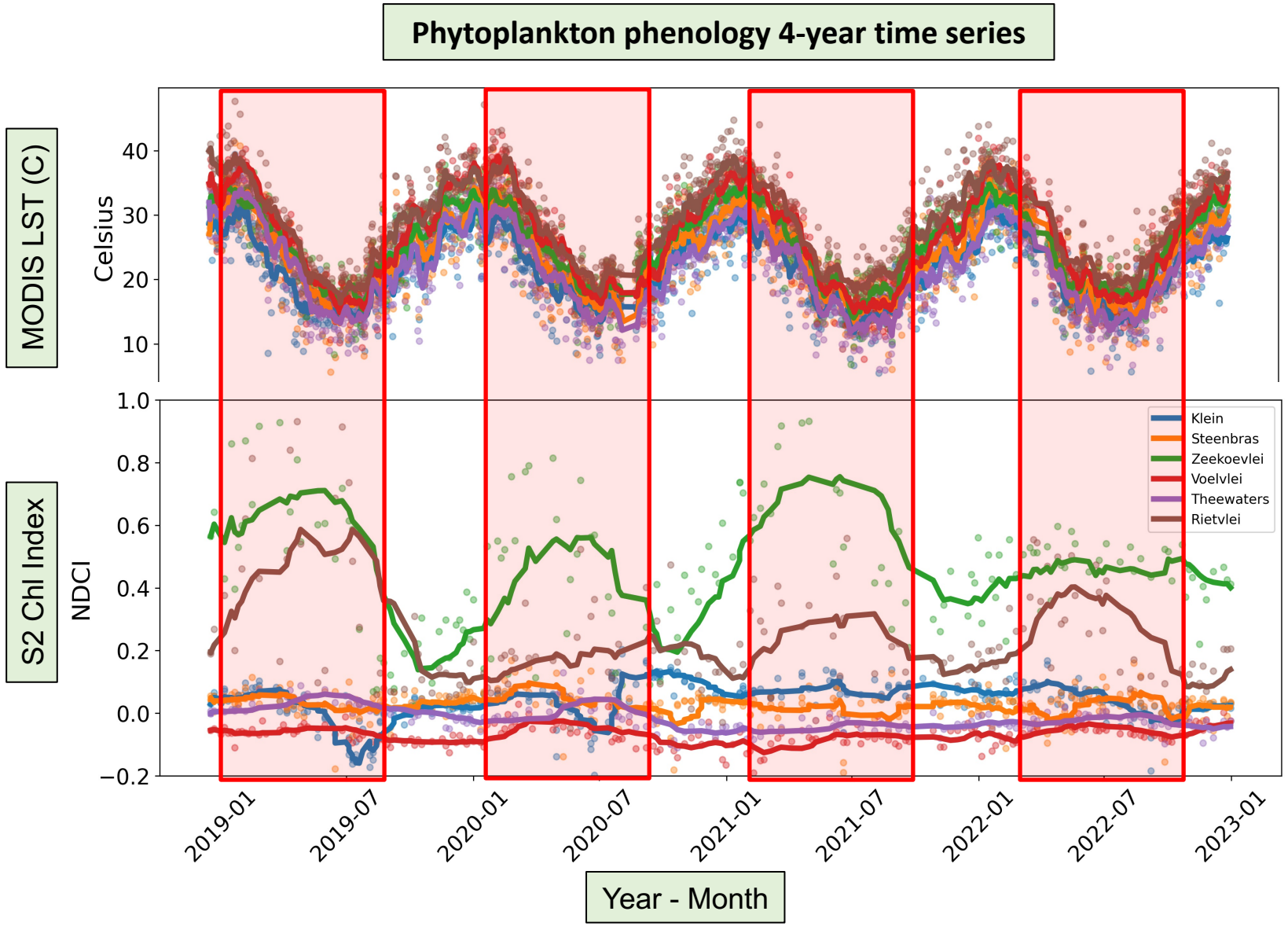
Goal: Utilize hyperspectral data with recently developed and next-generation algorithms to:

- **Determine the biodiversity of freshwater systems phytoplankton assemblages** with emphasis on phytoplankton functional type (PFT) level distinction, including potentially toxic cyanobacteria.

Objectives/Methods:

1. **Phytoplankton community composition**
   Characterize phytoplankton composition/diversity of example freshwater systems through aligned field spectroscopy, water sample collection, temperature, microscopy, and HPLC analysis
2. **Aligned field radiometry and optics coincident 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, phytoplankton functional type contribution, including well calibrated uncertainties.
4. **Airborne mapping**
   Application of published and next-generation algorithms to airborne PRISM and AVIRIS-NG for phytoplankton discrimination and spatial distribution
5. **Phytoplankton phenology**
   Historic seasonality of phytoplankton and meteorology with past/current multispectral observations (Landsat, Sentinel, MODIS) and opportunistic satellite matchup collection during airborne campaign

Land Surface Temperature and Chlorphyll Index Analysis

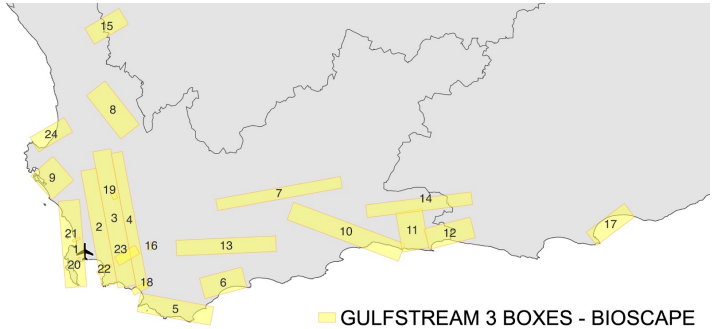


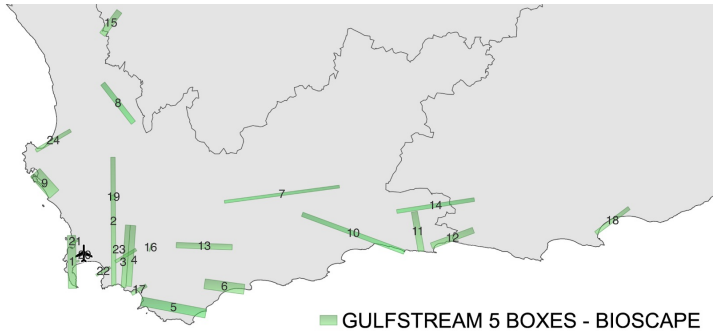
- Four-year time series of Normalized Difference Chlorophyll Index (NDCI), plotted with MODIS Land Surface Temperature (LST) product at each CyanoSCape site
- Algal blooms peak ~3 months after LST peaks at most productive sites
- Most productive sites are those closest to the Cape Town metropolitan area

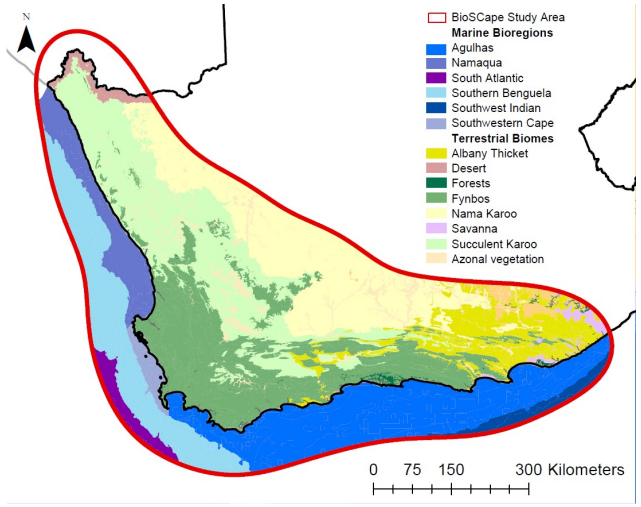
BioSCape Field Campaign (Oct-Nov 2023)

CyanoSCape:

- Successful field campaign with ~22 days of data collected (airborne/satellite coincident with field data).
- 11 (G-III) flights included CyanoSCape study sites.
- CyanoSCape's Theewaterskloof Dam site - BioSCape Cal/Val with hyperspectral radiometer buoy and thermal ring.







G-V	LVIS	Land, Vegetation, and Ice Sensor (Laser Altimeter)
G-V	HyTES	Hyperspectral Thermal Emission Spectrometer
G-III	PRISM	Portable Remote Imaging Spectrometer
G-III	AVIRIS-NG	Airborne Visible-Infrared Imaging Spectrometer (NextGen)

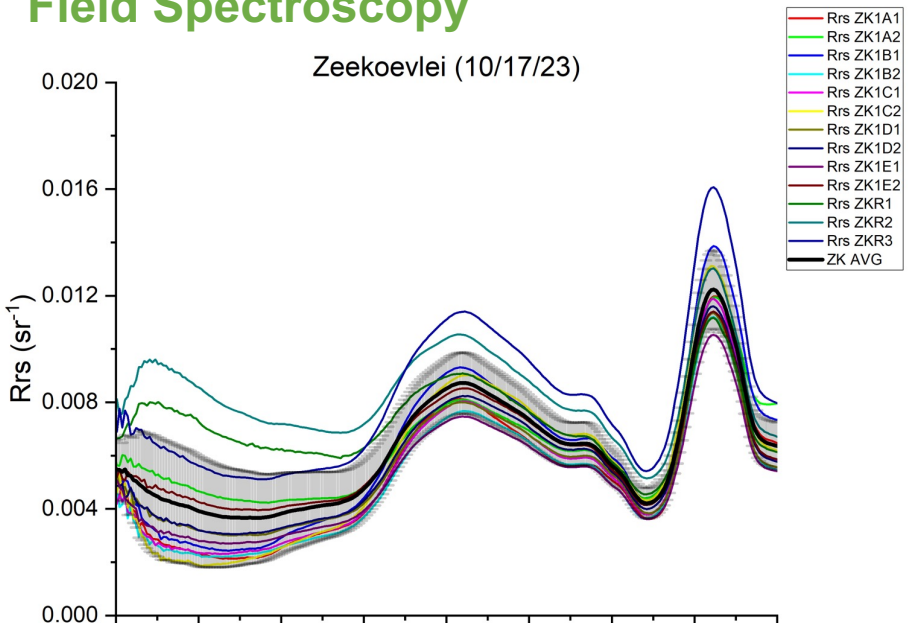
a b c d

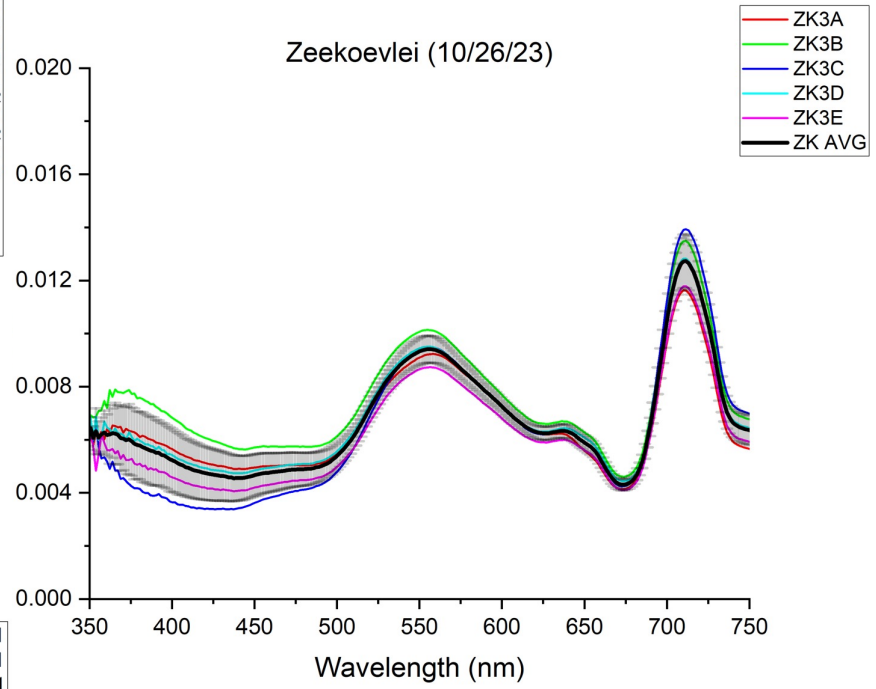
a: Field radiometry collection at Theewaterskloof Dam by Ryan O'Shea (GSFC) and Lisl Lain (CSIR).
b: Field radiometry collection at Rietvlei by Jeremy Kravitz (SGE) skippered by Samantha Sharp (SGE).
c: Glynn Pindihama and Rabe Mudzielwana, filtering water samples at CSIR.
d: CyanoSCape team contemplating ac-s operations at CSIR.
Photos: S. Sharp, H. Pillay, L. Guild

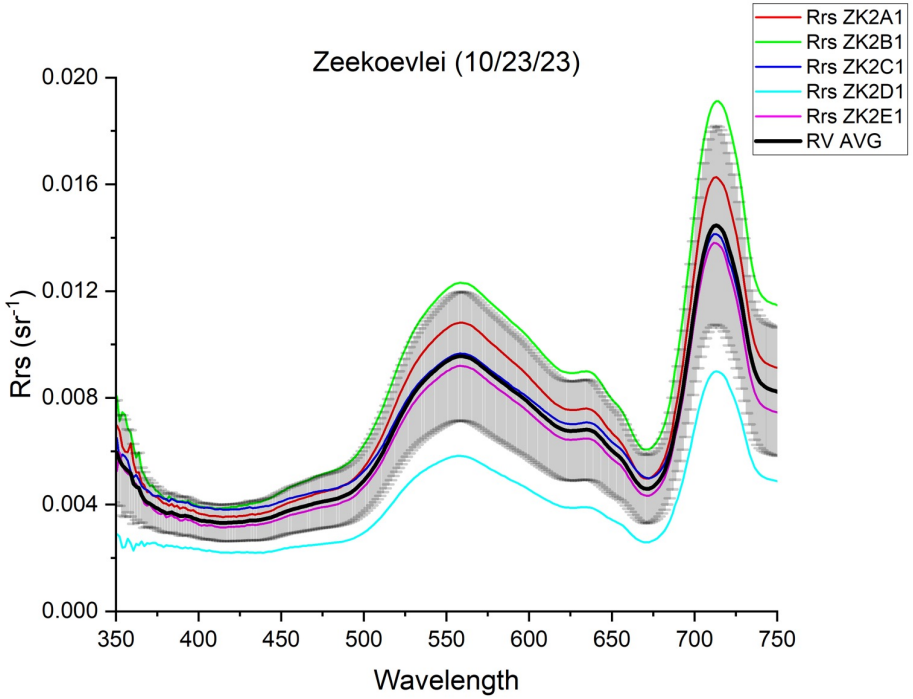
				Airborne		Satellite
Date	Site	Stations	Radiometry	AVIRIS-NG	PRISM	
10/17/2023	Zeekoevlei	A-E	✓ - Spectra Vista			OLCI-S3A/S3B
10/20/2023	Theewaterskloof Dam	A (Buoy)	✓ - Spectral Evolution			
10/23/2023	Zeekoevlei	A-E	✓ - Spectral Evolution + Spectra Vista			DESIS
10/23/2023	Klein River Lagoon, Rietvlei					DESIS
10/26/2023	Zeekoevlei	A-E	✓ - Spectra Vista	✓	✓	
10/26/2023	Rietvlei	A-E	✓ - Spectral Evolution + TriOS Ramses	✓	✓	
10/27/2023	Klein River Lagoon, Rietvlei, Theewaterskloof		✓ - TriOS Ramses on Theewaterskloof Bouy only			DESIS
10/27/2023	Theewaterskloof Dam		✓ - TriOS Ramses on Theewaterskloof Bouy			PRISMA
10/29/2023	Theewaterskloof Dam	A-C, + A (buoy)	✓ - Spectral Evolution + TriOS Ramses + Spectra Vista	✓	✓	
10/31/2023	Klein River Lagoon, Rietvlei, Zeekoevlei					DESIS
11/2/2023	Theewaterskloof Dam		✓ - TriOS Ramses on Theewaterskloof Bouy			PRISMA
11/4/2023	Rietvlei, Zeekoevlei					EMIT
11/5/2023	Rietvlei	A-E	✓ - Spectral Evolution + TriOS Ramses + Spectra Vista			OLCI-S3A/S3B
11/8/2023	Klein River Lagoon	A-E	✓ - TriOS Ramses + Spectra Vista	✓	✓	DESIS
11/8/2023	Theewaterskloof Dam	A-D	✓ - Spectral Evolution + TriOS Ramses (Buoy)	✓	✓	DESIS
11/9/2023	Rietvlei	A-C	✓ - Spectral Evolution + Spectra Vista	✓	✓	
11/10/2023	Theewaterskloof Dam	A (Buoy)	✓ - Spectral Evolution + TriOS Ramses (Buoy)	✓	✓	
11/11/2023	*Theewaterskloof Dam*	*A (Buoy)*	✓ - TriOS Ramses on Theewaterskloof Buoy	✓	✓	
11/13/2023	Theewaterskloof Dam		✓ - TriOS Ramses on Theewaterskloof Buoy			PRISMA
11/14/2023	Theewaterskloof Dam	A (Buoy)	✓ - TriOS Ramses on Theewaterskloof Buoy	✓	✓	
11/14/2023	Rietvlei, Zeekoevlei					PRISMA
11/17/2023	Rietvlei					EMIT
11/17/2023	Rietvlei, Zeekoevlei					DESIS
11/17/2023	Theewaterskloof Dam		✓ - TriOS Ramses on Theewaterskloof Buoy	✓	✓	
11/19/2023	Theewaterskloof Dam		✓ - TriOS Ramses on Theewaterskloof Buoy			PRISMA
11/21/2023	Rietvlei, Zeekoevlei					EMIT
11/22/2023	Theewaterskloof Dam		✓ - TriOS Ramses on Theewaterskloof Buoy	✓	✓	
11/25/2023	Rietvlei, Theewaterskloof, Zeekoevlei		✓ - TriOS Ramses on Theewaterskloof Bouy only			EMIT
11/25/2023	Zeekoevlei					DESIS
11/25/2023	Theewaterskloof Dam		✓ - TriOS Ramses on Theewaterskloof Bouy			PRISMA

Photo credit: S. Sharp.

Field Spectroscopy





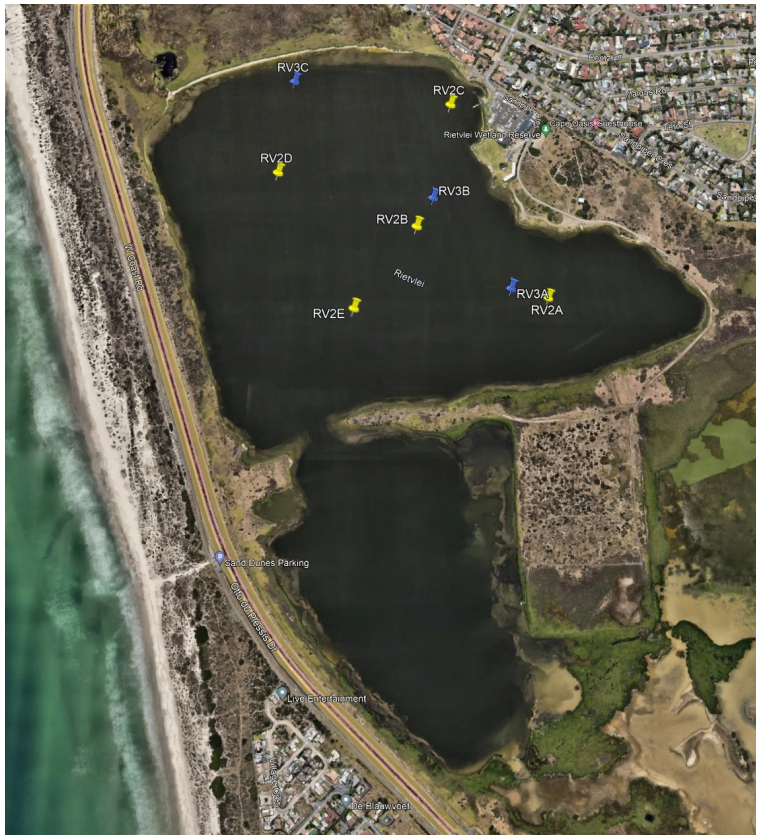


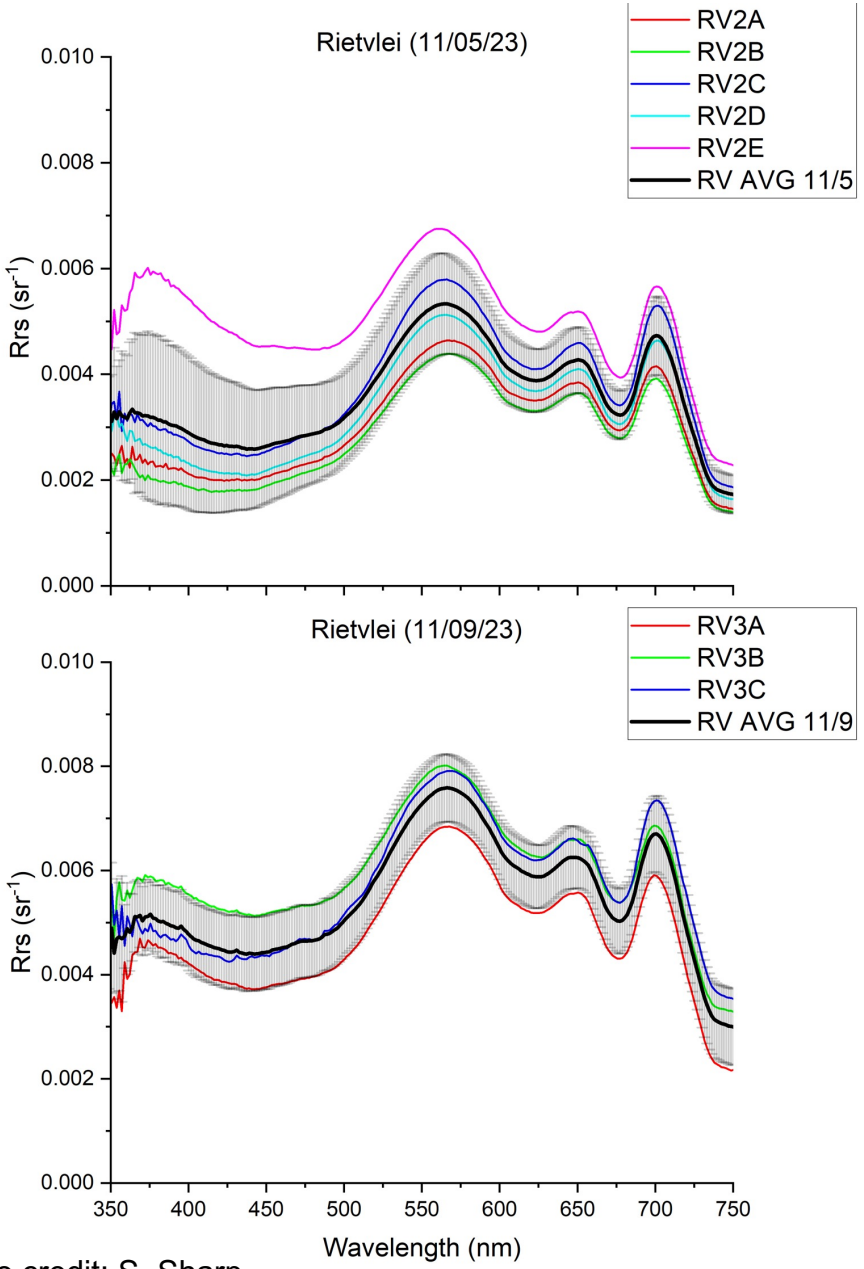
Zeekoevlei – urban wetland.

High phytoplankton – note how green it is! Still awaiting water sample results.

709 nm peaks indicative of **very** high chlorophyll concentrations.
650 nm bump is a typical high bio tension between absorption and backscatter, with pigment absorption "fighting" against both size- and biomass-driven backscatter features.

Field Spectroscopy





Rietvlei – natural freshwater site adjacent to wetland.

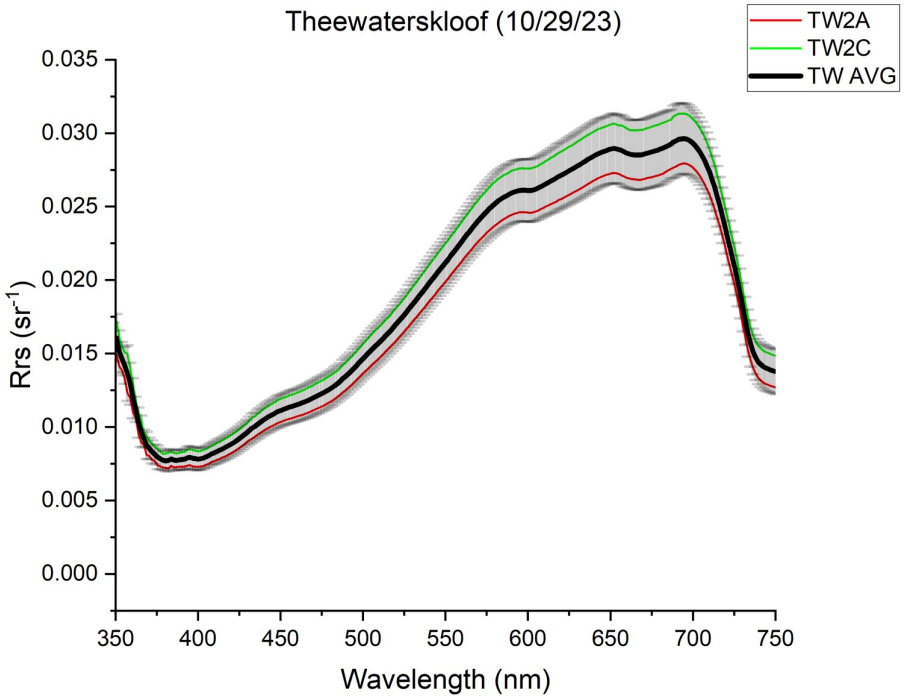
Clear water with benthic plants visible on the bottom.

Suspecting CDOM presence but awaiting water sample results.

Nothing definitive without pigment data results just yet.

Photo credit: S. Sharp.

Field Spectroscopy



Theewaterskloof Dam – Provides most of the water supply for Cape Town.

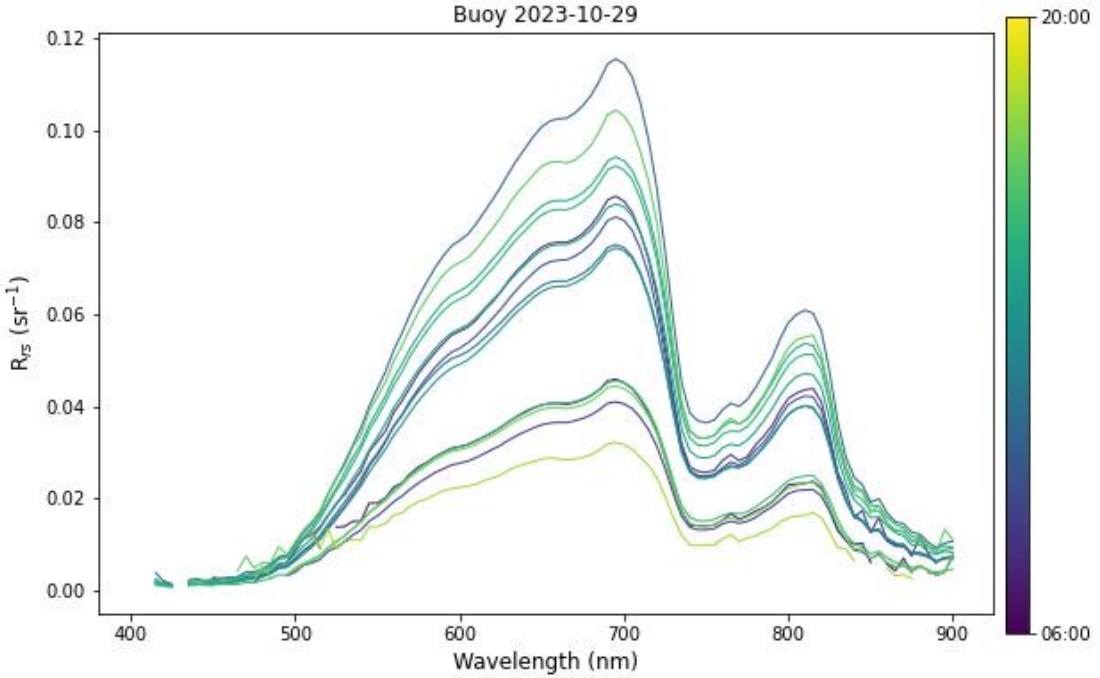
Heavy rains at the end of September 2023 prior to the field campaign, high sediment loading was visible.

Left: CSIR TriOS RAMSES (hyperspectral) buoy with additional TriOS RAMSES and Spectral Evolution radiometers. The money shot!

Photo credit: S. Sharp.

- Gizmo: CSIR hyperspectral radiometry buoy with TriOS Ramses instrument at Theewaterskloof Dam
- JPL thermal ring for HyTES cal/val

Theewaterskloof Dam. Photo credit: S. Sharp.



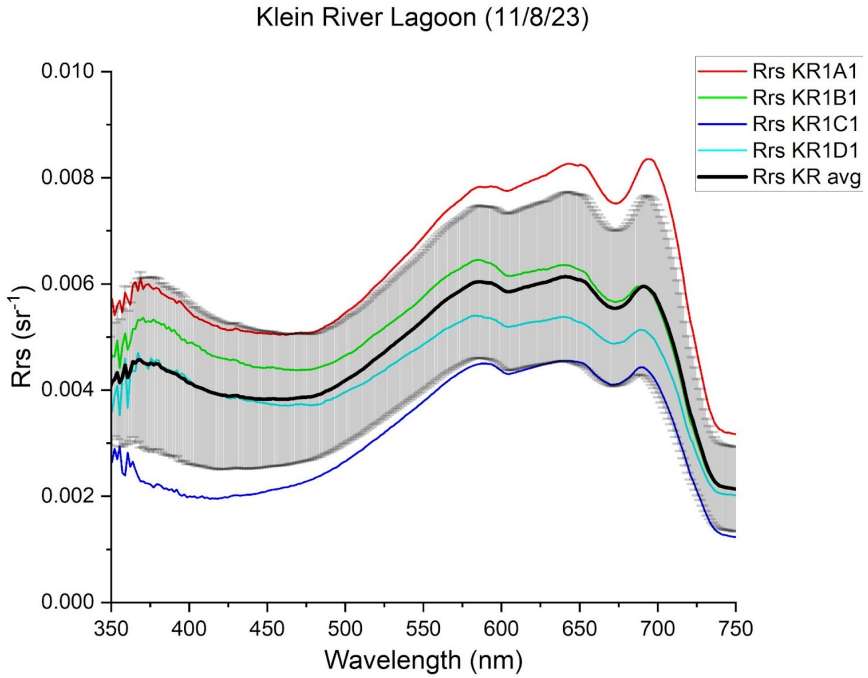
Hourly hyperspectral radiometry from Gizmo.

Scale from Blue (morning) to Yellow late in the day.

At least 41 days of data from 10/17/2023 to 11/29/2023

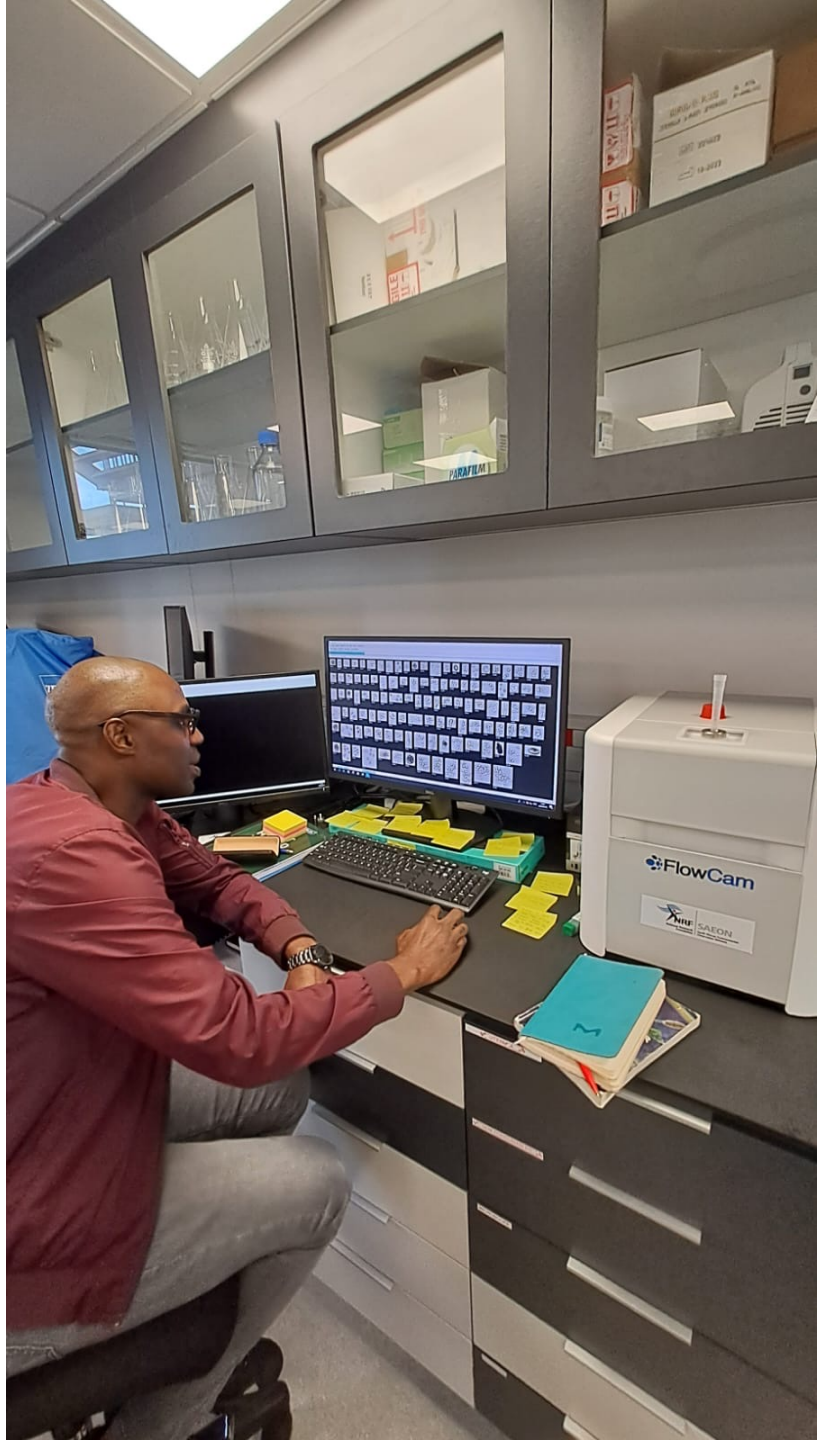
Mouth of the lagoon was open during the campaign as seen in the Sentinel 2 image.

Field Spectroscopy



Klein River Lagoon - Natural estuary site, with varying brackish levels depending on distance upstream from Walker Bay and tidal dynamics.

Photo credit: L. Guild.



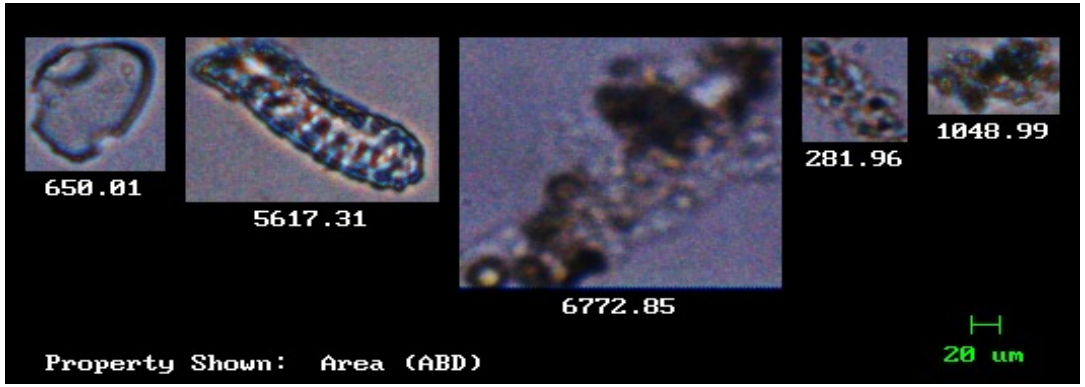
Laboratory

University of Venda – Flow imaging microscopy (FlowCam)

Phytoplankton identification (including cyanobacteria) and enumeration.

Glynn Pindihama and Rabe Mudzielwana have just started work processing water samples with the FlowCam!

CyanoSCape Next Steps



- Field spectral data processing
  - Spectral Evolution
  - TriOS RAMSES
  - Gizmo TriOS RAMSES from CSIR Buoy
- Water sample processing
  - Pigments – HPLC at GSFC
  - CDOM - CUNY
  - Nutrients, etc. at SAEON in the processing queue
- University of Venda – Flow imaging microscopy (FlowCam)
  - Phytoplankton identification (including cyanobacteria) and enumeration.
- AVIRIS-NG data downloaded, processing…..
- Modeling: Spectral Water Inversion Processor and Emulator (SWIPE) for phytoplankton biodiversity

Thanks!

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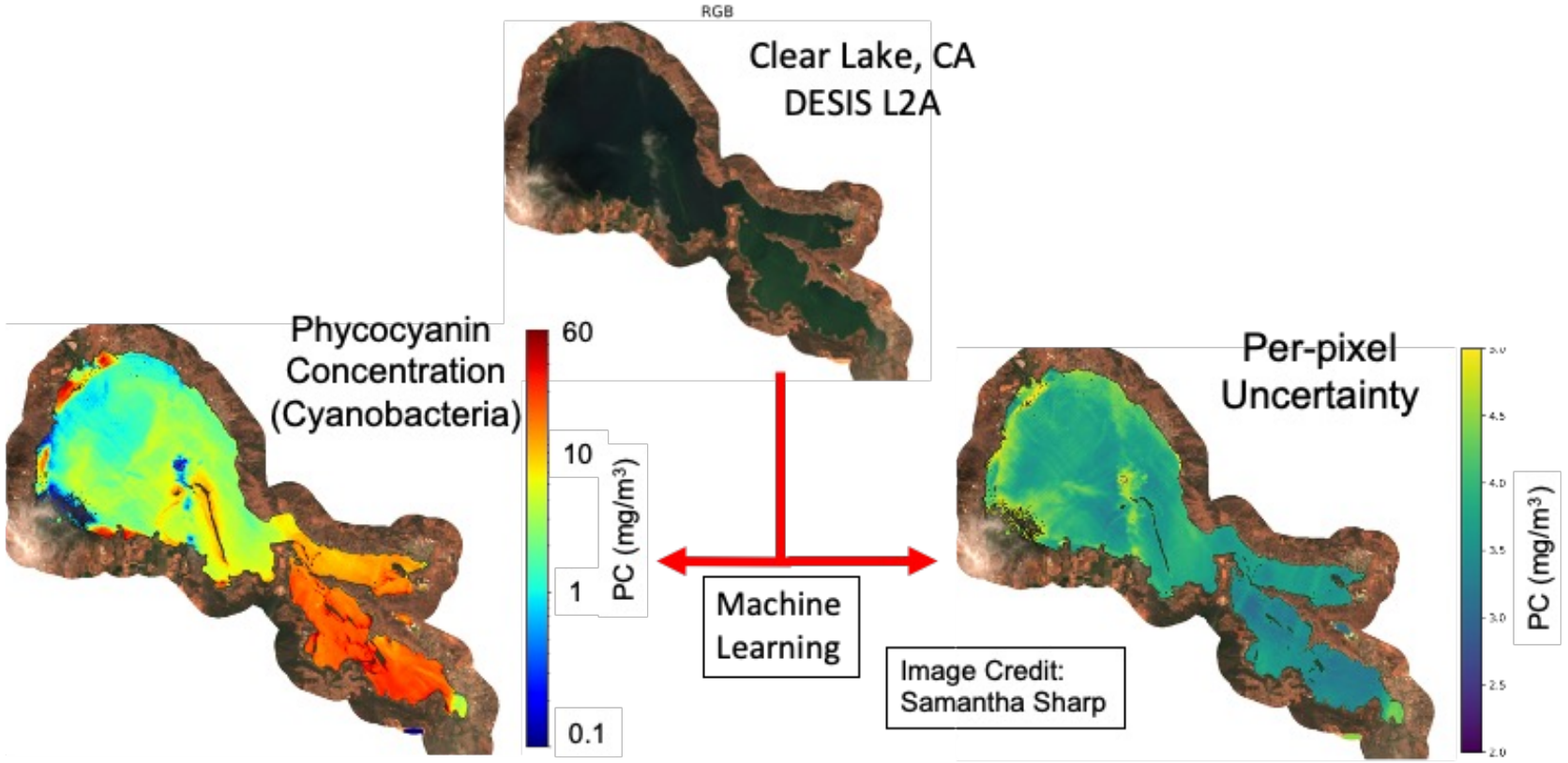
Test Site Clear Lake, California
Synthetic data and deep learning for fast, accurate hyperspectral retrievals with uncertainty

NASA Fellow - Samantha Sharp, PhD Project Site, UC Davis



- Jeremy Kravitz' Spectral Water Inversion Processor and Emulator (SWIPE), sensor agnostic processor.
- SWIPE: multi-faceted modeling platform for both **forward and inverse modeling of diverse aquatic ecosystems from the benthos to top-of-atmosphere** (TOA).
- SWIPE provides a cohesive application which leverages recent advancements in **particle modeling, Big Data analytics, and machine learning** to develop a high-fidelity synthetic training ground for sensitivity studies and algorithm development for multispectral or upcoming hyperspectral missions.