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

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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...
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

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
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

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

**Benefit**
OCIMS – Motivation and Challenge

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

Land Size:

1.2 million km²

Exclusive Economic Zone (EEZ) Size:

1.5 million km²

We need new ways to monitor and manage this space!
A system where available Oceans and Coastal information resources are accessible that include:

- Data
- Decision support tools
- Documents

social media: #ocims_sa
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.
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 $1 Billion 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

± $8M losses

± $14M losses
Aquaculture: Mussels and Oysters

**Risk**
- Can accumulate biotoxins from some dinoflagellates and diatoms species

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

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

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

Mitigation

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

Aquaculture: Abalone

- Herbivores
- Grown in tanks on land
- Flow through system
HABs: Types and impacts

High biomass Dinoflagellates

• Reaches [Chl-a] of 100-1000 mg m\(^{-3}\)
• Some produce saxitoxin (PSP) yessotoxins, or diarrhetic shellfish toxins
• Persistence in one 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\(^{-3}\), 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
Regional Products with Sentinel OLCI

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


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.)

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 ± 10 mg m⁻³

Global OLCI OC4Me product
Validated OLCI Regional

No data in high biomass bloom
Chl > 100 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

*Ceratium balechii*  
*Gonyaulax spinifera*  
*Pseudo nitzschia*

<table>
<thead>
<tr>
<th><strong>709 peak</strong></th>
<th><strong>681 peak</strong></th>
</tr>
</thead>
</table>

Graphs show the spectral shape with peaks at 709 and 681 nm respectively.
For these blooms the primary identification bands are in the red-NIR

- We focus on the moderate to high biomass region [Chl-a] > 15 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 [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
HAB Detection: phytoplankton count data

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

Phytoplankton count data

**Ciliates**
- Other ciliates
- *Mesodinium rubrum*
- *Syrachosphaera pulchra*
- Other dinoflagellates
- *Scripsiella trochoideum*
- *Protoperidinium sp*
- *Protoceratium reticulatum*
- *Prorocentrum triestinum*
- *Prorocentrum micans*
- *Prorocentrum balticum*
- Polykrikos
- *Gyrodictium sp*
- *Gonyaulax spinifera*
- *Gymnodinium zeta*
- *Dinophysis rotundata*
- *Dinophysis fortii*
- *Dinophysis acuminata*
- *Ceratium lineatum*
- *Ceratium furca*
- Other diatoms
- *Chaetoceros spp*

**Coccolithophores**

**Dinoflagellates**

**Diatoms**
Phytoplankton biomass drives the magnitude of the reflectance peaks in the red.

Increase in biomass ≈ 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

<table>
<thead>
<tr>
<th>LHR &lt; 0.3</th>
<th>0.3 &lt; LHR &lt; 1</th>
<th>LHR &gt; 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peak height &gt;</strong></td>
<td>Pseudo-nitzschia</td>
<td>Mixed assemblage, moderate</td>
</tr>
<tr>
<td>0.0026</td>
<td>dominated</td>
<td>biomass</td>
</tr>
<tr>
<td><strong>Peak height &gt;</strong></td>
<td>Mixed assemblage, high</td>
<td></td>
</tr>
<tr>
<td>0.0036</td>
<td>biomass</td>
<td></td>
</tr>
<tr>
<td><strong>Peak height &gt;</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0058</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Confirmation of phyto-type usually associated with high biomass

Detection of phyto-type that might have been missed if using only biomass
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
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....
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...
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.
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
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.
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 Apperture Radar
- Vessel Monitoring Service
- Optical cameras

Sentinel 1 Synthetic Aperture Radar (SAR)
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
EO marine service development and delivery
Regional

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

**Benguela Current Commission**
Trilateral resource management at ministerial level, coordinating the user engagement, training and policy/impact engagement components.

**Council for Scientific and Industrial Research**
Lead, developing core IT systems & services and support. User, training and policy engagement

**ABALOBI**
NPO empowering artisanal fishing communities through mobile ICT

**Mauritius MOI Nansen-Tutu Centre Associates**

**Coastal Oceans Research and Development in the Indian Ocean**
Leading coastal and coral reef applications regionally, economic value assessments

**University of Dar es Salaam**
Leading coastal & resource focused applications & user development, training in Tanzania

**Western Indian Ocean Marine Science Association**
Resource management at regional level, coordinating the user engagement, training and policy/impact engagement components.

**Eduardo Mondlane University**
Leading coastal & resource focused applications & user development, training in Mozambique

**National Sea Rescue Institute**
Leading end-user application testing of new real time met-ocean information and forecasts.
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

<table>
<thead>
<tr>
<th>Current Service</th>
<th>Fisheries &amp; Aquaculture</th>
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<th>Coastal Monitoring</th>
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<th>Vessel Tracking</th>
<th>Ops at Sea/NSRI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus</strong></td>
<td>ABALOBI &amp; artisanal fish</td>
<td>Aquaculture support</td>
<td>Coral Bleaching Alerts</td>
<td>Water Quality</td>
<td>Vessel tracking</td>
<td>Ops at Sea/NSRI</td>
</tr>
<tr>
<td><strong>Copernicus Products</strong></td>
<td>Sentinel 3</td>
<td>Sentinel 3</td>
<td>CMEMS &amp; Sentinel 2</td>
<td>Sentinel 3 FR &amp; Sentinel 2</td>
<td>Sentinel 1 &amp; AIS</td>
<td>ECMWF</td>
</tr>
</tbody>
</table>
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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