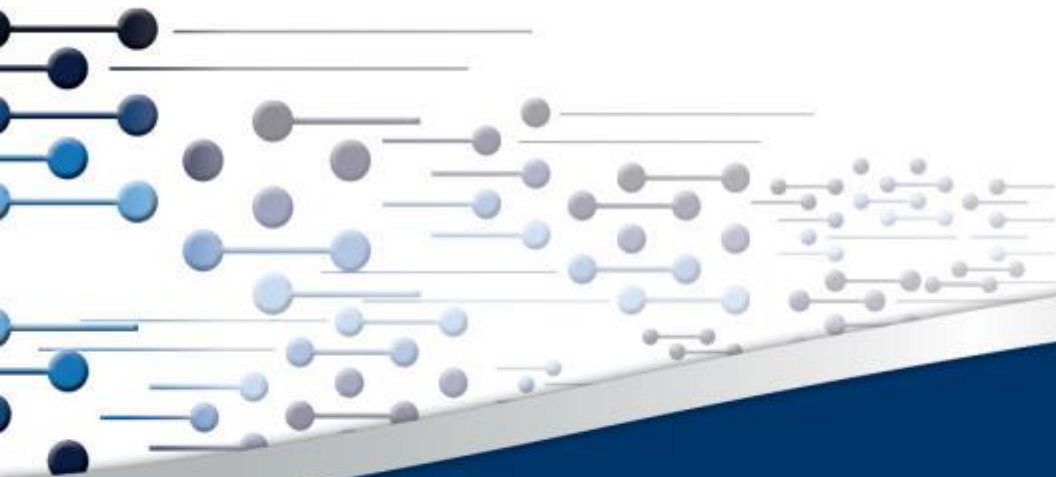


# Southern African Initiatives Empowering Marine-related Decision-makers through Earth Observation



**Dr Marié Smith**

Marine Earth Observation

Council for Scientific and Industrial Research, Cape Town, South Africa

**CSIR**

*our future through science*

# Introduction



## Council for Scientific and Industrial Research (CSIR)

- ↳ Cape Town office, South Africa
  - ↳ Ecosystem Services
    - ↳ Marine Earth Observation Unit

Research group background in Oceanography, bio-optical modeling, satellite validation, algorithm development, operational applications...



# EO marine service development and delivery

## Continental scale



### Global Monitoring for Environment & Security and Africa

Thematic areas include:

- Long-term management of resources
- **Marine and Coastal Areas**
- Water resources Management

# EO marine service development and delivery

## Regional scale



marco  
SOUTH

### **Marine and Coastal Service Development for Southern Africa (MarCoSouth)**

The southern African consortium of  
GMES & Africa Marine and Coastal  
Areas

Includes partners from Angola,  
Namibia, South Africa,  
Mozambique, Tanzania and Kenya

# EO marine service development and delivery

## National scale



NATIONAL  
OCIMS

**National Oceans and Coastal  
Information Management  
System (OCIMS) project**

Provides decision support for  
the effective governance of SA's  
oceans and coasts

# National Oceans and Coastal Information Management System

# Operation Phakisa – Oceans Economy

## Vision

Develop a locally relevant and globally cognisant **technological solution that supports the economic potential** of South Africa's Oceans through information for effective governance.

## Mission

Integrate current and future **systems, information and expertise** into a user-friendly and cost effective national Oceans and Coasts information system for the benefit of relevant stakeholders

## Benefit

- Decision making support
- Strategic and operational planning
- Protection oceans and coastal environment
- Economic growth and job creation

# OCIMS – Motivation and Challenge



SA is responsible for managing >3000 km of coastline and an oceans space that is greater than the land territory

Extended continental shelf claim will double the size of the ocean geographic extent

Land Size:

**1.2 million km<sup>2</sup>**

Exclusive Economic Zone (EEZ) Size:

**1.5 million km<sup>2</sup>**

We need new ways to monitor and manage this space!

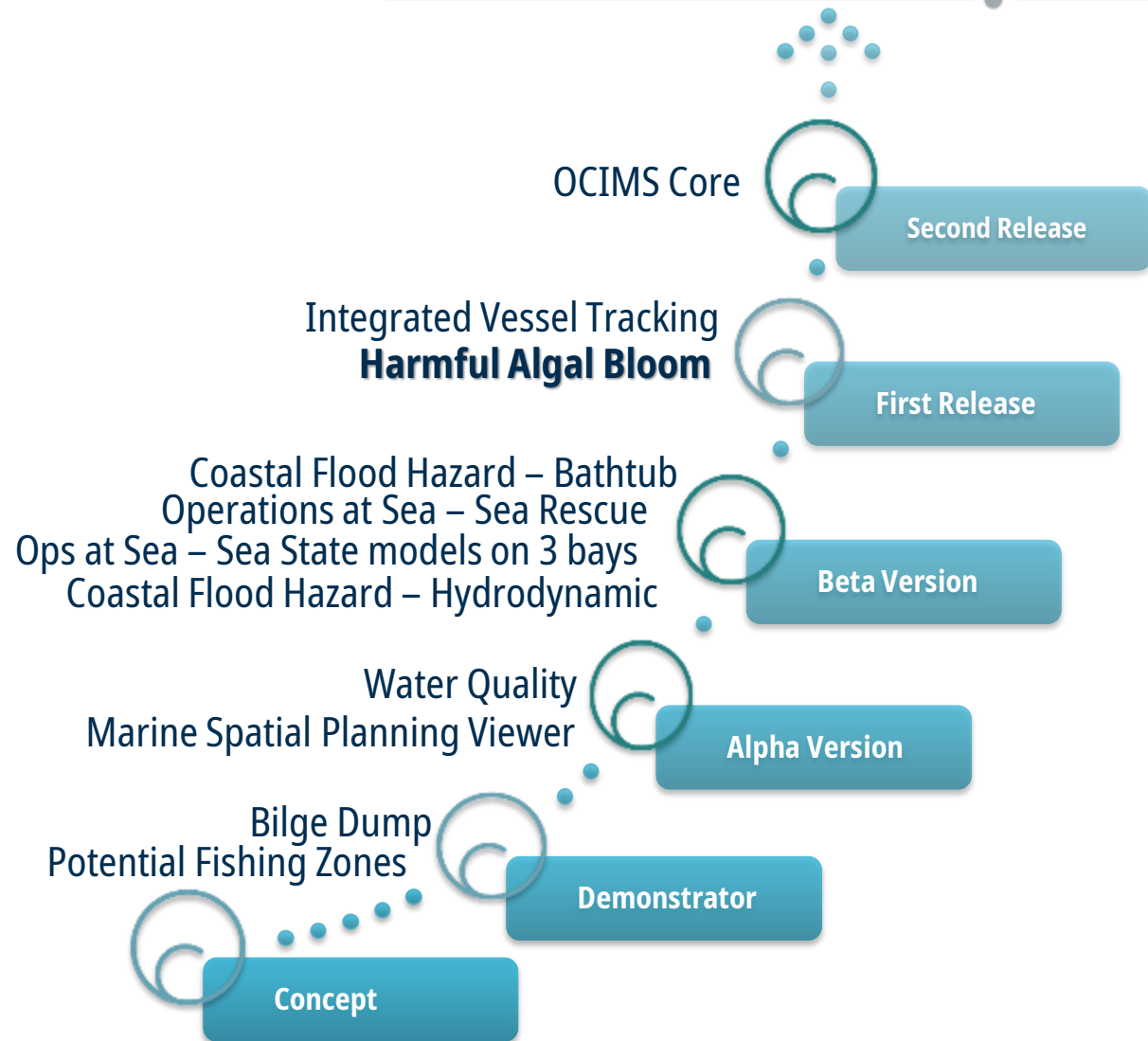


# OCIMS – Decision support tools (DeST)

A system where available Oceans and Coastal information resources are accessible that include:

- Data
- Decision support tools
- Documents

social media: #ocims\_sa

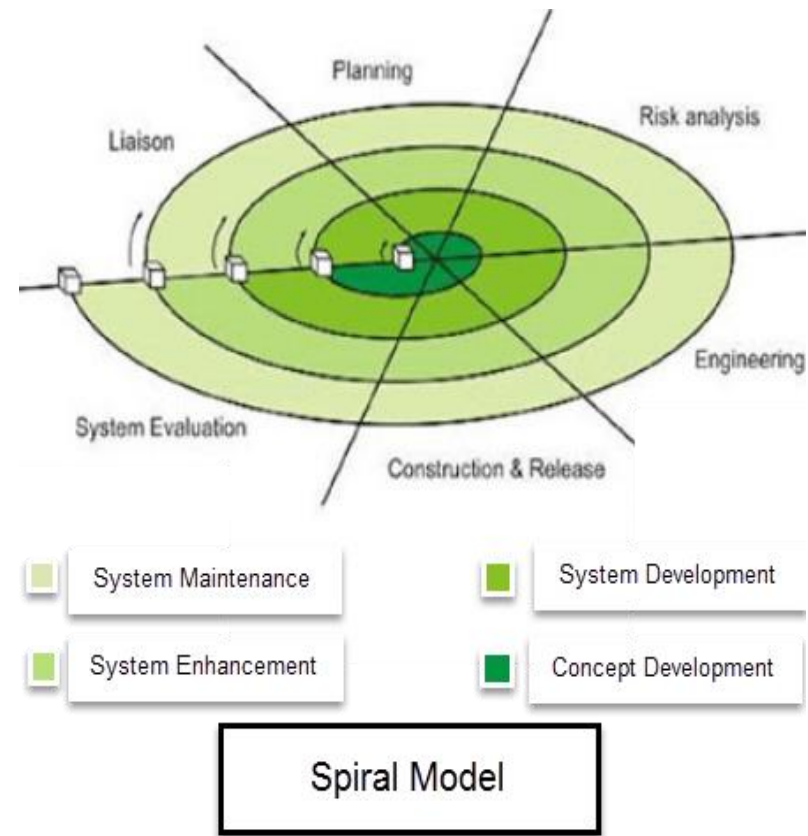


# OCIMS – Development of DeSTs

As an EO community we have years of experience in building capabilities, understanding limitations, and developing regional products

*However:*

- It can be difficult to relate the scientific information to industry needs
- And to communicate this information in an easily understandable format
- The users might not know what is available, but they tend to know what they need
- SOLUTION: user co-design



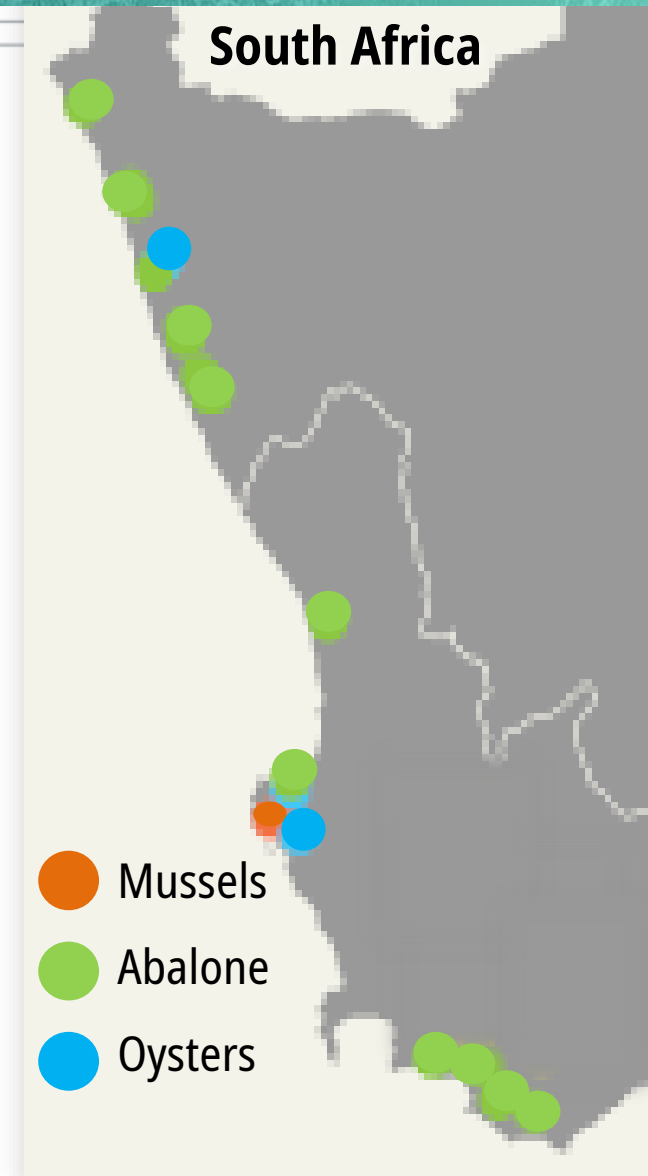
# Example development : HAB DeST

Harmful Algal Blooms, also known as “red tides”, are a significant threat to the aquaculture and rock lobster industries, and have caused several hundred million ZAR damages in the last five years....



# Aquaculture: Background

- **Productive** region due to the Benguela current upwelling system
- Ideal conditions for **marine aquaculture**
  - mussels
  - abalone
  - oysters
- Important for the **blue economy**:
  - Sector could contribute \$1Billion to SA's GDP
- Optical conditions: **Phytoplankton** dominates the water-leaving signal



# Aquaculture: Challenges and risks

- **Harmful Algal Blooms (HABs):**
  - The phytoplankton that have a **negative impact** on people and marine life
- They cause harm through:
  - production of **biotoxins**
  - **mechanical damage**
  - **hypoxic events**
- HABs can potentially lead to devastating **economic losses**

The image displays two screenshots of news articles. The top screenshot is from BusinessDay, dated 20 March 2017, with the headline "Abagold in red tide sales alert". The sub-headline reads "The abalone farming venture is still assessing red-tide damage". Below the headline is a photograph of abalone shells. A red-bordered box overlaid on the article text states "± \$14M losses".

The bottom screenshot is from Africa Trade, dated Wednesday, 11 February 2015, with the headline "Harmful Algae Kills 200 Tons of Rock Lobsters Off South Africa". Below the headline is a photograph of a beach with a large area of orange-brown water. A red-bordered box overlaid on the article text states "± \$8M losses".

# Aquaculture: Mussels and Oysters

## Risk

- Can accumulate biotoxins from some dinoflagellates and diatoms species

- *Filter feeders*
- *Grown on rafts & in cages in water*



## Mitigation

- Water & tissue monitoring
- Pre-emptive harvesting
- Temporarily closing farms

# Aquaculture: Abalone

## Risk

- Some dinoflagellates can damage epithelial cells
- Affected by anoxia
- Directly affected by PSP, paralysis

- *Herbivores*
- *Grown in tanks on land*
- *Flow through system*



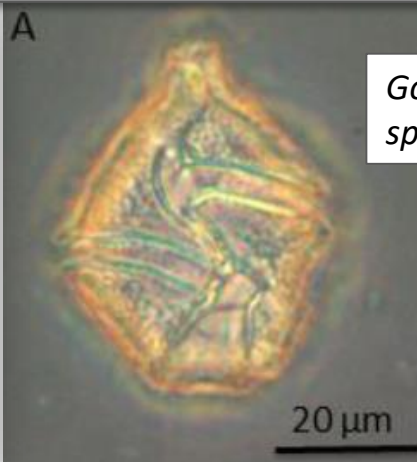
## Mitigation

- Additional filters and screens at intake pipes
- Switch off pumps
- Recirculation and extra oxygenation in tanks

# HABs: Types and impacts

## High biomass Dinoflagellates

*Ceratium  
balechii*



*Gonyaulax  
spinifera*

- Reaches [Chl-a] of 100-1000 mg m<sup>-3</sup>
- Some produce **saxitoxin** (PSP)  
**yessotoxins**, or **diarrhetic** shellfish  
toxins
- Persistence in once place can lead to  
bloom collapse and **anoxia**
- Affect both abalone and filter-feeders

## *Pseudo nitzschia*



- Pennate Diatom
- Some produce **domoic acid**
- Ingestion can cause **Amnesic shellfish  
poisoning** (brain damage)
- Can reach [Chl-a] up to ~60 mg m<sup>-3</sup>, usually  
lower biomass



# HAB Detection : User requirements

Useful information for management include:

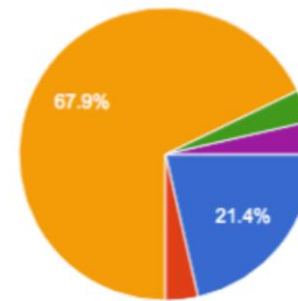
- ✓ Bloom proximity
- ✓ **Phytoplankton type ~ risk**
- ✓ Bloom spatial extent
- ✓ Persistence ~ anoxia
- ✓ Trajectory

...provided in near-real time



Is your interest in this decision support tool based on obtaining:

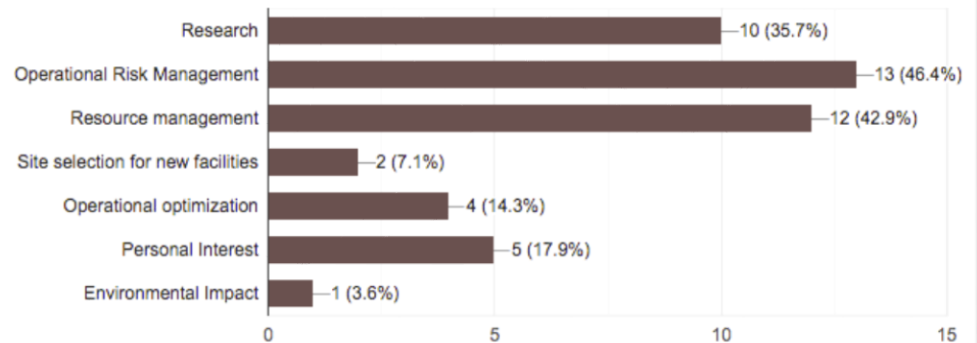
28 responses



- Near real time information
- Historical analysis of products
- Both
- General marine decision support tools
- Food security enhancement

Please indicate your interest in this decision support tool:

28 responses



# HAB Detection : Product Development

## Regional Products with Sentinel OLCI

Simple switching algorithm chosen over other available, e.g. optical water type classification, semi-analytical, as simple and robust...

An optimized Chlorophyll a switching algorithm for MERIS and OLCI in phytoplankton-dominated waters, ME Smith, LR Lain, S Bernard, 2018, *Remote sensing of environment* 215, 217-227

M.E. Smith et al.

Remote Sensing of Environment 215 (2018) 217–227

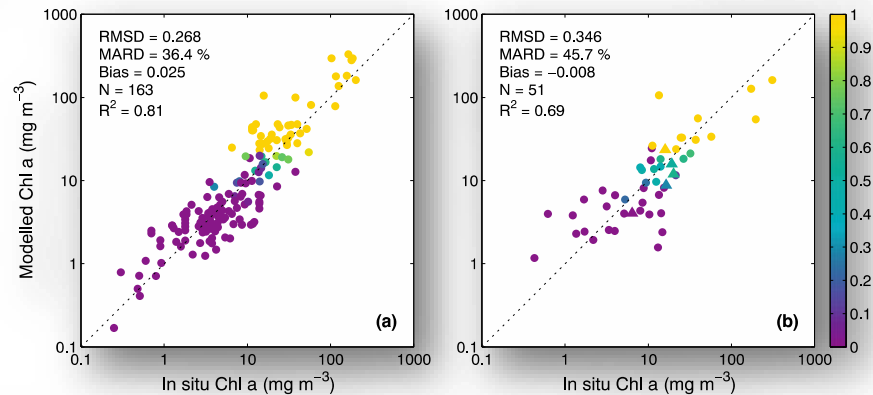
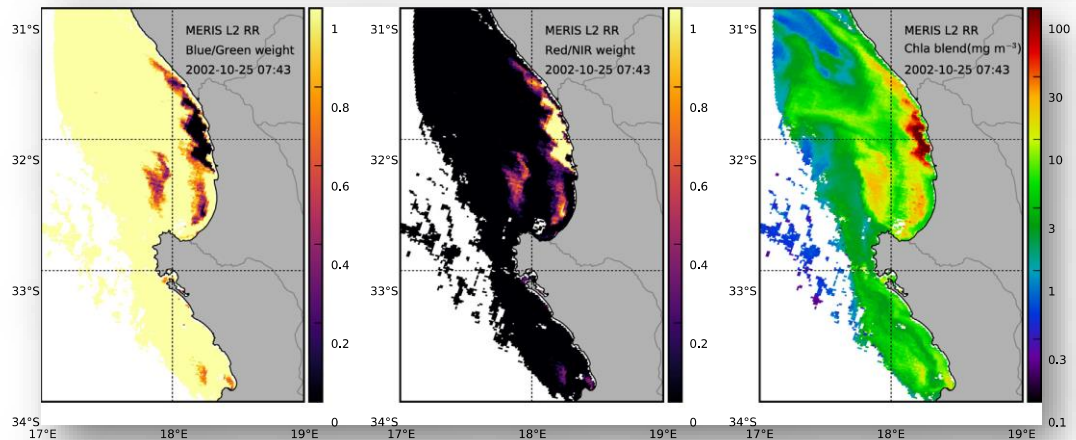


Fig. 3. Scatterplot showing the relationship between *in situ* Chl a and the modeled Chl a obtained by application of the switching and blending method to (a) *in situ* and (b) satellite-derived reflectance from MERIS ( $N = 46$ , circles) and OLCI ( $N = 5$ , triangles). The colour bar indicates the weighting of the G2B algorithm (i.e. a weighting of zero means that only OCI was applied). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



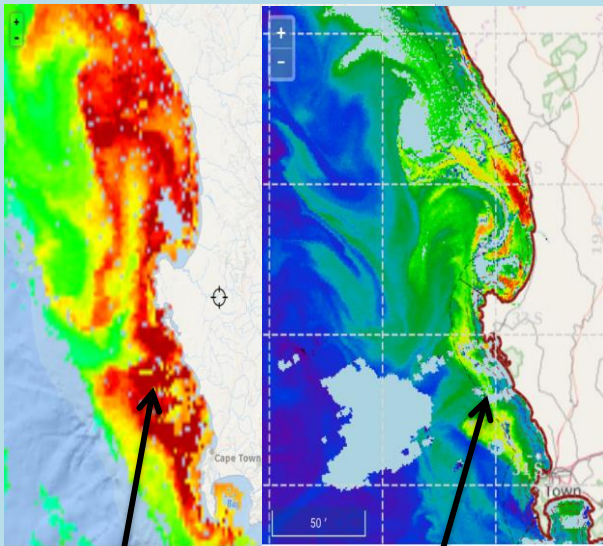
(c) Sentinel3A OLCI - *Ceratium* sp.

Fig. 4. Examples of algorithm blending application for reduced resolution MERIS reflectance on the 25th of October 2002 (a) and the 30th of March 2005 (b), as well as for OLCI on the 10th of May 2017 (c). Panels on the left and centre show the weighting used to blend the OCI and G2B algorithms respectively, with the final blended Chl a product on the right.

# HAB Detection : Product Development

Commercial  
Fishtrack.com  
MODIS Aqua

Validated OLCI  
Regional

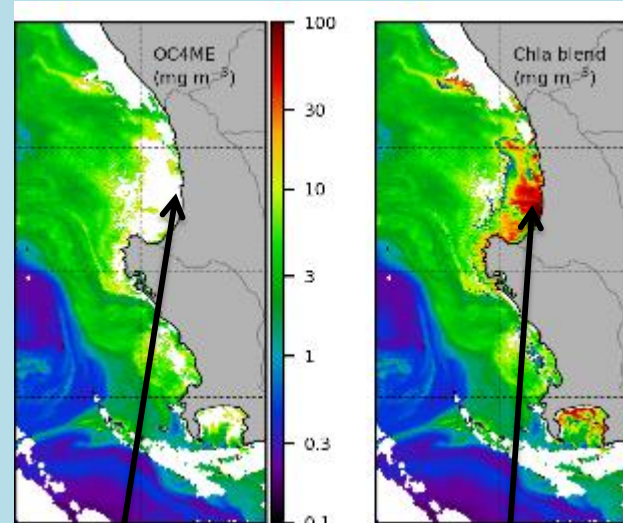


Severely over-  
Estimated Chl

Chl  $\pm 10 \text{ mg m}^{-3}$

Global OLCI  
OC4Me product

Validated OLCI  
Regional

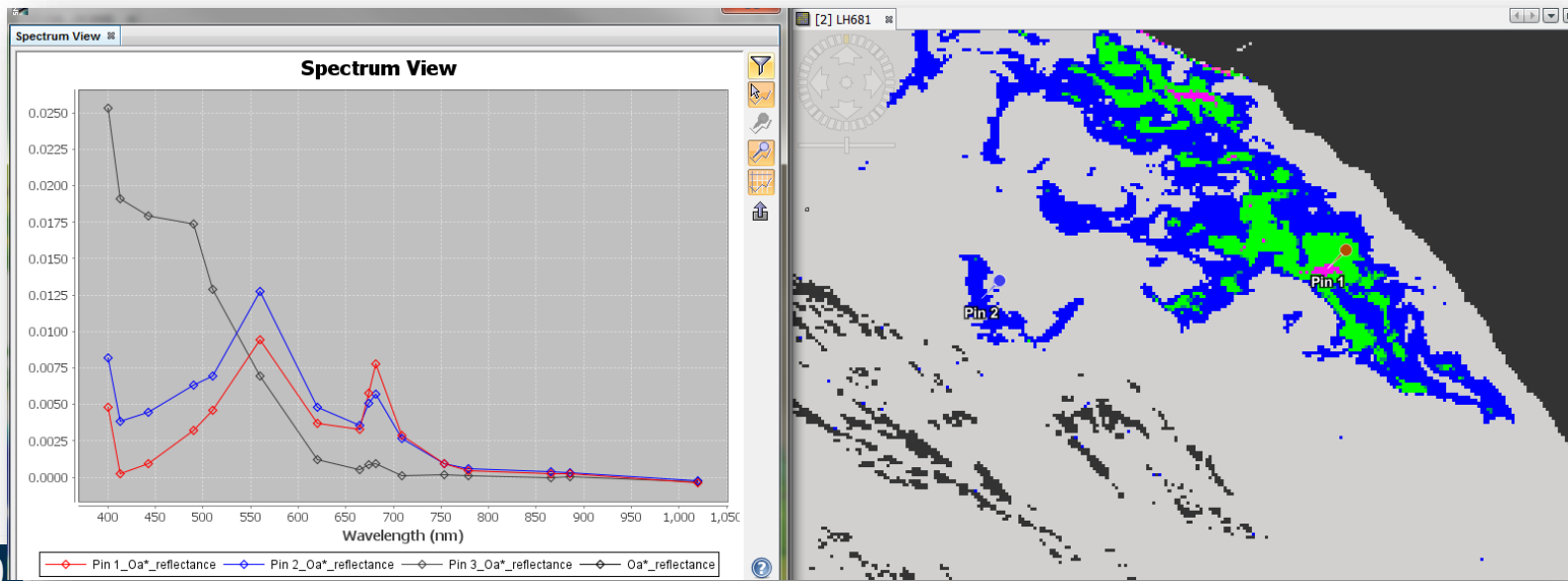


No data in high biomass  
bloom

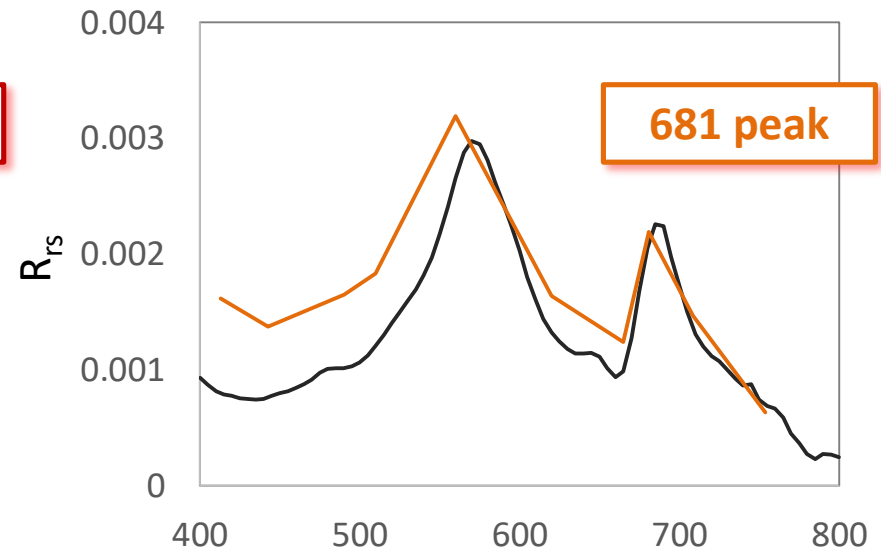
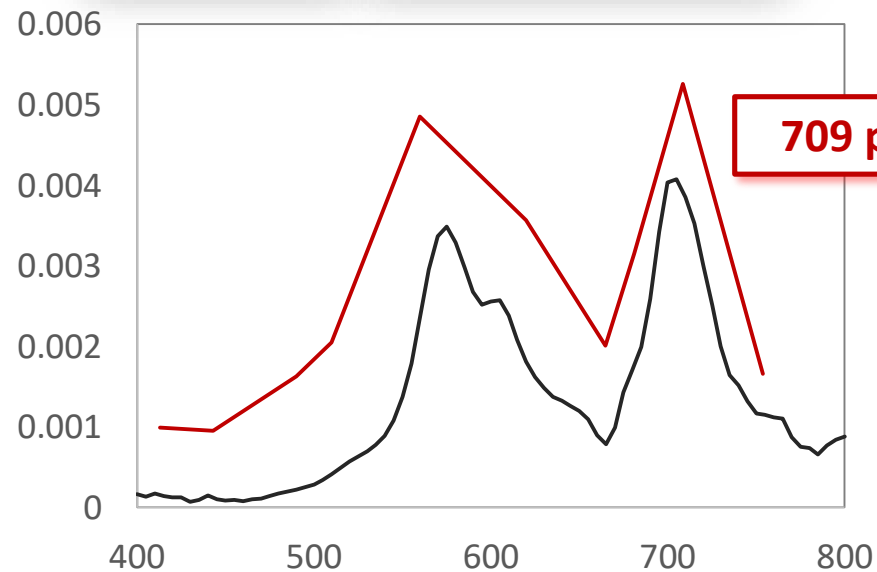
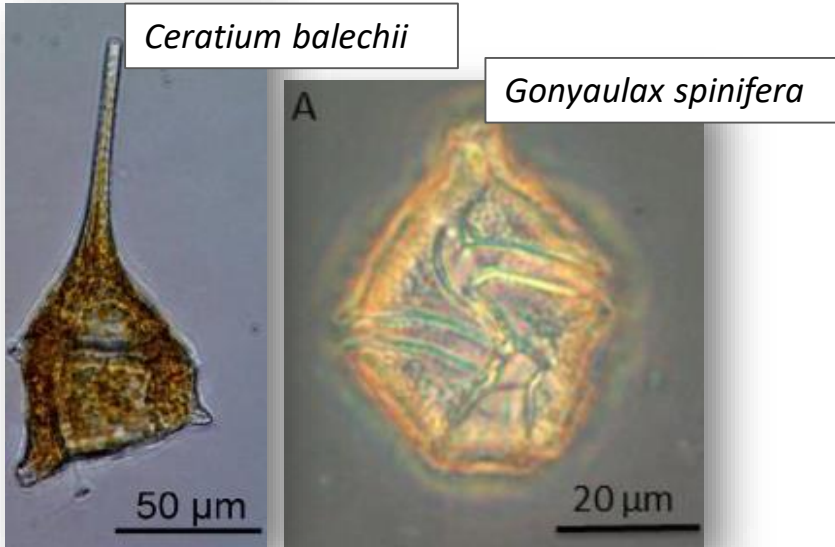
Chl  $> 100 \text{ mg m}^{-3}$

# HAB Detection : Product Development

- We have produced a variety of scientific products for regional satellite applications:
  - Effective cell diameter
  - Optical water type identification
  - Optimized [Chl-a] switching algorithms
- Kept going back to the reflectance spectra when it came to identification
- What follows is an attempt to automate this procedure



# HAB Detection : Spectral shape



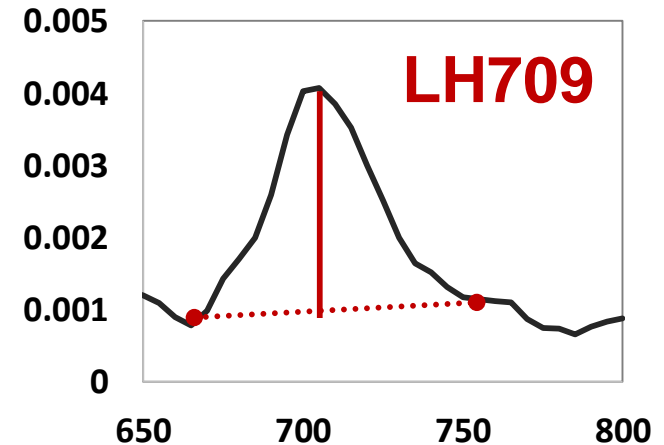
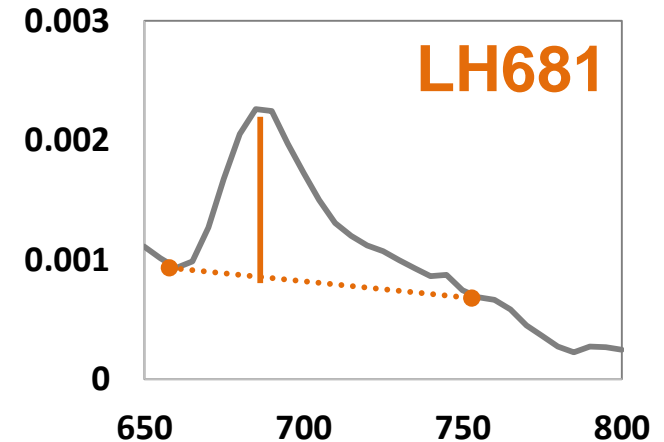
# HAB Detection : EO Requirements

- For these blooms the primary identification bands are in the red-NIR
  - We focus on the moderate to high biomass region  $[\text{Chl-a}] > 15 \text{ mg m}^{-3}$
  - where the dominant optical signal shifts from the blue-green to the **red-NIR**
- Focus our application on **OLCI & MERIS** as they have good spectral coverage in this region
- Historically relied on  $[\text{Chl-a}]$ 
  - Not that meaningful for aquaculture management



# HAB Detection : Methods

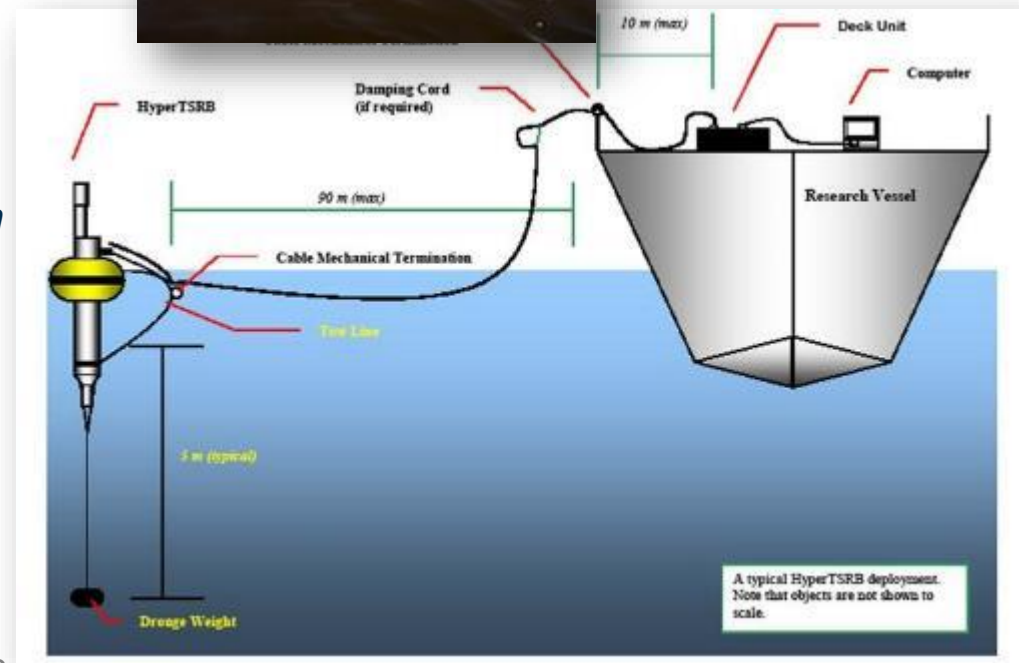
- Focus on moderate to high biomass signal in the **red/NIR**:
  - OLCI & MERIS have bands at 665, 681, 709 and 754 nm
  - We use the line height of the peak at 681 & 709 nm over a baseline between 665 and 754 nm
- We used the **line height ratio** (LHR) as an indication of peak shift



$$LHR = \frac{LH709}{LH681}$$

# HAB Detection : *in situ* data collection

- *In situ* data:
  - 68 stations off Lambert's Bay with phytoplankton counts, [Chl-a], and radiometry
  - Collected 2004 – 2008
  - Various bloom conditions
- Performed data clustering and Principle component analysis on the *in situ* dataset



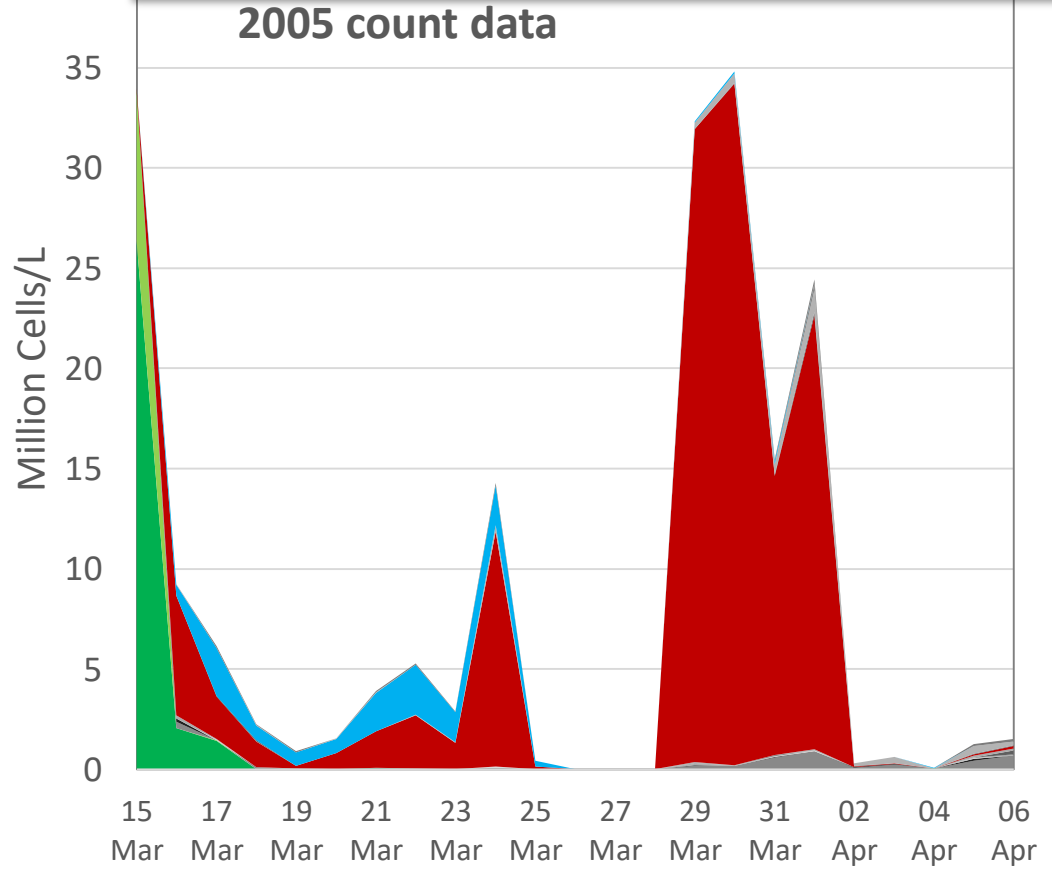
H-TSRB graphic from Ryan A. Vandermeulen



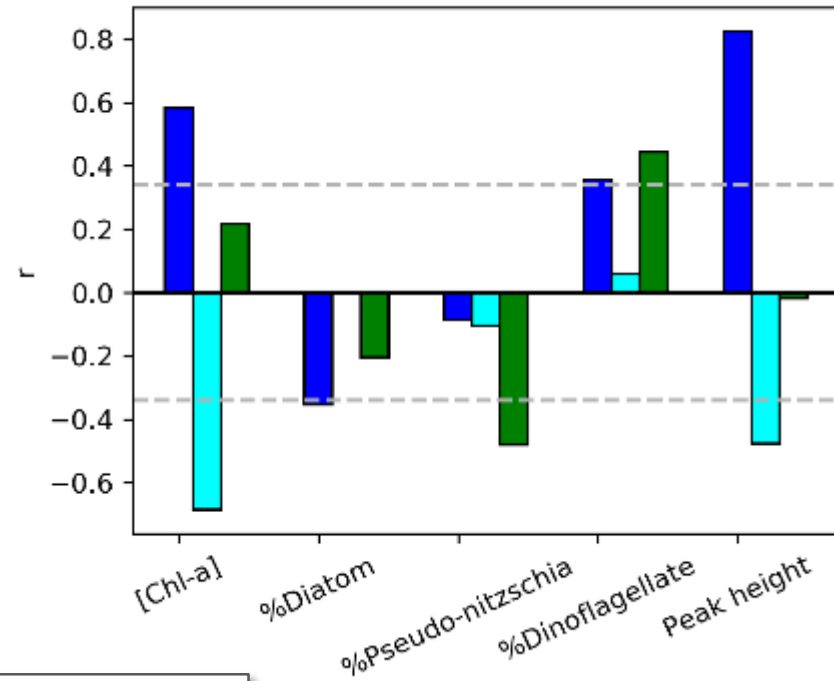
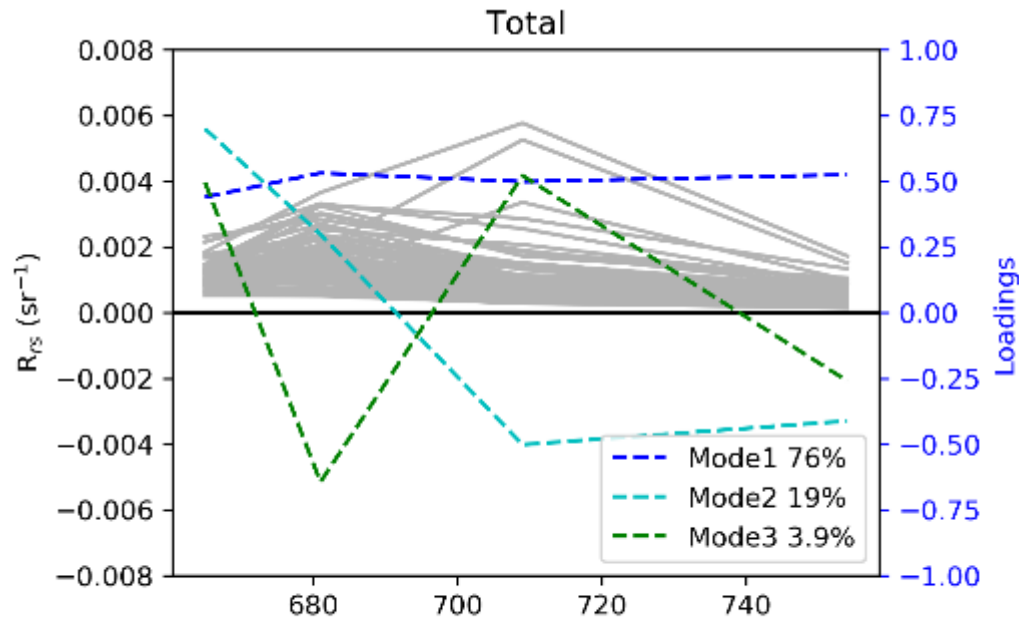
# HAB Detection : phytoplankton count data

- Ciliates** {
  - Other ciliates
  - *Mesodinium rubrum*
- Coccolithophores** {
  - *Syracosphaera pulchra*
- Dinoflagellates** {
  - Other dinoflagellates
  - *Scropsiella trochoideum*
  - *Protoperidinium sp*
  - *Protoceratium reticulatum*
  - ***Prorocentrum triestinum***
  - *Prorocentrum micans*
  - *Prorocentrum balticum*
  - *Polykrikos*
  - *Gyrodinium sp*
  - *Gonyaulax spinifera*
  - *Gymnodinium zeta*
  - *Dinophysis rotundata*
  - *Dinophysis fortii*
  - *Dinophysis acuminata*
  - *Ceratium lineatum*
  - *Ceratium furca*
- Diatoms** {
  - *Other diatoms*
  - *Chaetoceros spp*

- Phytoplankton count data are relatively **complex**
- Requires **consolidation** for practical application



# HAB Detection : principle component analysis



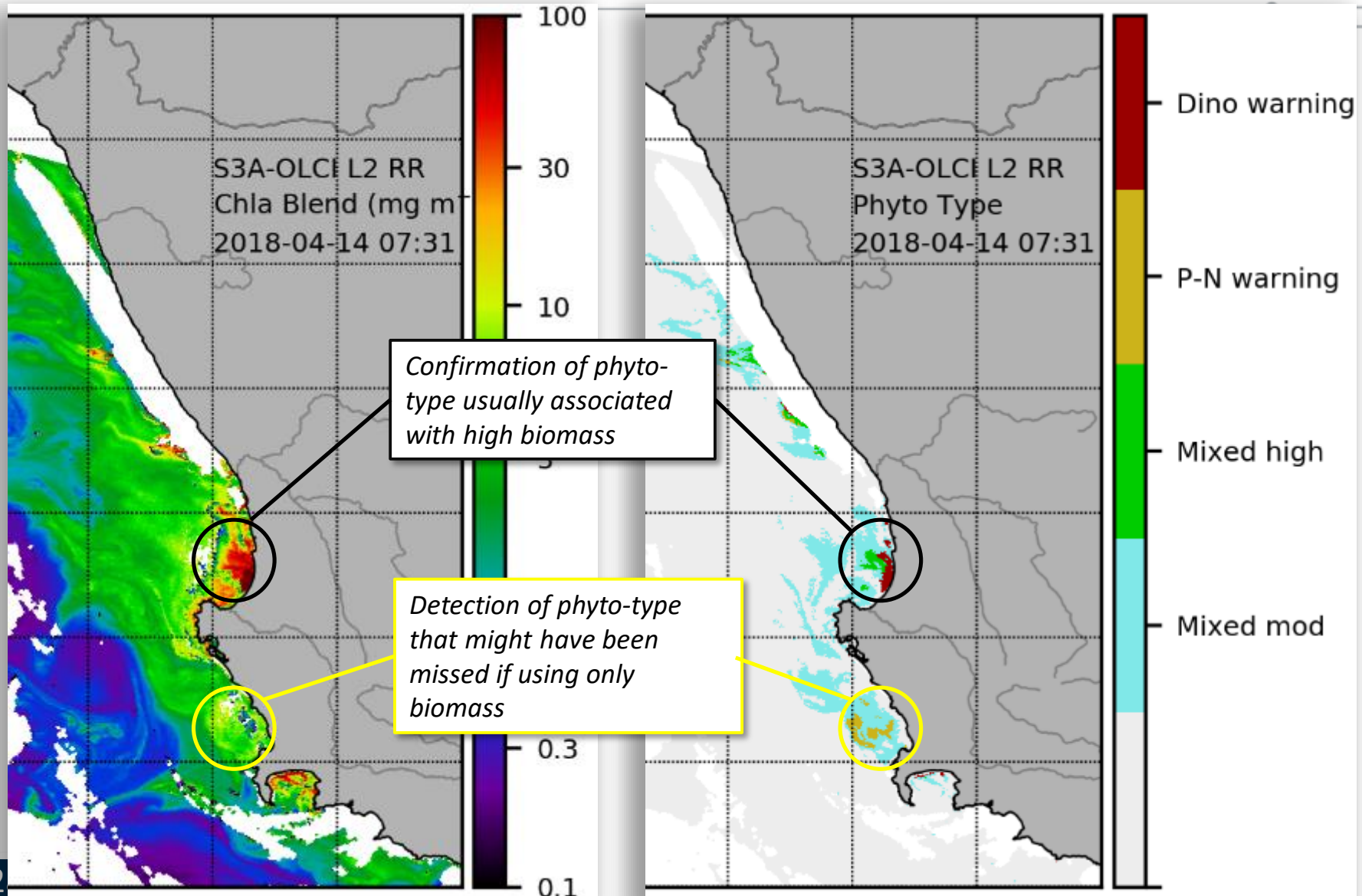
- Phytoplankton **biomass** drives the magnitude of the reflectance peaks in the red
- Increase in biomass  $\approx$  increase in phytoplankton **backscatter** (709 nm) and **absorption** (665 nm)
- Pseudo-nitzschia has largest effect on the **fluorescence** peak whilst dinoflagellates have largest effect on the **709 nm** peak

# HAB Detection : decision tree

	LHR < 0.3	0.3 < LHR < 1	LHR > 1
Peak height > 0.0026	<i>Pseudo-nitzschia</i> dominated	Mixed assemblage moderate biomass	
Peak height > 0.0036		Mixed assemblage, high biomass	Dinoflagellate dominated, moderate biomass
Peak height > 0.0058			Dinoflagellate dominated, high biomass

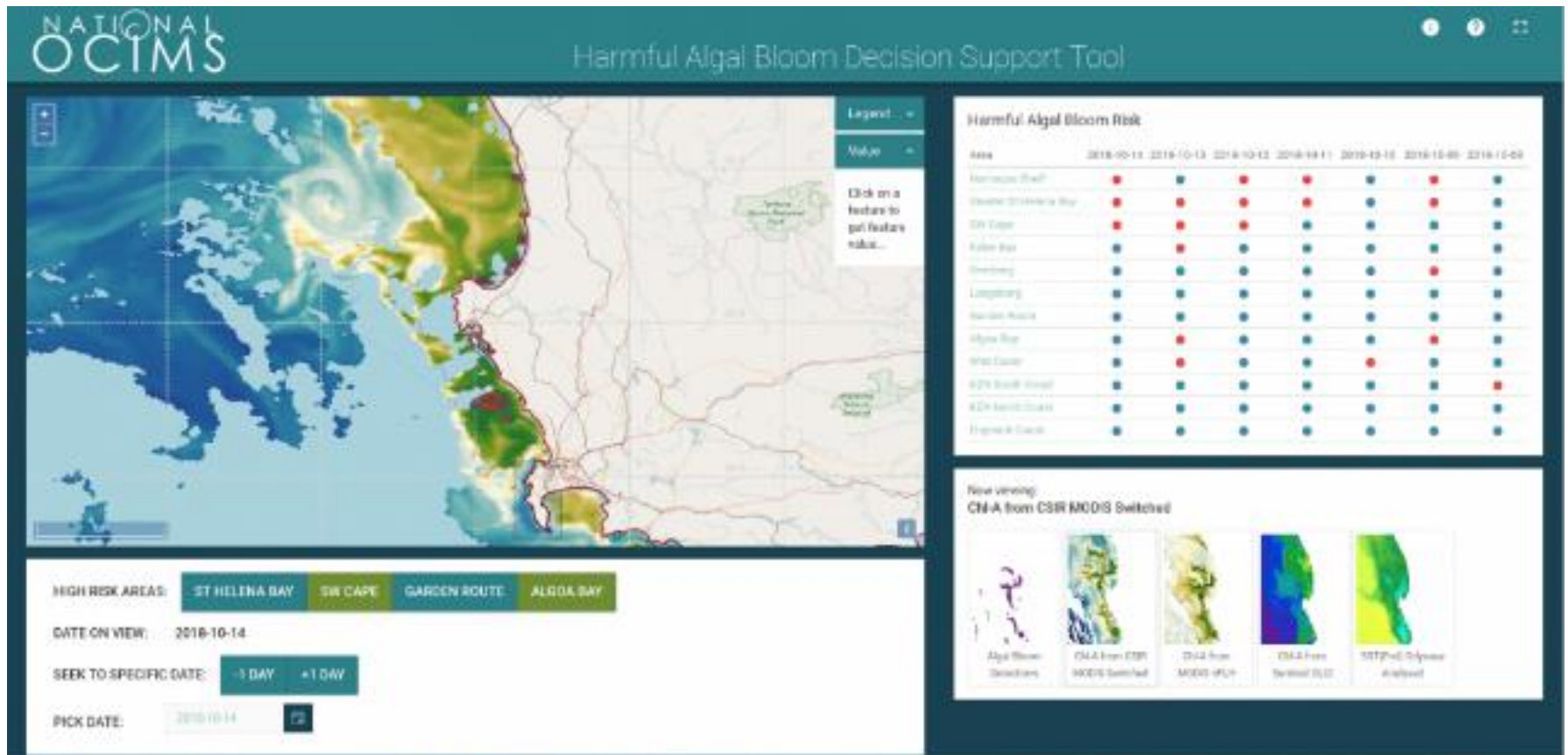
Note: This algorithm is for phytoplankton-dominated waters; as a rough estimate the integral between 665 and 754 nm must be <0.5

# HAB Detection : Bloom identification maps



# HAB DeST

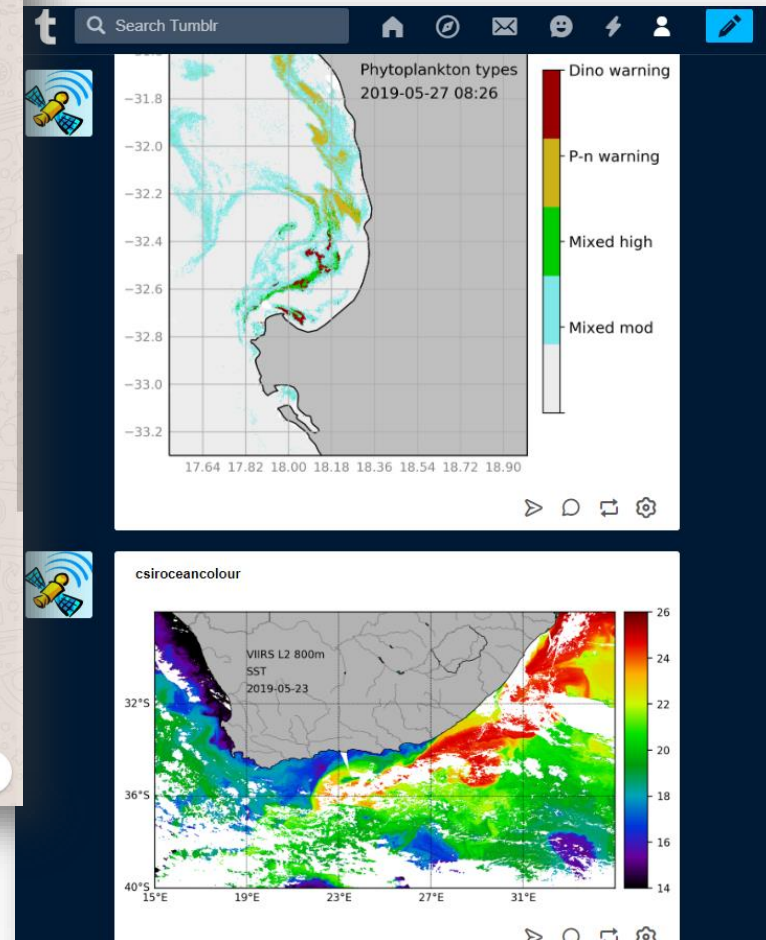
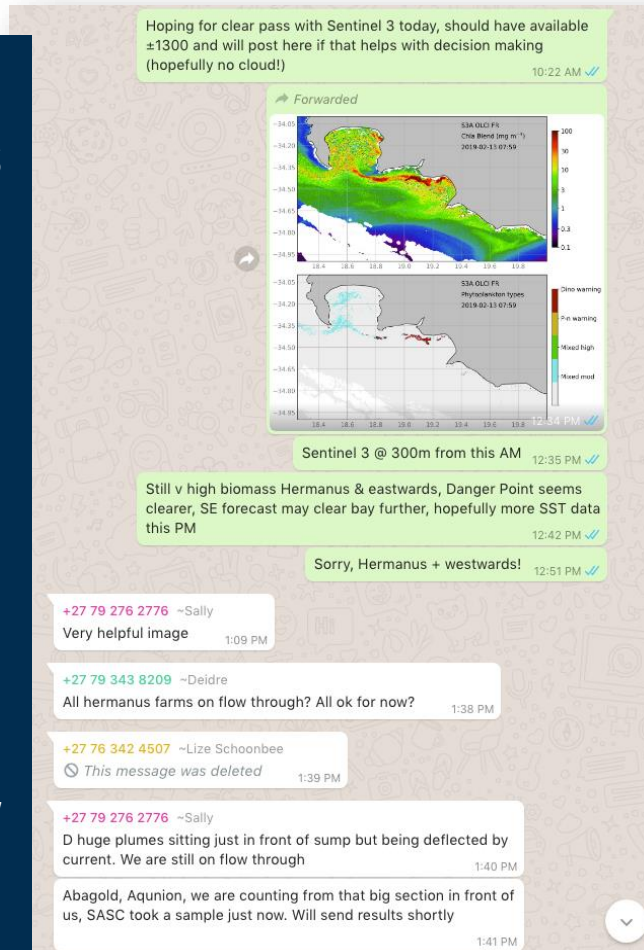
- Provide near-real time warnings for high risk situations to the aquaculture industry, DAFF, municipalities and desalination plants.
- Bloom analytic, 1 week persistence product, regional Chl-a, SST



# HAB Detection : Aquaculture preference

However: during high risk bloom events users want more frequent updates – preferred methods are WhatsApp groups and blogs to share additional information and insights

Here we tend to provide any additional products e.g. VIIRS SST, OLCI full resolution phytoplankton type products, RGB images

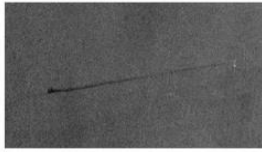


# Other DeSTs : Bilge Dump Tools

Automatic identification of oil spills and bilge dumps using Satellite Synthetic aperture radar to protect our South African oceans, maintain environmental security and protect sensitive and high economic value coastal ecosystems....

**Bilge Dump ALERT REPORT**

Report by: BD\_DeST  
Report Date: 2018-09-17

DETECTION	ATTRIBUTES
	Date : 2015/05/16 Location : -17.3842, 20.6192 Length : 9.9 km Size : 5 km sq. Wind : 5.4 m/s Alert Level: High Confidence Level: High
NOTES	
<ul style="list-style-type: none"> <li>- Bilge dump not verified.</li> <li>- Possible source identified from SAR.</li> </ul>	

**Recent Events**

**DURBAN - SOUTH AFRICA**

20 Oct 2014 - 16:36  
16 May 2015 - 07:04  
25 Jul 2015 - 18:21  
28 Aug 2015 - 02:51  
02 Oct 2015 - 06:50  
01 Jul 2016 - 06:27  
14 Apr 2016 - 16:21  
24 Aug 2016 - 18:18

Latitude : 31.272874  
Longitude : -29.830913

Size : 70 km sq  
Length : 40 km

**News**   **Statistics**

Lawyers for the Bodo community in Nigeria's oil-producing Niger Delta, devastated by two major oil spills a decade ago, went to court in London this week to fend off what they said was an attempt by Shell to kill off litigation.

The Bodo oil spills have been the subject of years of legal wrangling. In 2015, Shell accepted liability, agreeing to pay 55 million pounds (83 million dollars at the time) to Bodo villagers and to clean up lands and waterways.

source: defence web

**NATIONAL OCTIMS**

Recent Bilge Dumps   GEOFENCES   SAR

Date	Name	Lat	Long	Source	Remove All
20160414	S1A_IW_GRDH_VV_6466	-26.377	39.037	SAR	Remove
20151222	S1A_IW_GRDH_VV_5065	-36.123	32.782	SAR	Remove
20160607	S1A_IW_GRDH_VV_1030	-34.737	26.841	SAR	Remove

**Bilge Details**

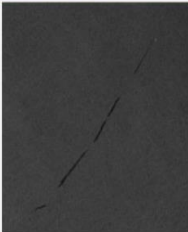
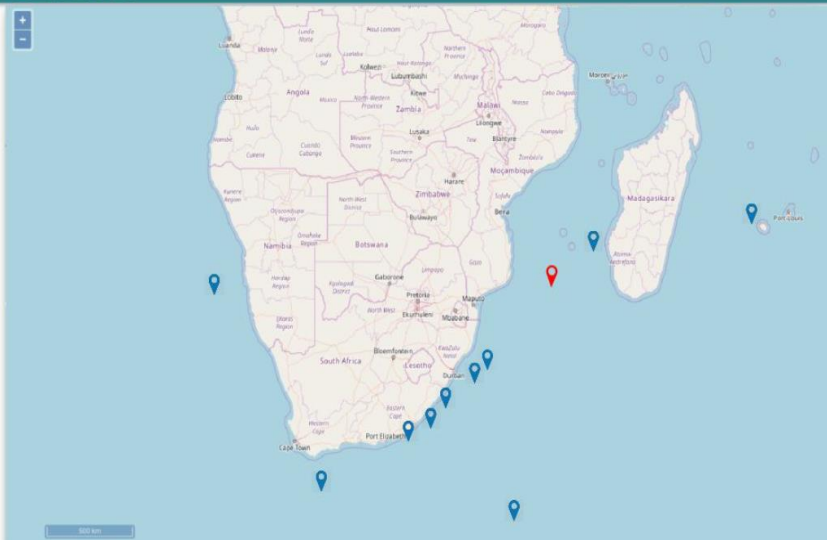
Date: 20160414 - 04:14

Location: -26.377, 39.037

Length: 24 km

Size: 12.6 km sq.

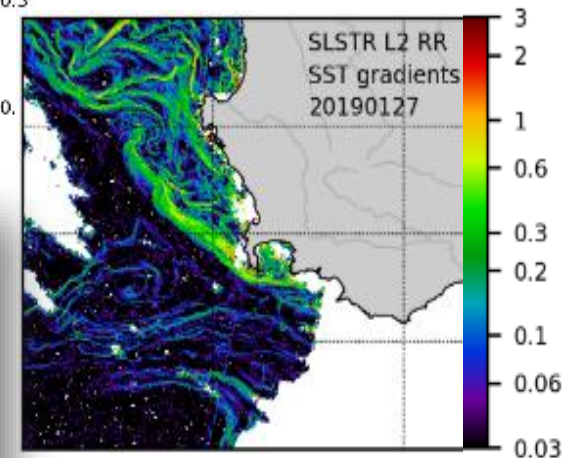
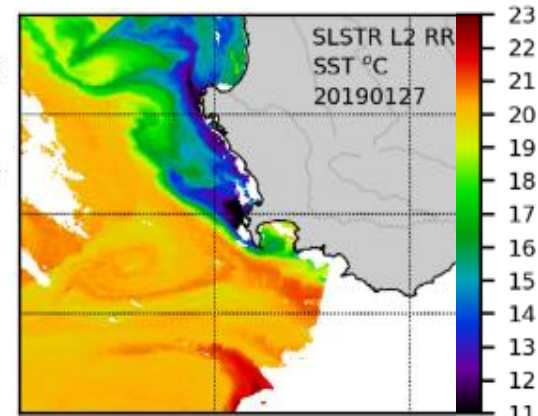
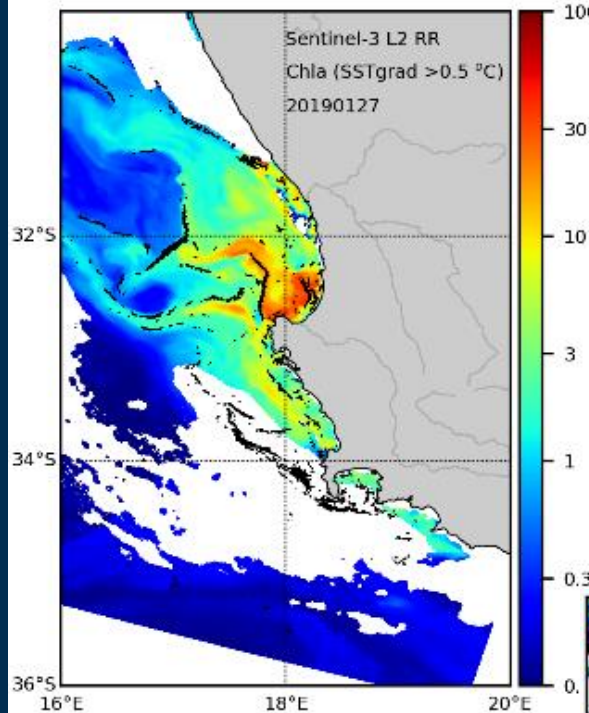
Wind: 8.4 m/s.

# Other DeSTs : Fisheries Support

A combination of regionally optimised temperature and ocean colour products, such as ocean fronts, in combination with vessel tracking tools, will provide for holistic fisheries management, industry and community support:

- Tools to understand ecosystem & catch changes over decades to better manage fisheries,
- Tools to provide both industrial and small scale fishers the means to catch allowable quotas more effectively & sustainably,
- Tools to lower risk in going to sea and allowing more effective asset management,
- Tools to assist in fisheries certification programmes, such as the Marine Stewardship Certification, increasing market value and sustainability...





# Other DeSTs : Operations at Sea

NATIONAL OCIMS Coastal Operations at Sea

**SEARCH AND FILTER - HISTORIC WEATHER**

Latitude: 34 18.46 Longitude: 18 42.578

Download Format: CSV/Excel/JSON

Wind Direction (degrees): 135.276 Wind Gust (km/h): 15.482

Last known time: 10:05 AM Status: OK

Weather station: GPS

Search Tool: Perform in real-time Data Collection

Buttons: [SEARCH] [CLEAR] [RESET]

Tag	Event Date	Event Type
11	19 Oct 11:00	Search
11	19 Oct 11:00	Search

Last location	Lat	Long	Vessel Type	Person in water	Weather station	GPS
Weather Data	34.18276	18.42578	1:481 Rescue Plane	18 Oct 11:00	Rescue ETA	18 Oct 11:00
CAPSM	34.18276	18.42578		34.18276	18.42578	
Search A	34.18276	18.42578		Search ID	34.18276	18.42578
Search B	34.18276	18.42578		Search ID	34.18276	18.42578

Logos: Department of Transport, Department of Forestry, Fisheries and the Environment, CSIR

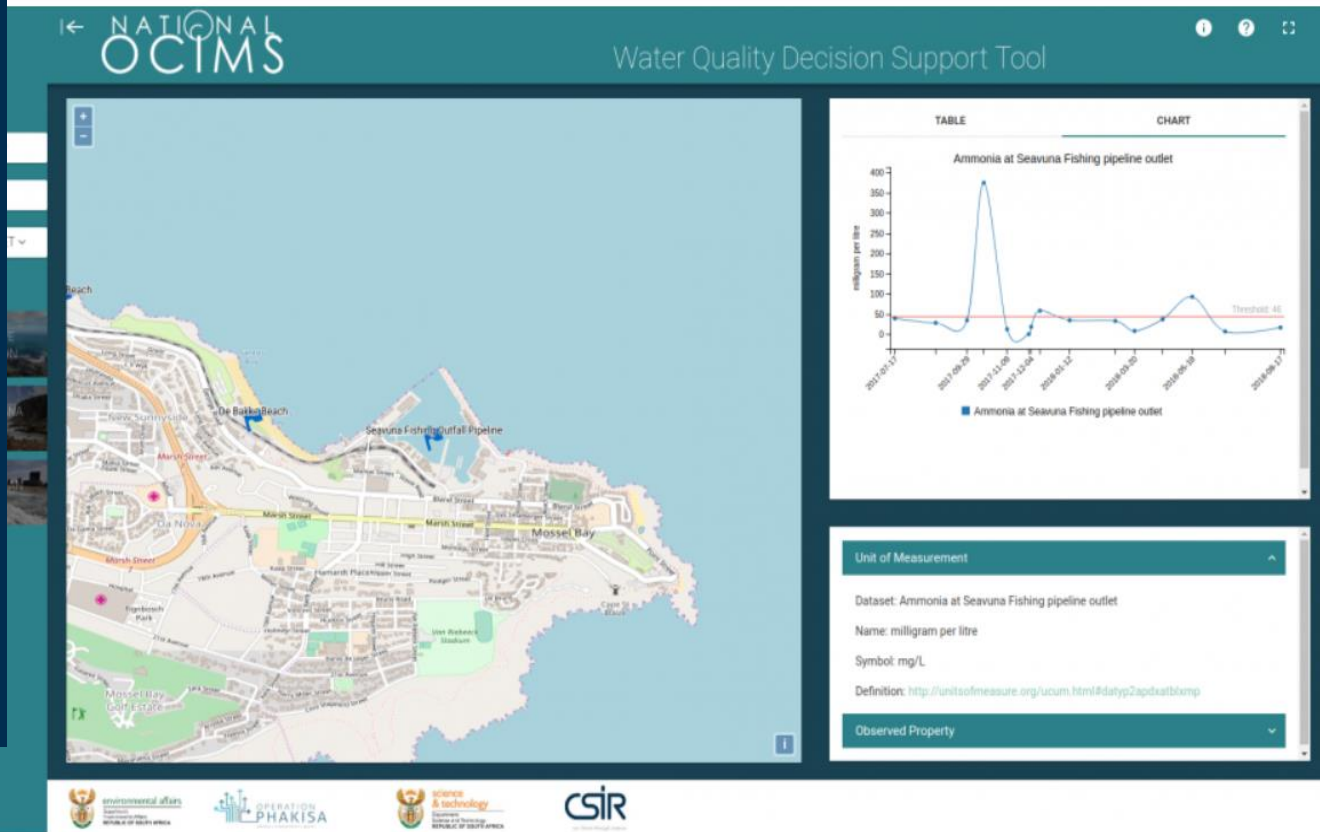


A tool that monitors and predicts sea conditions for the purposes of a number of coastal and ocean operations

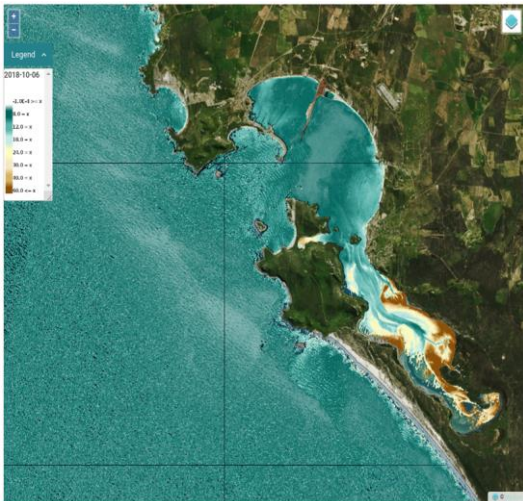
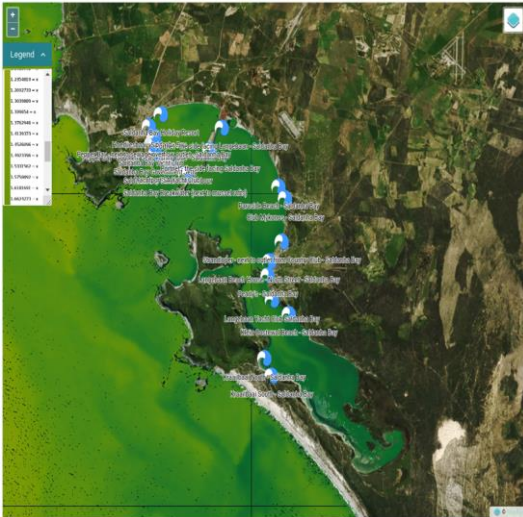
National Sea Rescue Institute have collaborated in co-designing new search planning tools, e.g. for rapid search patterns in rescue operations.

# Other DeSTs : Water Quality

The Water quality DeST combines a number of available datasets to monitor water quality around the South African Coast. Focus will be on sites for tourism, aquaculture, desalination plants, estuarine nursery grounds, fluvial sediment footprints as catchment monitors, discharge and abstraction sites,....



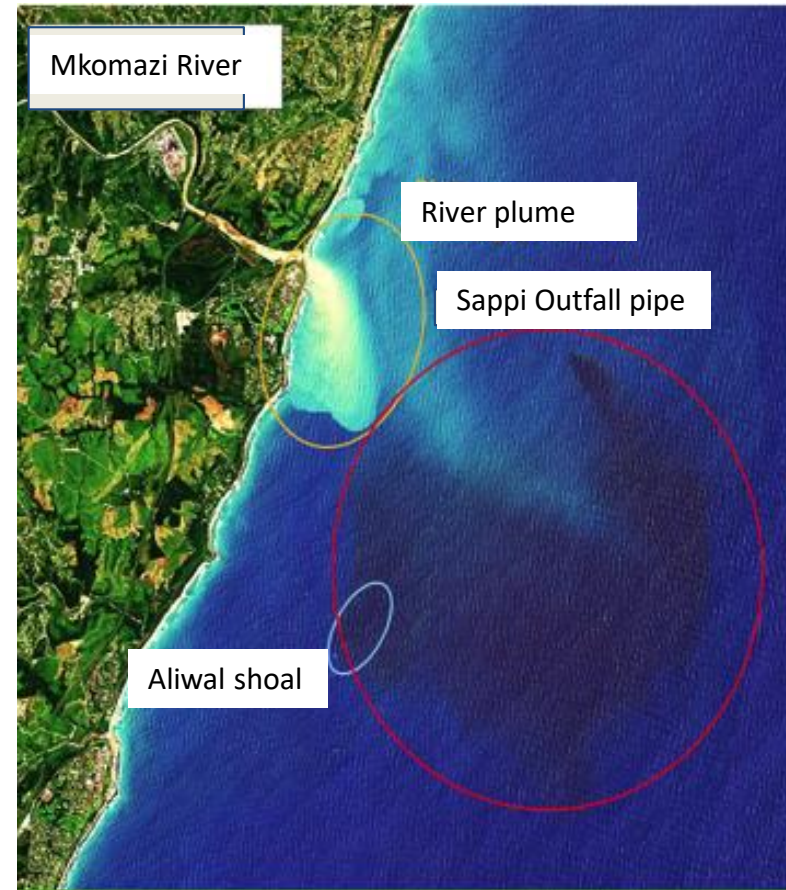
# Other DeSTs : Water Quality



Focus on Sentinel 2  
(10-60m) and OLCI Full  
resolution (300m)

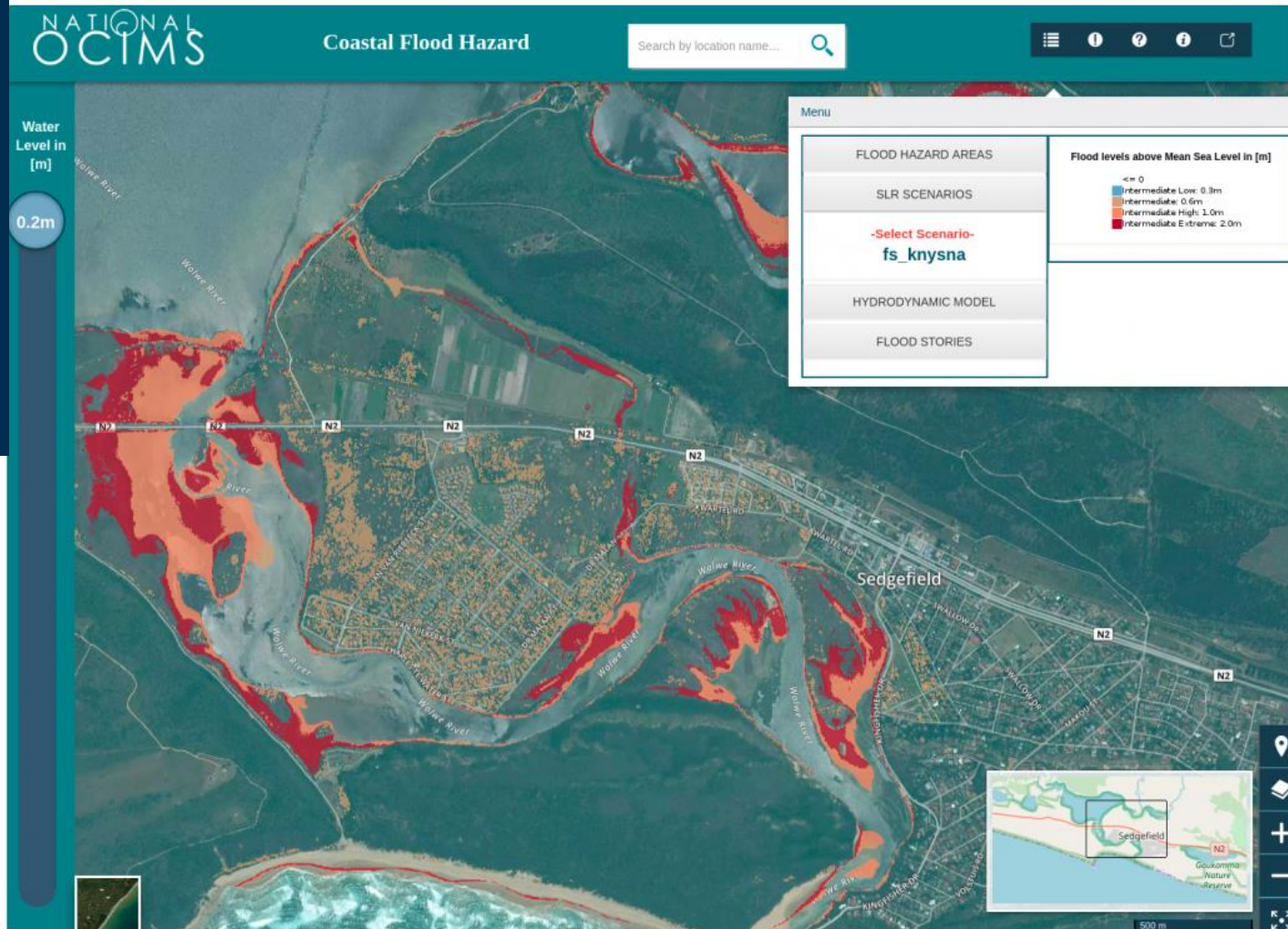
Turbidity vs  
productivity

RGB images for dark vs  
absorbing plume  
detection



# Other DeSTs : Coastal Flood Hazard

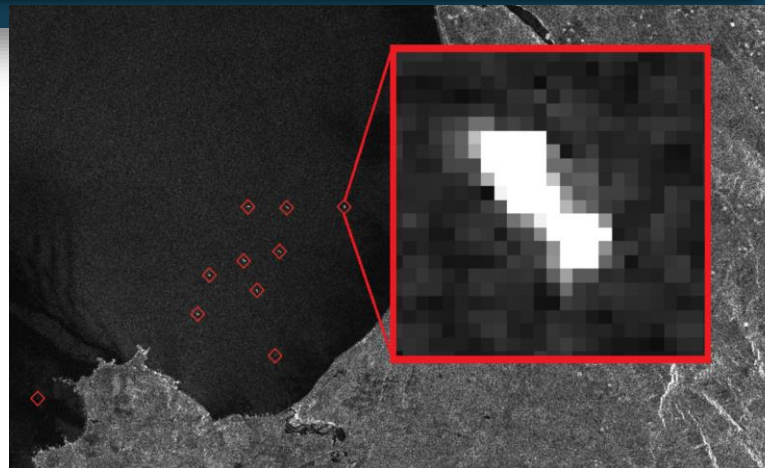
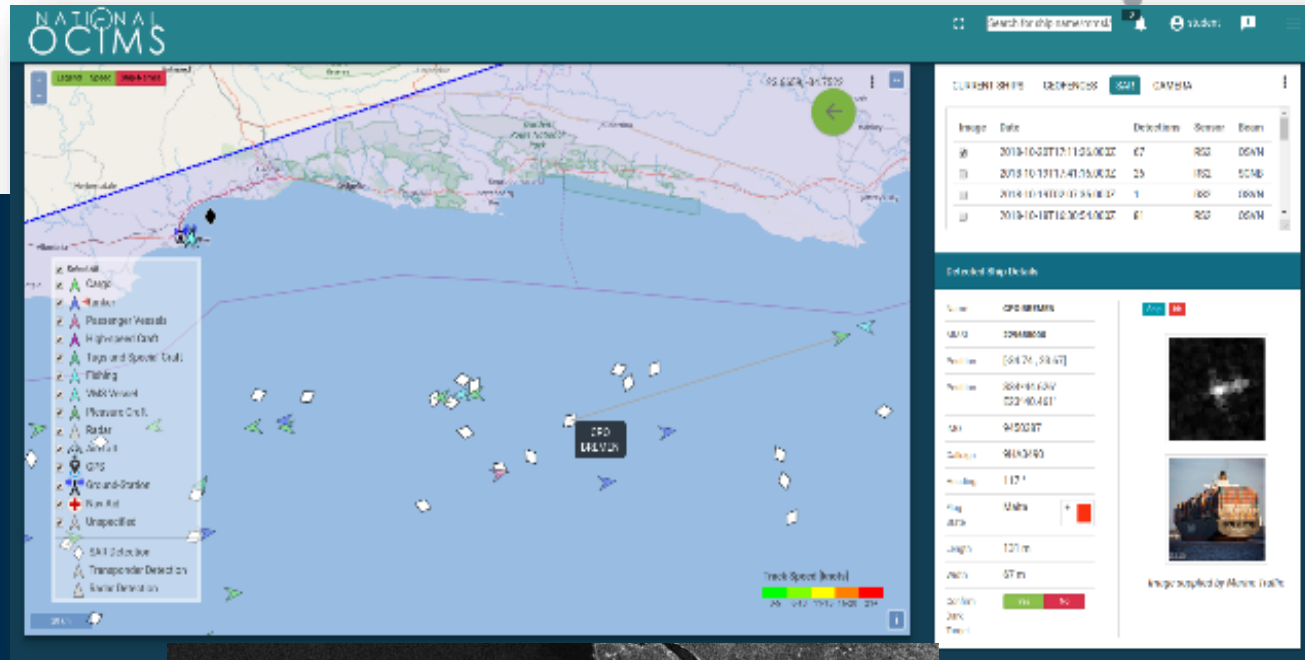
Provides a tool that allows e.g. disaster managers, spatial planners and the general public an estimation of coastal areas that are potentially at risk of flooding.



# Other DeSTs : Integrated Vessel Tracking

Tracking and monitoring of large vessels in the South African Exclusive Economic Zone by combining various data sources that include:

- Automatic Identification System (ORBCOMM)
- Synthetic Aperture Radar
- Vessel Monitoring Service
- Optical cameras



Sentinel 1 Synthetic Aperture Radar (SAR)

# Other DeSTs : Integrated Vessel Tracking

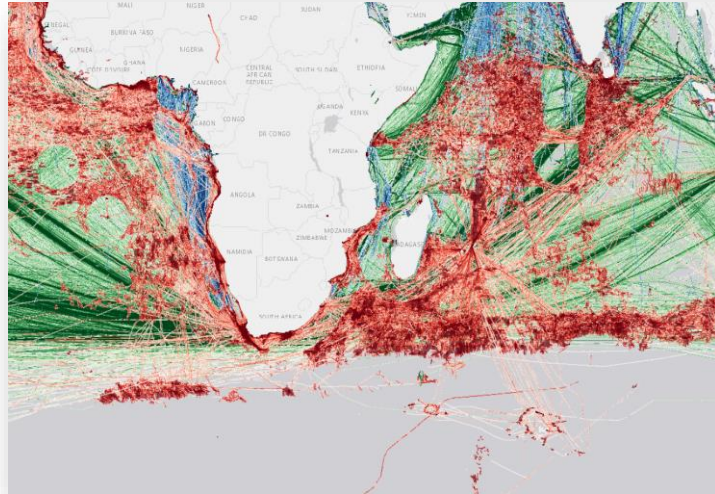
## Ship Traffic Monitoring

Users often need to :

- 1) Find and track specific vessels
- 2) Be warned of vessels inside restricted areas (geofencing)
- 3) Find the history of a vessel
- 4) See the normal behaviour of vessels over history
- 5) Find vessels that are not transmitting their position (dark targets)

These requirements are used in:

- Fisheries enforcement
- Tracking of vessels suspected of smuggling
- Pollution monitoring
- Determining port activity



MMSI	Name	Callsign	Flag	Remove All
538002531	YASA PIONEER	V7JJJ	MH	Remove

Ship Details	
Name	YASA PIONEER
MMSI	538002531
Position	[36.28, 14.65]
Position	S36°16.945' E14°38.788'
IMO	9286578
Callsign	V7JJJ
Source ID	fusion.all
Reported Time	29/07/2019, 11:05:28 (SAST)
Heading	88.00 °
Flag State	Marshall Islands
Track	Refresh Remove
Avg Speed	

# EO marine service development and delivery

## Regional



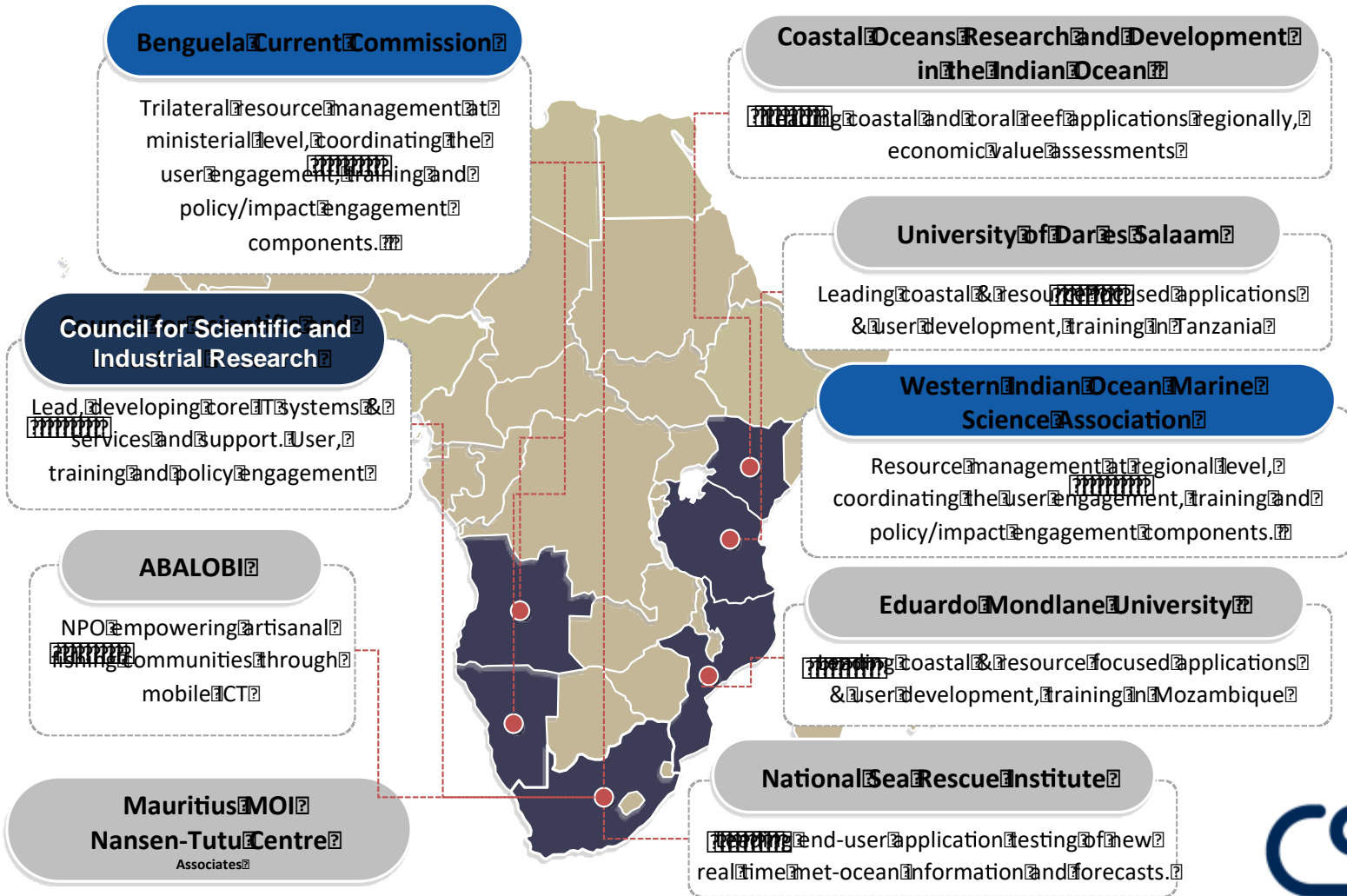
marco  
SOUTH

### **Marine and Coastal Service Development for Southern Africa (MarCoSouth)**

The southern African consortium of  
GMES & Africa Marine and Coastal  
Areas

Includes partners from Angola,  
Namibia, South Africa,  
Mozambique, Tanzania and Kenya

# Consortium Structure

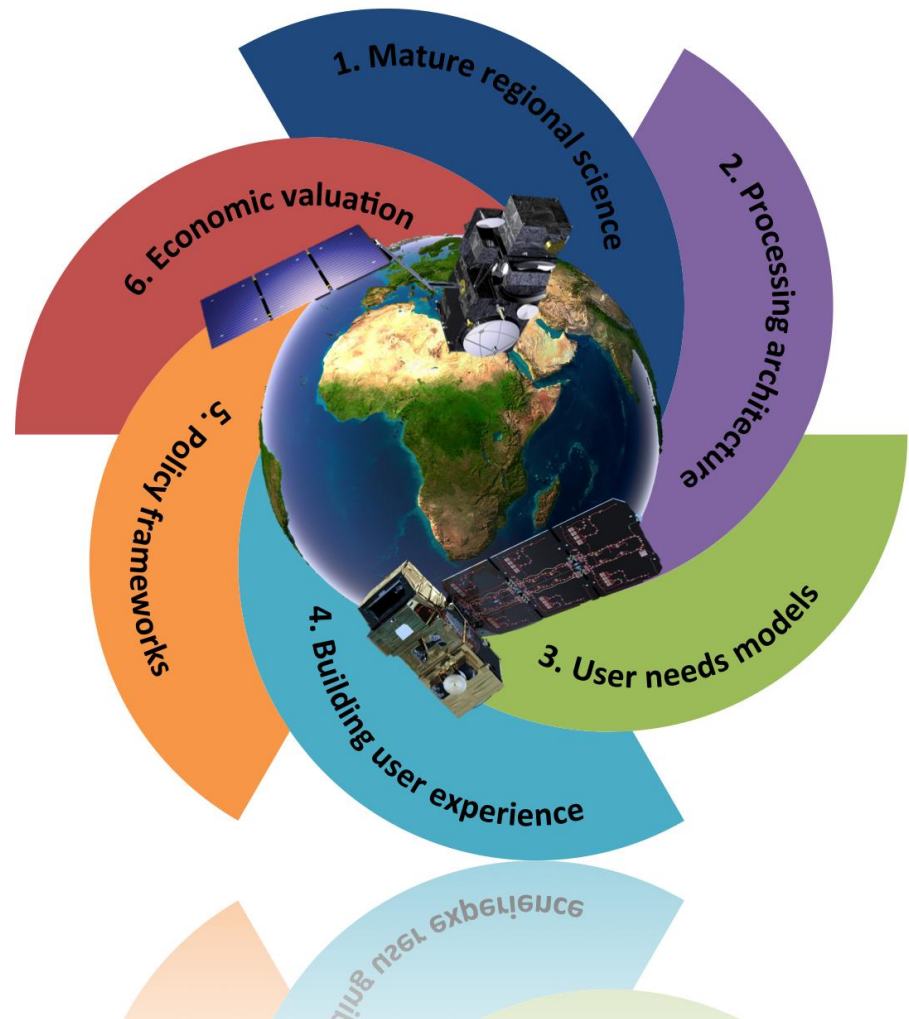




Regional scaling of selected OCIMS services

OCIMS provides a technical springboard and co-funding. GMES-Africa will follow similar development pathways, much accelerated in practice due to both the OCIMS development and MESA forerunners...

An example of the components needed for service development and lessons learnt from the research to operational transition from OCIMS



# Service Development

Current Service	Fisheries & Aquaculture	Fisheries & Aquaculture	Coastal Monitoring	Coastal Monitoring	Vessel Tracking	Ops at Sea/NSRI
<b>Focus</b>	ABALOBI & artisanal fish	Aquaculture support	Coral Bleaching Alerts	Water Quality	Vessel tracking	Ops at Sea/NSRI
<b>Copernicus Products</b>	Sentinel 3	Sentinel 3	CMEMS & Sentinel 2	Sentinel 3 FR & Sentinel 2	Sentinel 1 & AIS	ECMWF



## GMES & Africa and Copernicus Marine Earth Observation Training

➤ *Theme: Earth Observation to services across the value chain*

- Pre-course online phase 21 Oct – 8 Nov
- Workshop phase Zanzibar, Tanzania from the 12th - 20th November 2019
- For 20 Participants
- Fully funded
- Applications closed 23 August 2019

***134 applications***

# Thank you 😊

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