Monitoring change for managing uncertainty within coastal systems…from space

Dr. Magnus Wettle

EOMAP
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Mapping and monitoring aquatic environments worldwide

Satellite remote sensing – Earth Observation

Two main product suites:
- bathymetry and seafloor mapping
- water quality monitoring

Innovative, proprietary algorithms

Operational processing systems

Software: enabling capabilities

First and leading commercial provider of SDB

Spin-off German Aerospace Center, 20+ years R&D

Partnerships

bp
Landgate
Shell
woodside
NOAA
CSIRO
Queensland Government
BAW
BMT WBM
Dolphin geophysical
bfg Bundesanstalt für Gewässerkunde
ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and EADS
RioTinto
Van Oord
Marine ingenuity
THE WORLD BANK
Cardno
Shaping the Future
GHD
DILLON CONSULTING
GSI
Environment Agency ABU DHABI
ILF CONSULTING ENGINEERS
COMMISSION DE L'OCÉAN INDIEN
THE UNITED KINGDOM HYDROGRAPHIC OFFICE
GOLD COAST WATERWAYS AUTHORITY
JAMES COOK UNIVERSITY AUSTRALIA
Australian Government
Geoscience Australia
DLR
NIWA
Taihoro Nukurangi
AUSTRALIAN INSTITUTE OF MARINE SCIENCE
CONABIO
FUGRO
ABP mer
marine environmental research
iXblue
esa
DigitalGlobe
THE UNIVERSITY OF QUEENSLAND AUSTRALIA
INPEX
INPEX CORPORATION
EMODnet
BSH
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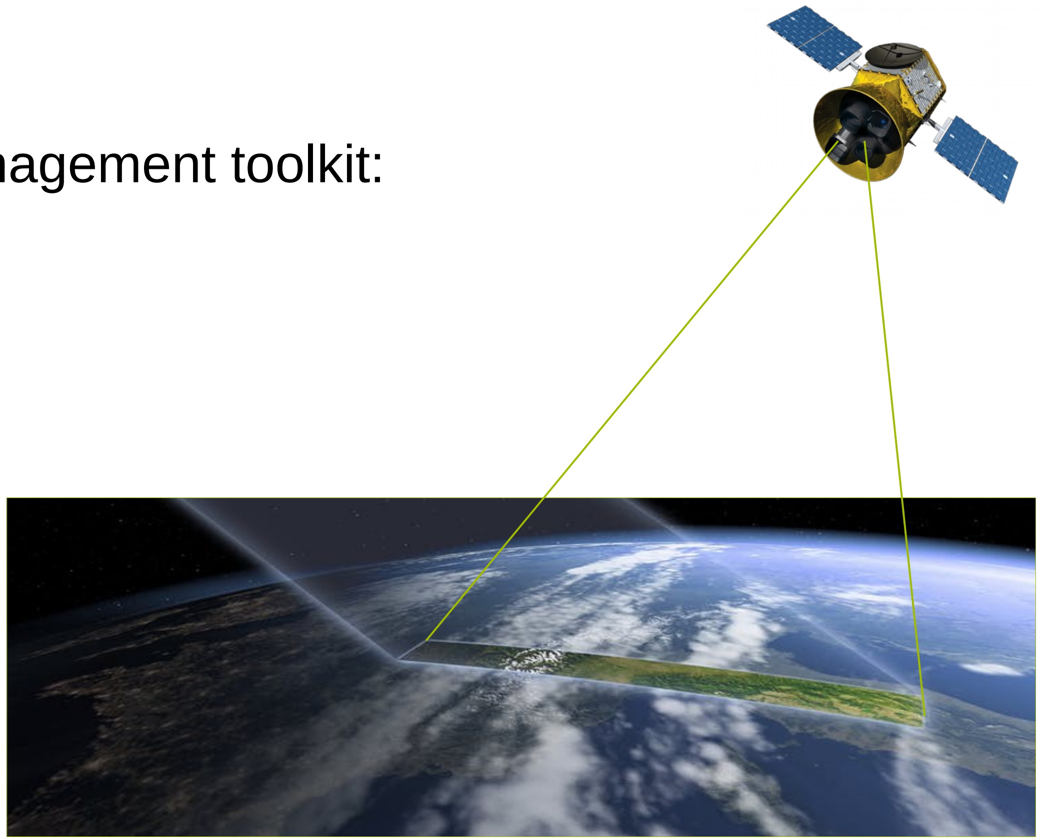
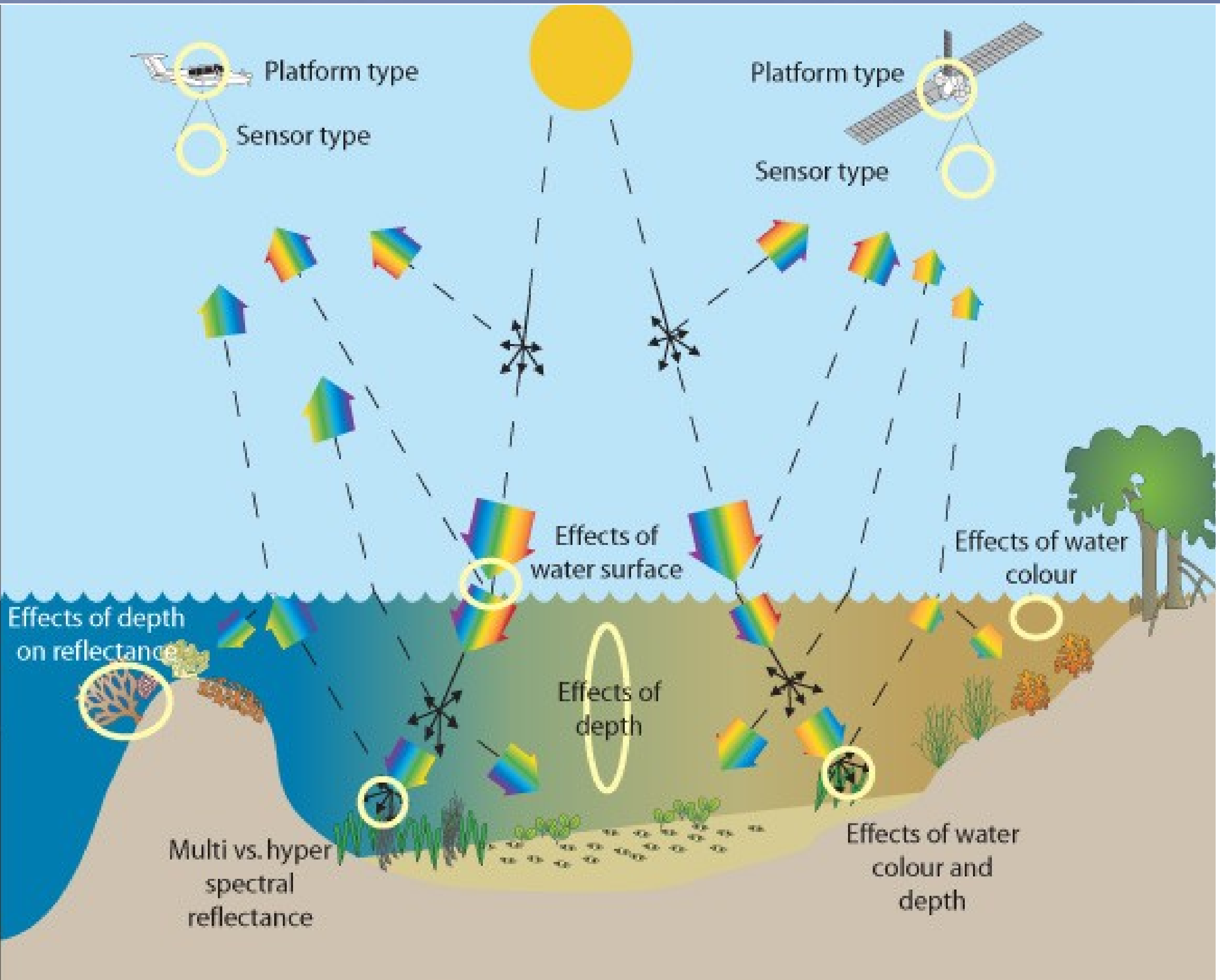
Aquatic Earth Observation

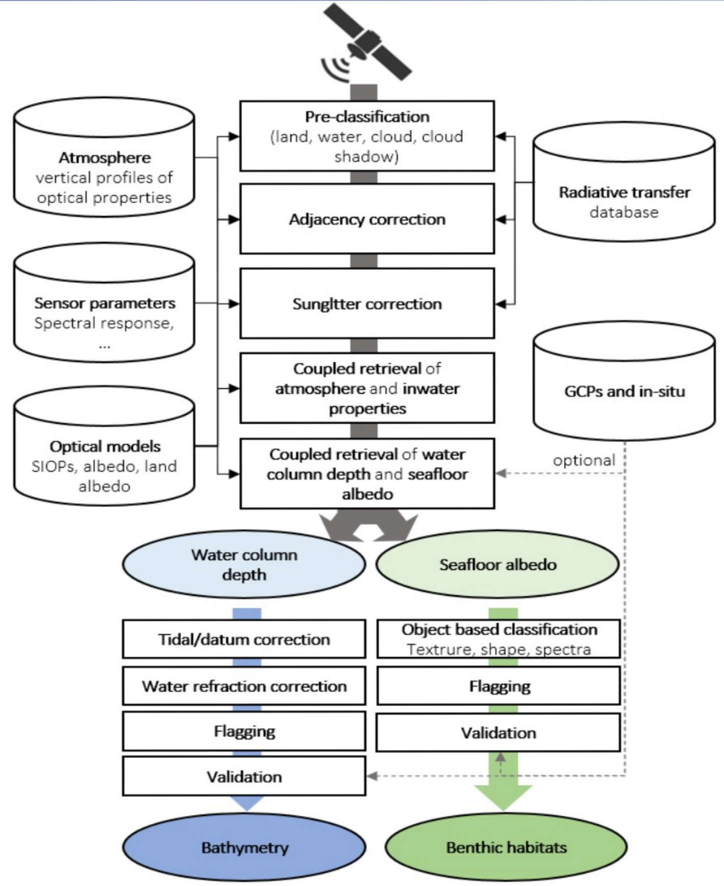
Why it should be in your coastal management toolkit:

- non-intrusive
- remote/inaccessible locations
- extensive coverage
- spatial and temporal continuity
- time travel
- quantitative, inter-comparable
- multiple information layers
- low cost
- rapid



Mapping aquatic environments with sunlight





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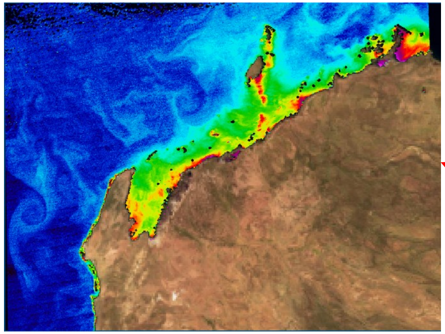
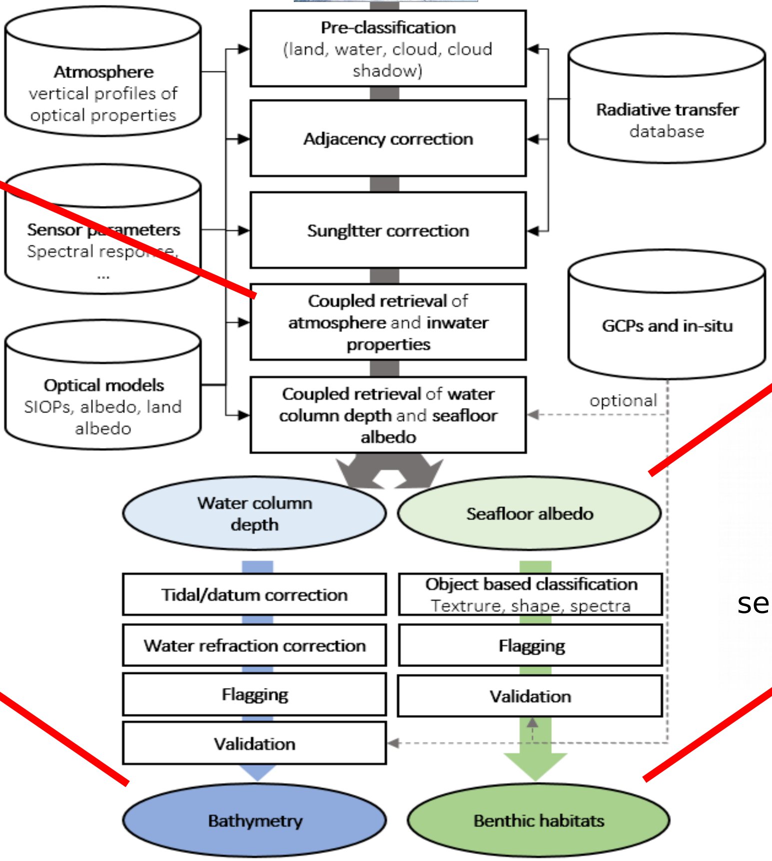
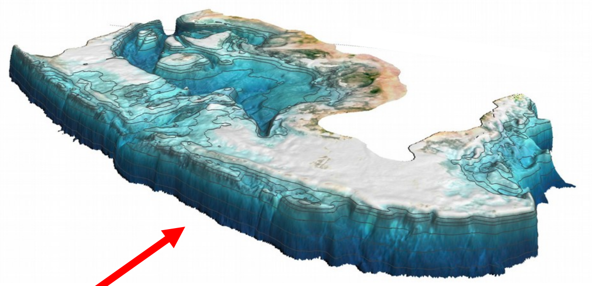
Physics-based Modular Inversion

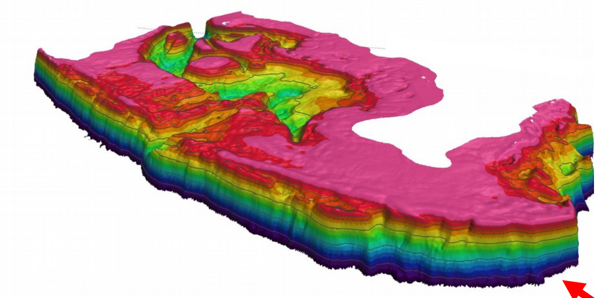
Water quality





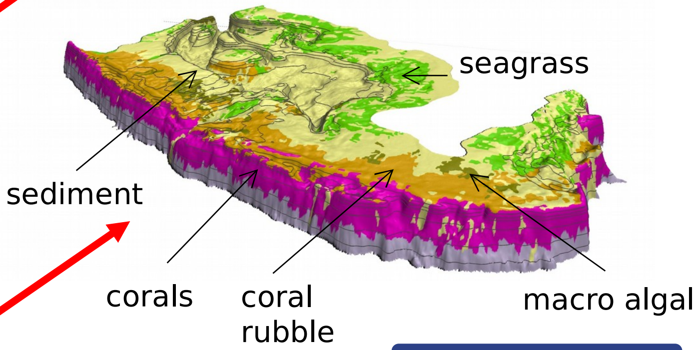
Seafloor reflectance (colour)



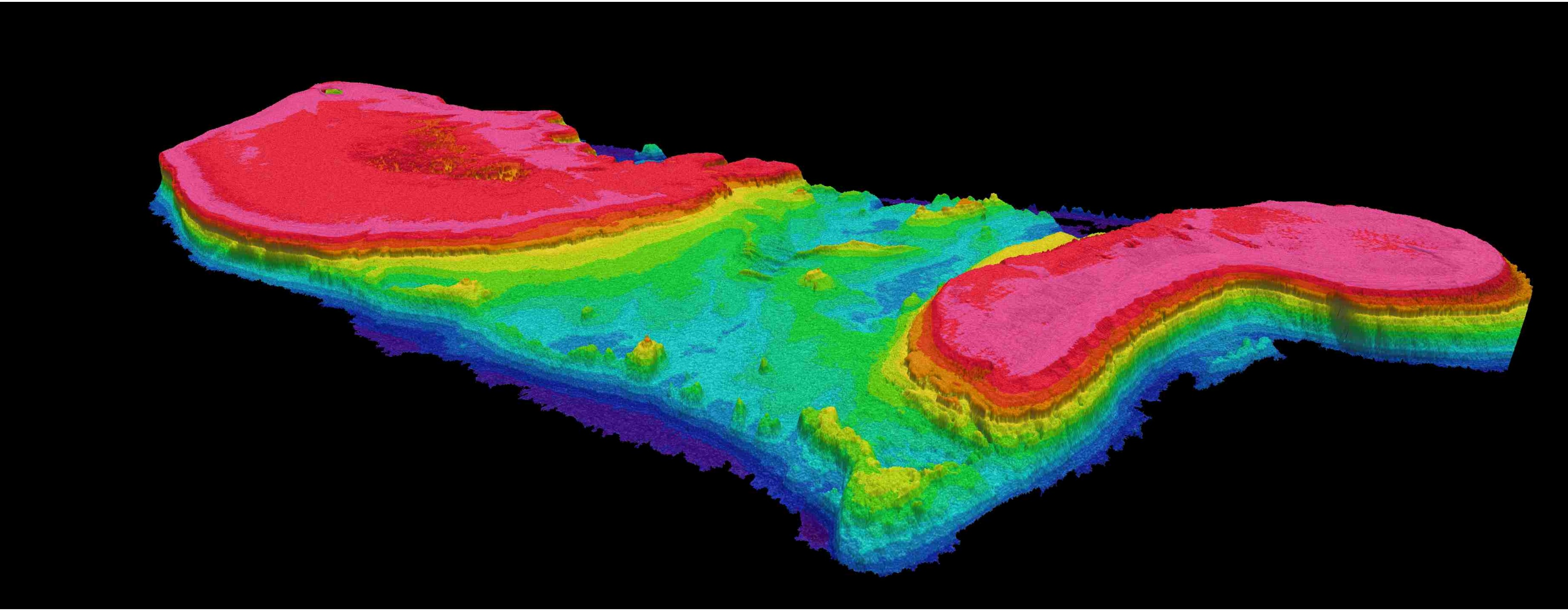


SDB (Satellite-derived bathymetry

Benthic habitats

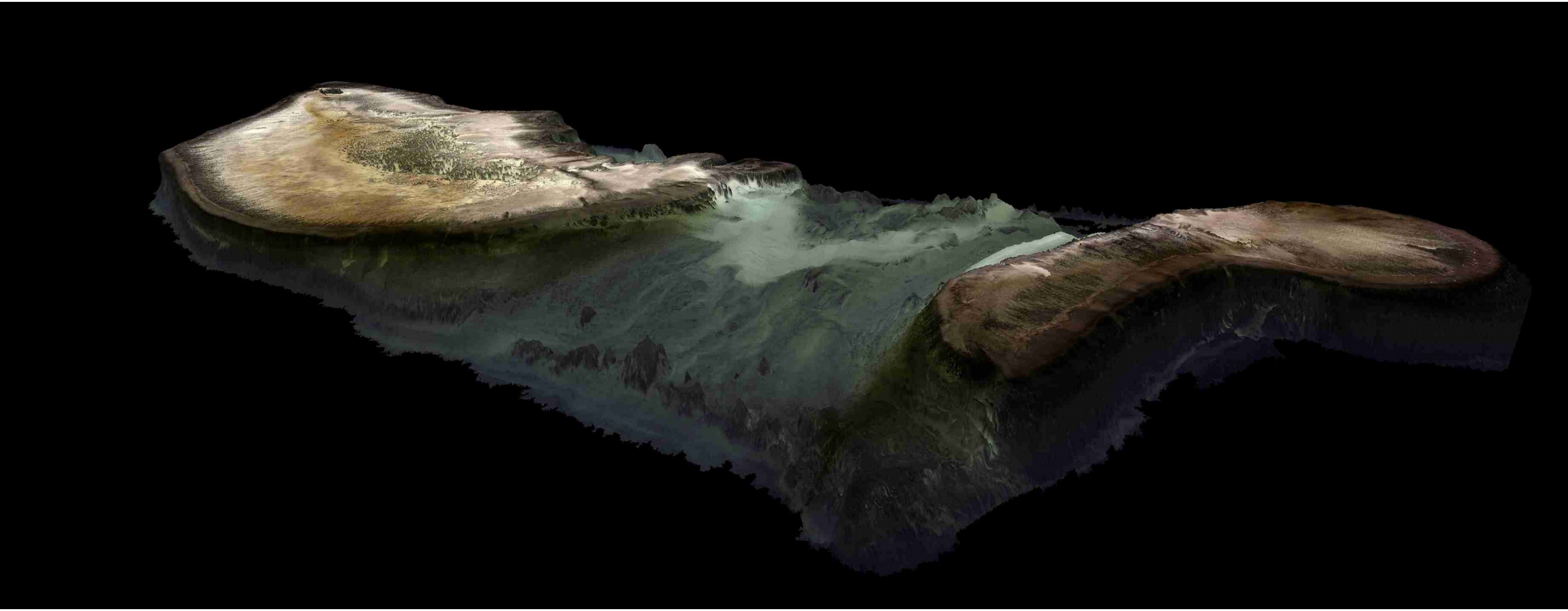


SDB @2m grid resolution



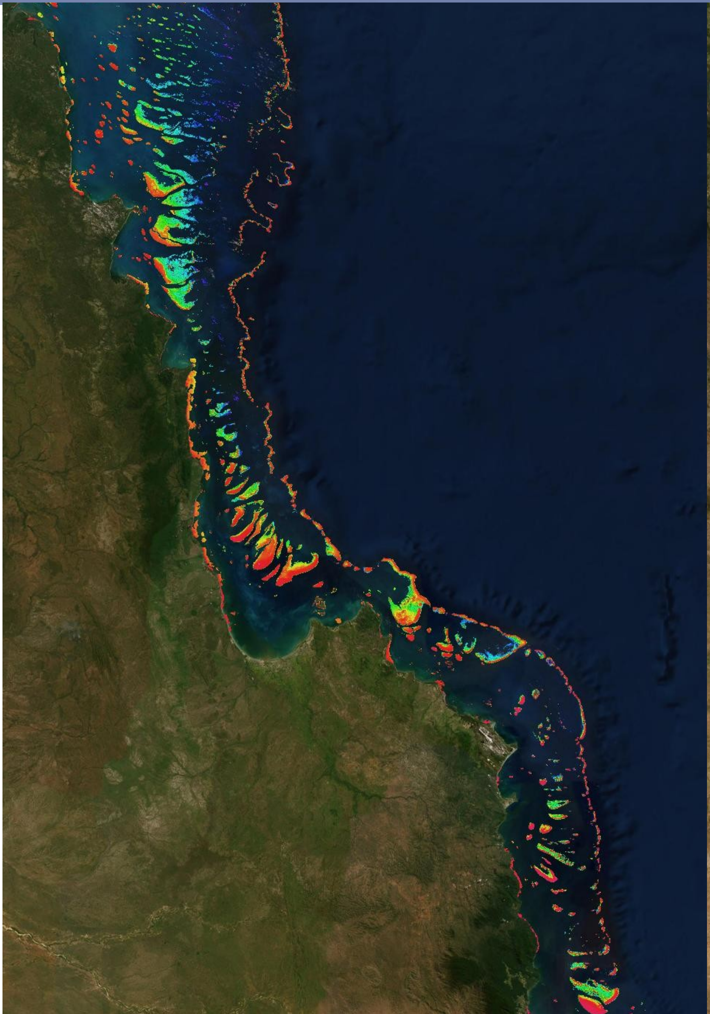
Heron and Sykes Reef, Great Barrier Reef

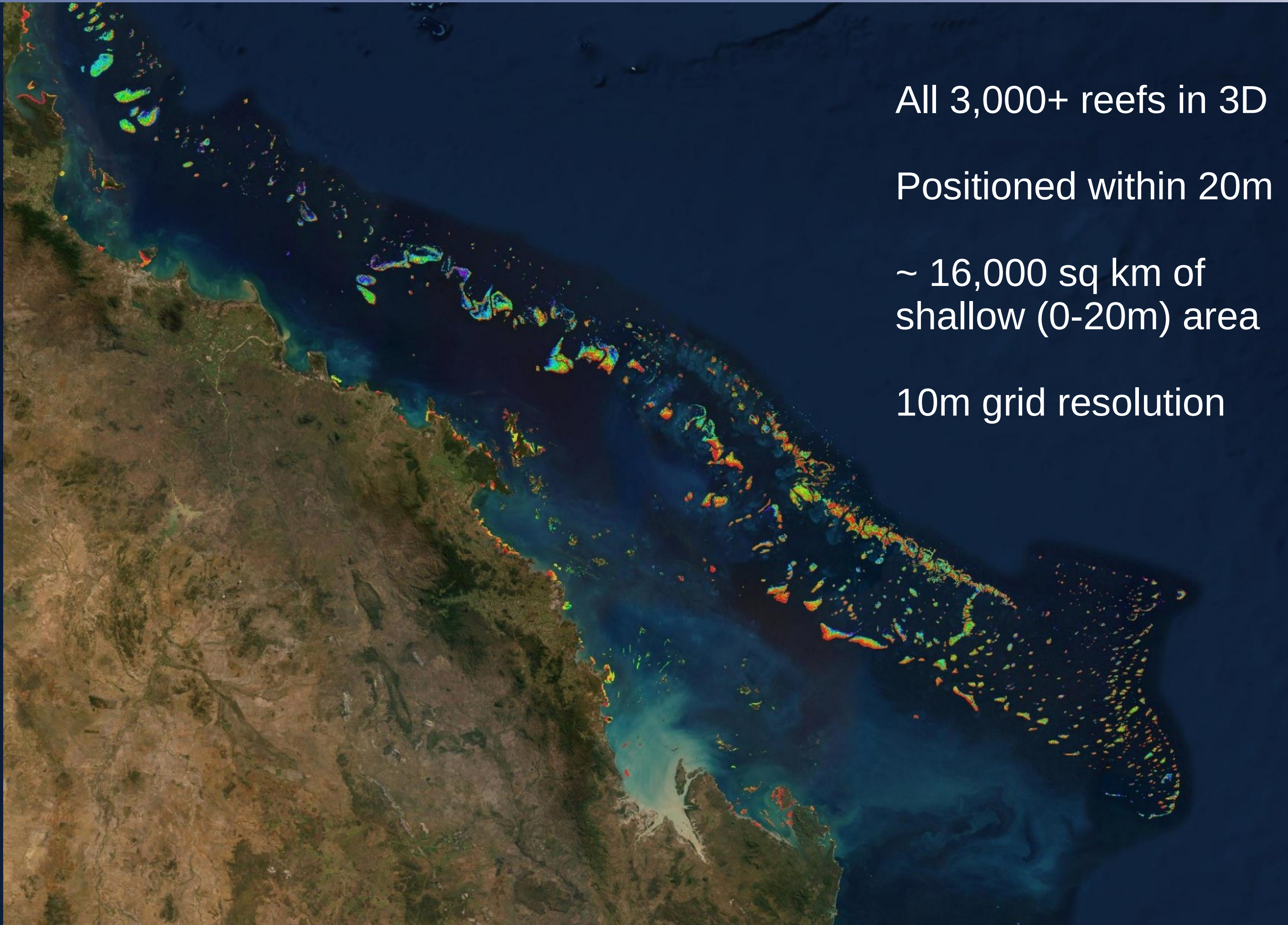
Seafloor reflectance draped over SDB



Heron and Sykes Reef, Great Barrier Reef

Entire Great Barrier Reef at 10m resolution





All 3,000+ reefs in 3D

Positioned within 20m

~ 16,000 sq km of shallow (0-20m) area

10m grid resolution

Norfolk and Phillip Islands: Baseline Mapping (2021)

www.tosp.com.au

Australian Government
Parks Australia

Australian Marine Parks

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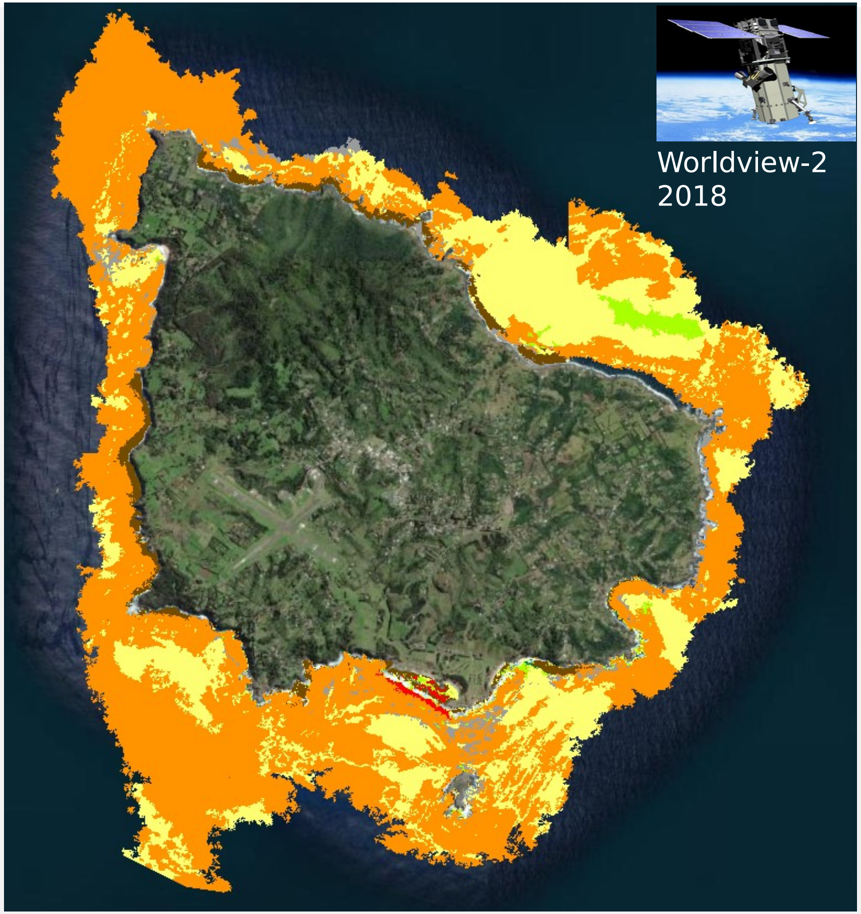
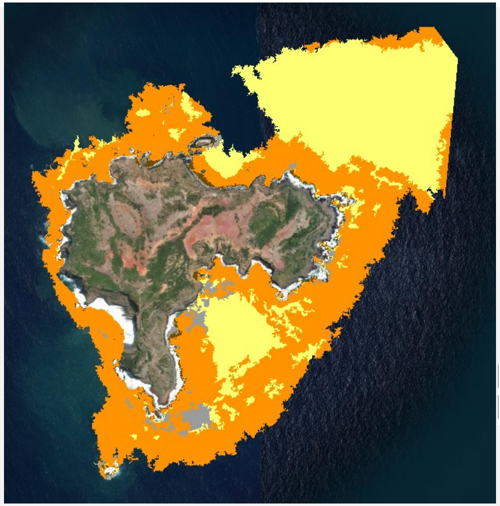
Norfolk and Phillip Islands: Baseline Mapping (2021)





Norfolk Island Mapping

Habitat Class

- Coral
- Hardbottom partly covered with macroalgae
- Hardbottom partly covered with coral and macroalgae
- Hardbottom uncovered
- Dense seagrass
- Unconsolidated sediment (sand/gravel)
- Unconsolidated sediment with sparse seagrass

- Mosaic of WorldView-2 (2m) images from 2018
- Object-based image analysis - segmentation in Trimble eCognition software (sub-surface reflectance and SDB)
- Segments classified based on spectral thresholds and texture

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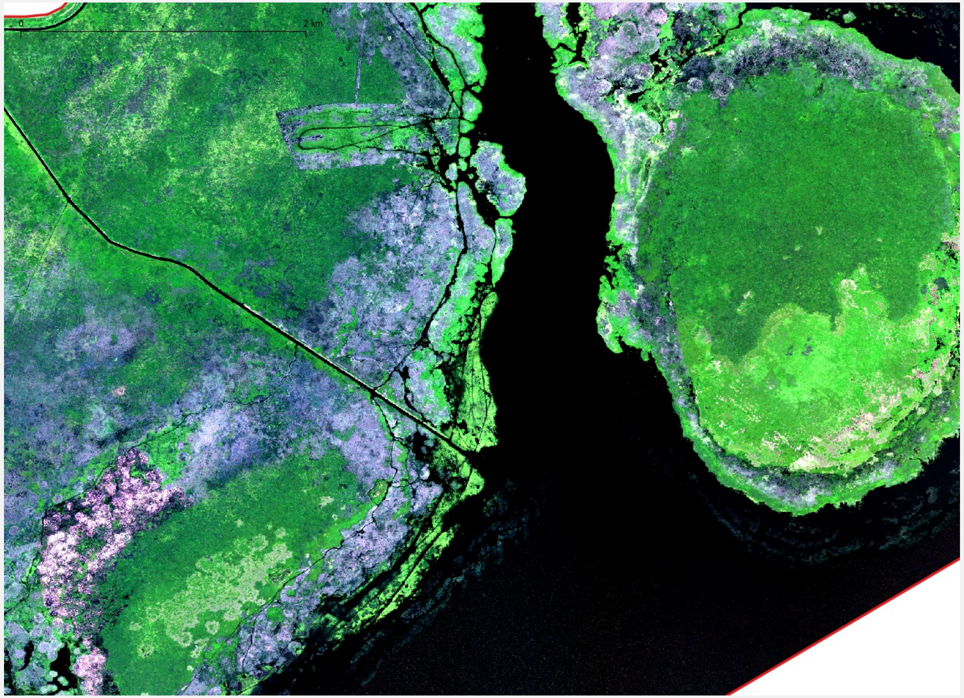
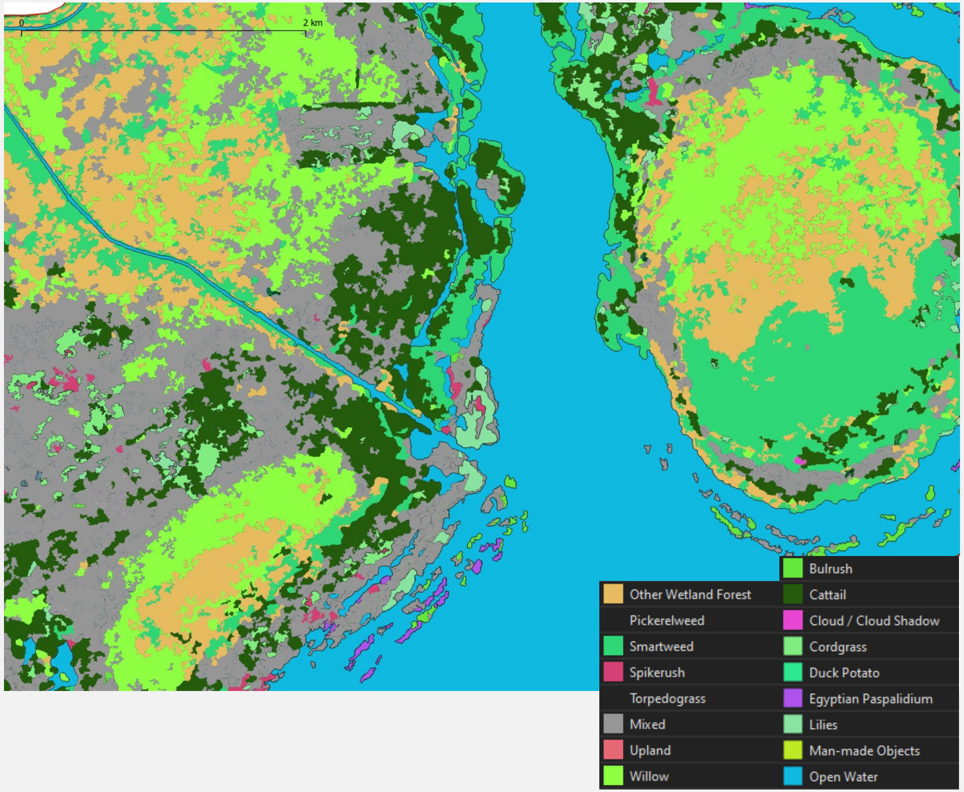
detect more.

Species level classification of Florida‘s lakes

VHR satellite image



Vegetation classification species level

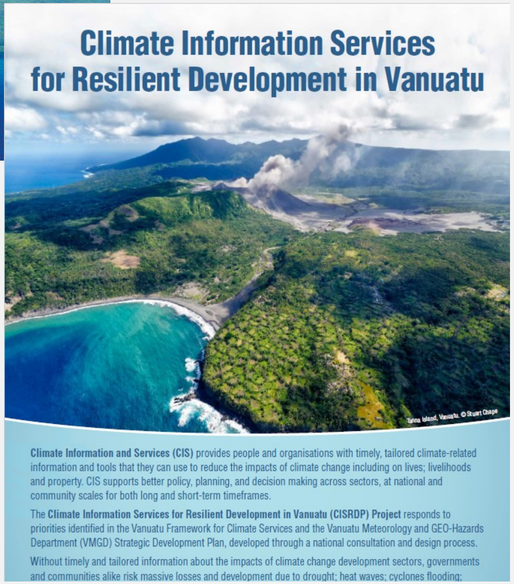


detect more.

Vanuatu Archipelago: Climate Change Resilience (2021)

Climate Information Services for Resilient Development in Vanuatu

- Vanuatu extremely vulnerable to climate change
- Standardise science-based climate information
- Underpins awareness and long-term policy planning around climate change
- Hydrodynamic, wave, and biogeochemical models amongst others



SPREP Secretariat of the Pacific Regional Environment Programme

CSIRO

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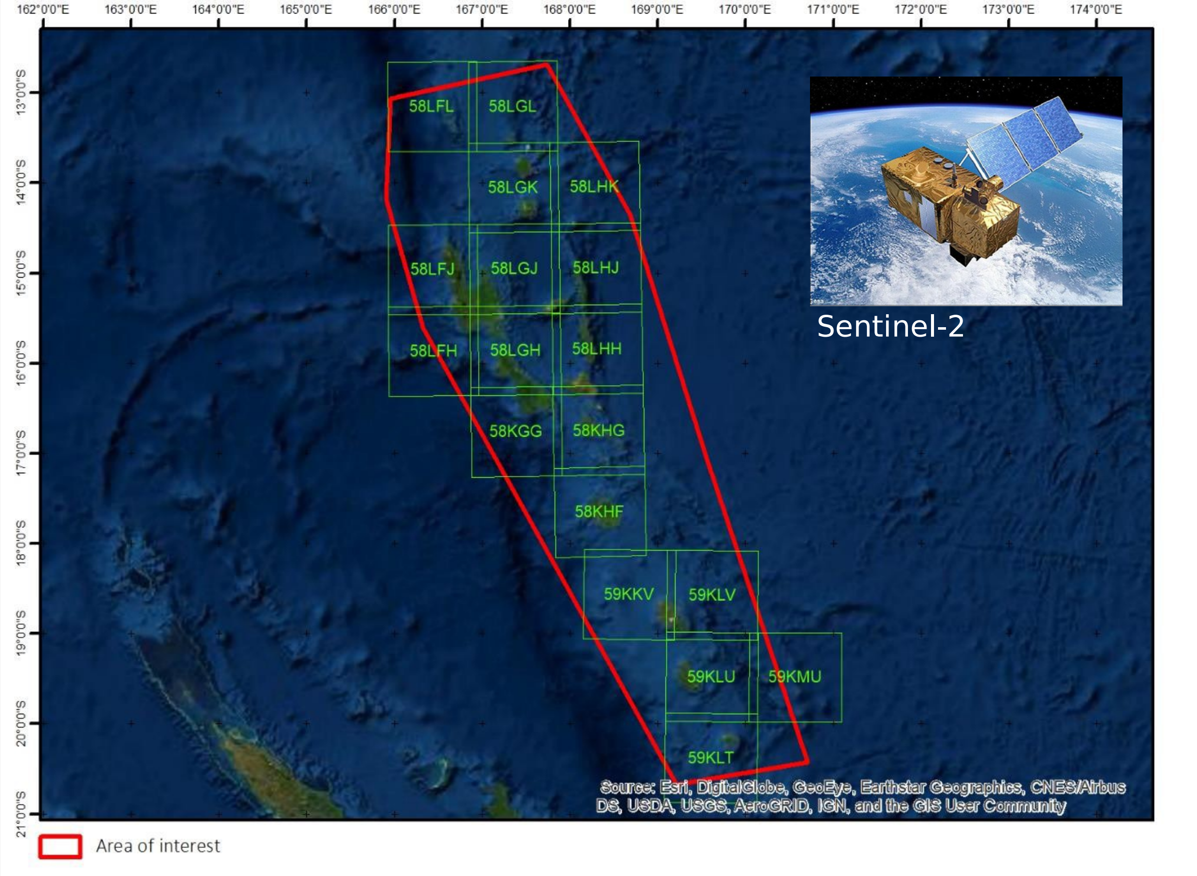
Vanuatu Archipelago: Climate Change Resilience (2021)

- **SDB** using Sentinel-2 (10m) for feasible shallow waters over entire area (~710km²)
  - Multi-temporal approach
  - Water depth to -23m (MSL)
- **Multi-source bathymetry** grid for entire area (~209,000km²)
  - SDB + ENC data interpolation (ANUDEM)
  - 50 and 250m grids for entire area
  - 10 and 20m grids for 0-200m depth
  - Water depth to -7732m (MSL)



SPREP Secretariat of the Pacific Regional Environment Programme

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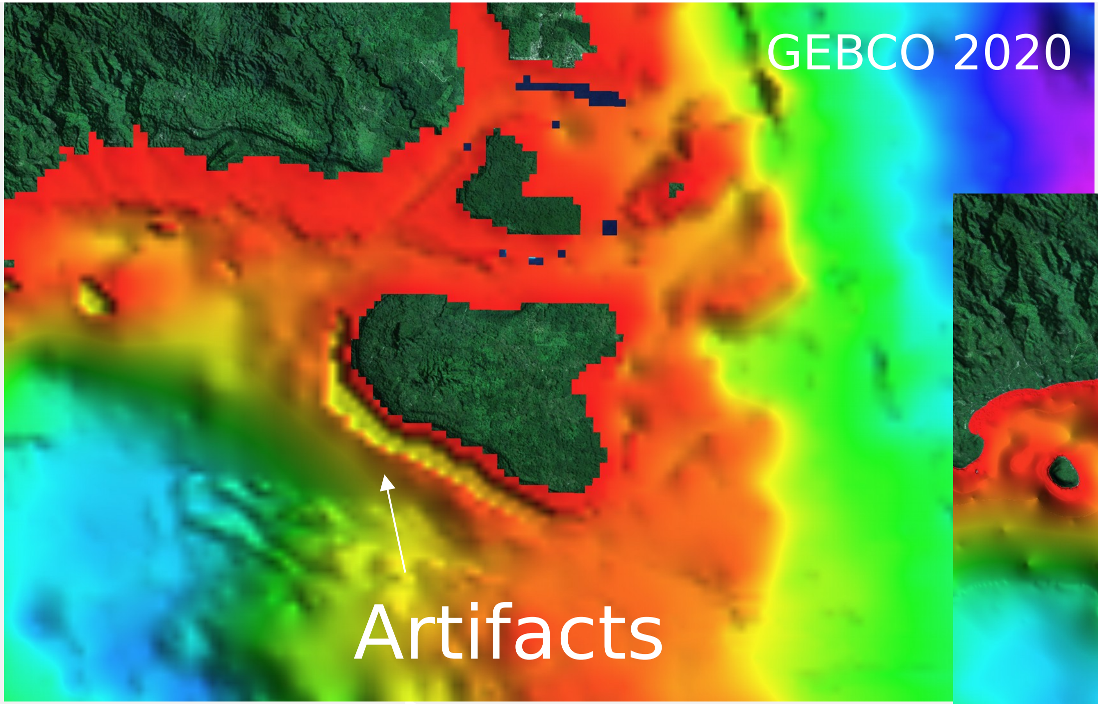
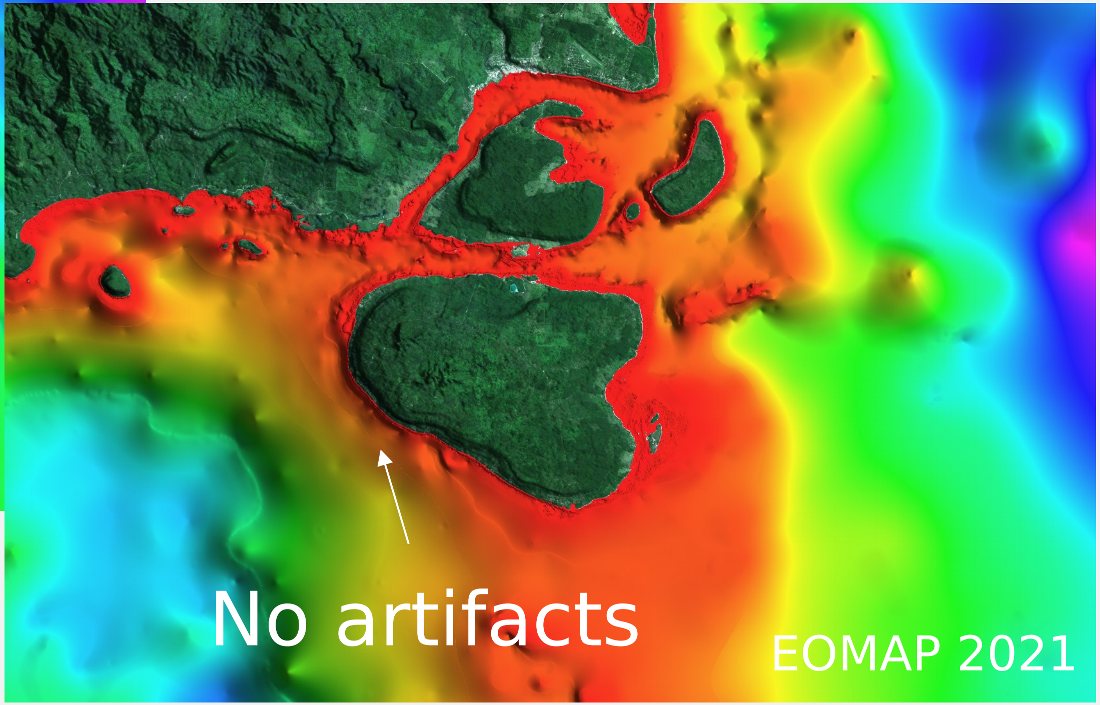
Vanuatu Archipelago: Climate Change Resilience (2021)





SPREP Secretariat of the Pacific Regional Environment Programme

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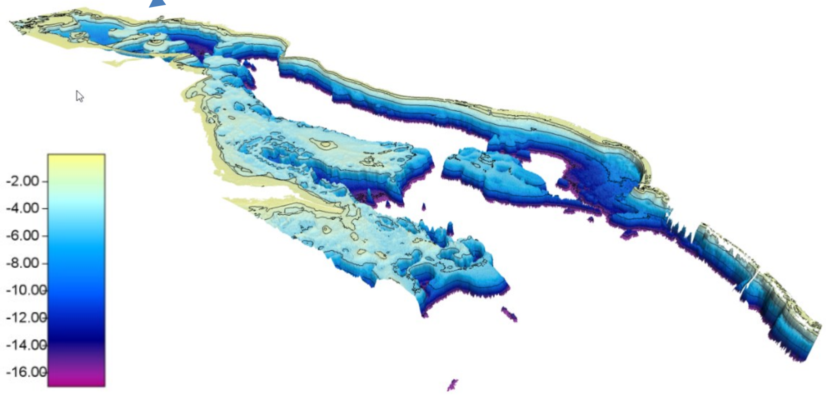
Example SDB – Satellite-Derived Bathymetry

Van Oord
Marine ingenuity

Can our csd Athena enter the area safely?



DIMENSIONS

Length over all	: 135.80 m
Breadth over all	: 27.82 m (without fendering)
Length between perpendiculars	: 108.00 m
Breadth moulded	: 27.80 m
Depth moulded	: 9.00 m
Draught - Light ship weight	: 5.62 m
Draught - International freeboard	: 6.60 m

Self-propelled cutter suction dredger Athena:

Monitoring and managing the Gold Coast Waterways

GCWA responsibilities include:
- manage ongoing dredging program for maintaining design depth spec's
- monitor changes in submerged vegetation (seagrass) distributions

Challenge: spatial complexity of waterways, timely data, limited resources

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Earth Observation monitoring of Gold Coast Waterways

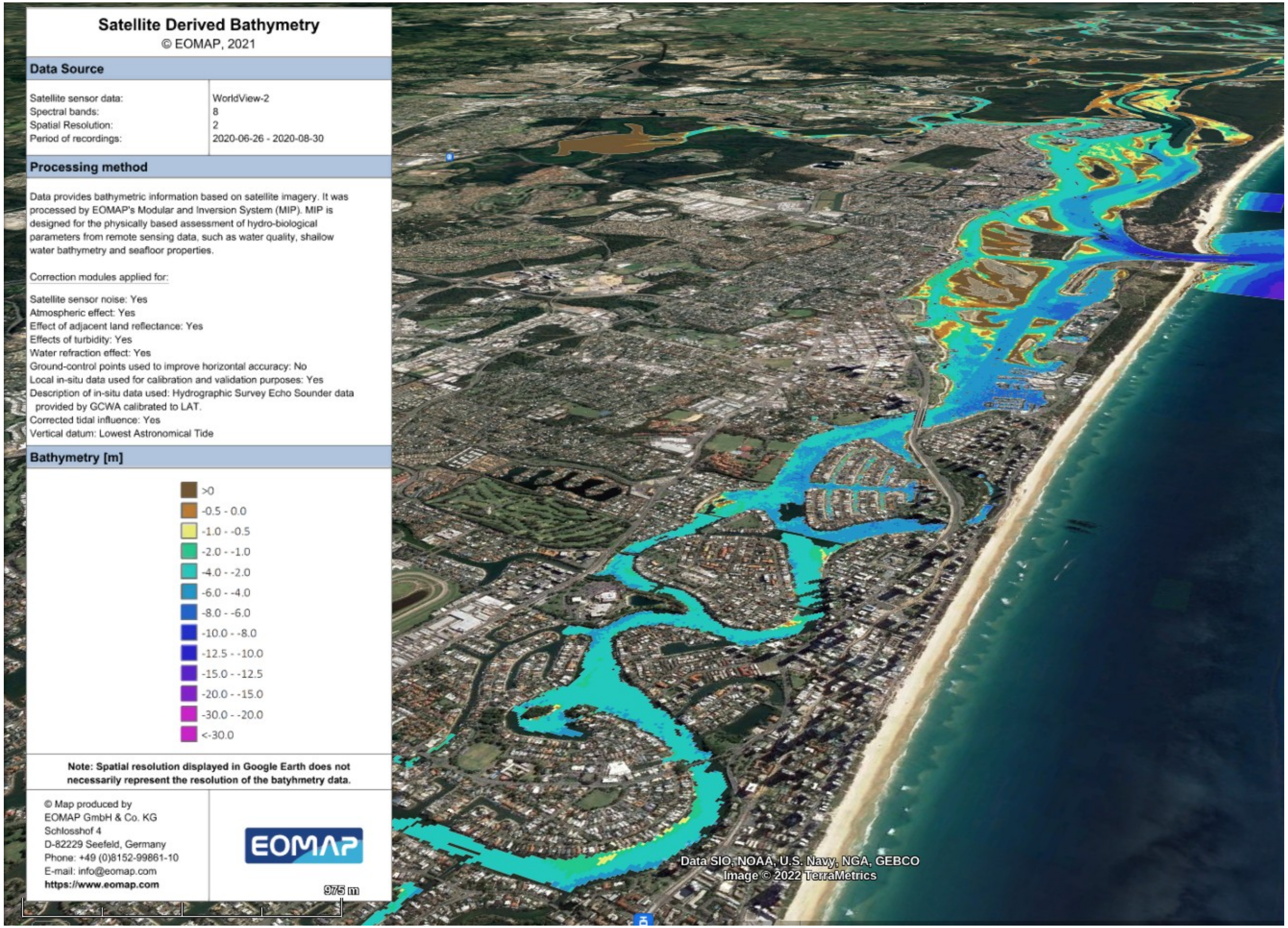

Image data capture:

- June-July 2020 and 2021
- 2m grid resolution

Geospatial products:

- SDB
- Z90
- SFC (submerged vegetation distribution)

Formats

- Geotiff
- Vector
- KMZ
- etc….

2m resolution SDB of Gold Coast Waterways

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Augmenting SDB coverage with z90

Significant proportion of optically deep channels (water visibility combined with geometric depth)

z90 = theoretical depth of 90% of light extinction

z90 = seafloor not visible - theoretical minimum depth

SDB coverage

z90 coverage

GOLD COAST WATERWAYS AUTHORITY

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Augmenting SDB coverage with z90

SDB coverage

z90 coverage

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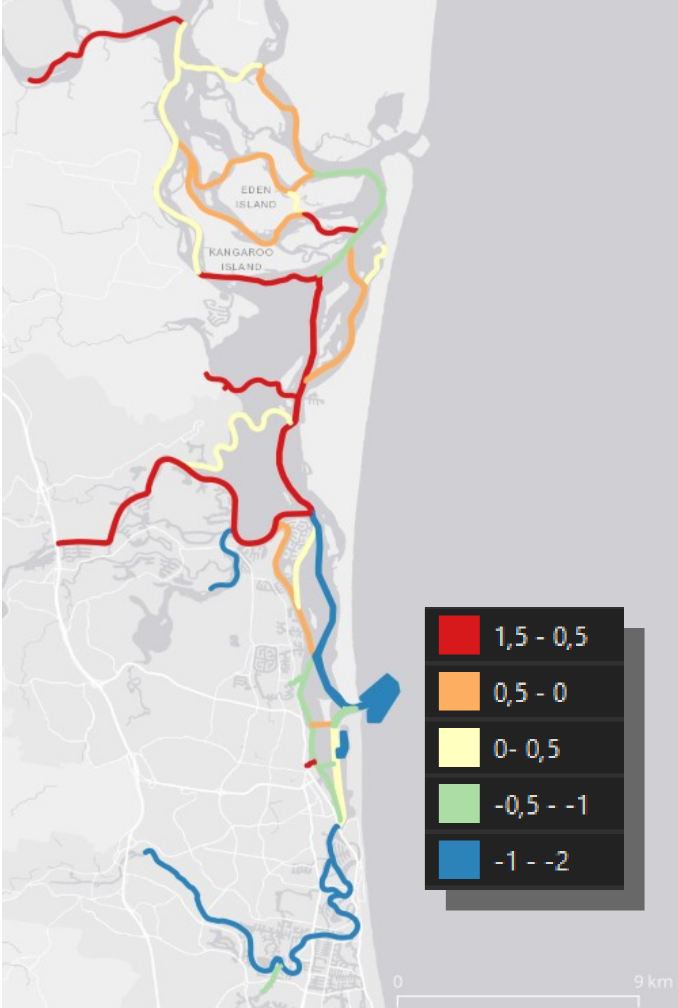
Monitoring SDB vs Design Depth: first pass dredging guidance



Design Depth – SDB
(positive value means shallower than design depth)

Seafloor Classification (SFC) of Gold Coast Waterways

unconsolidated sediment

submerged vegetation

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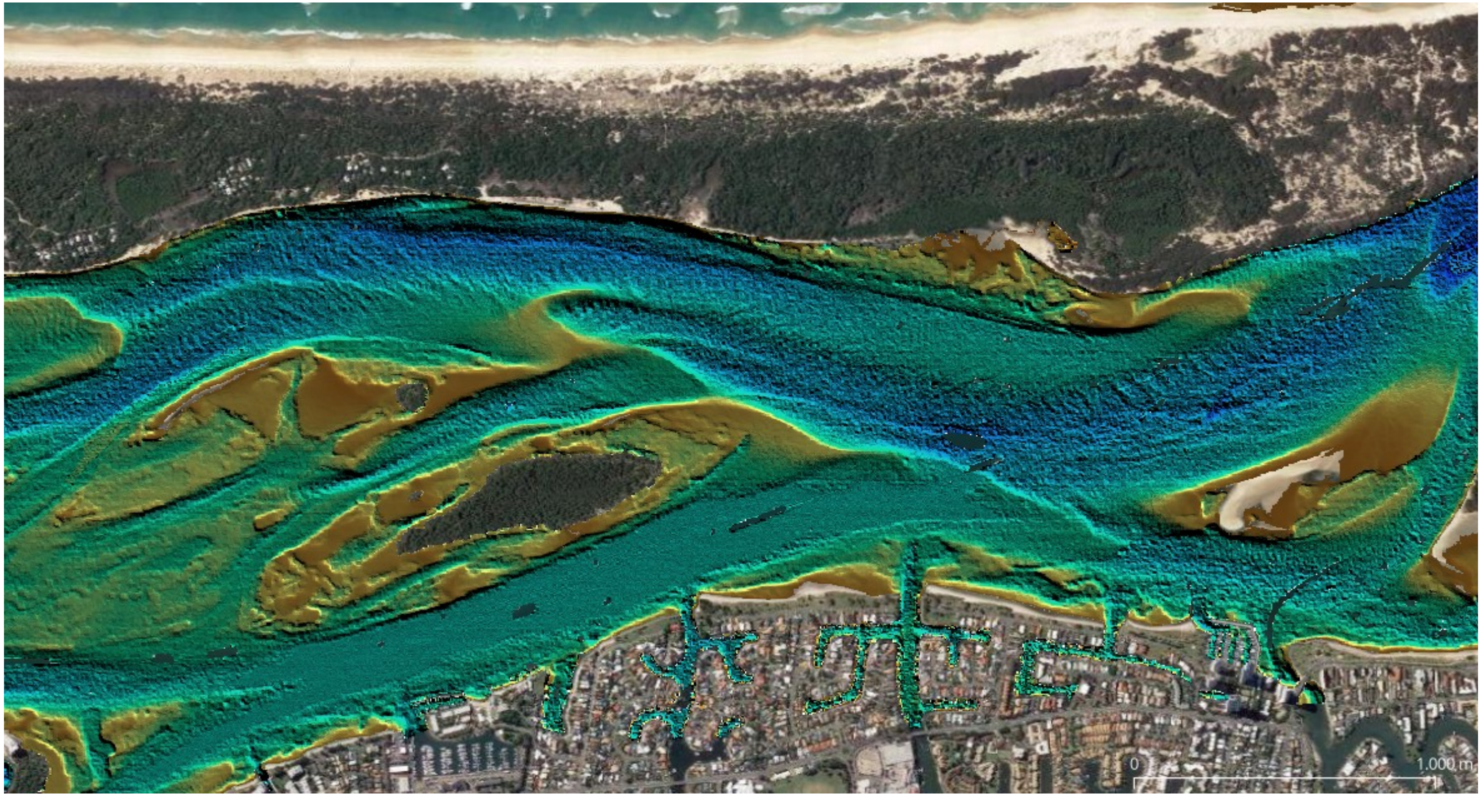
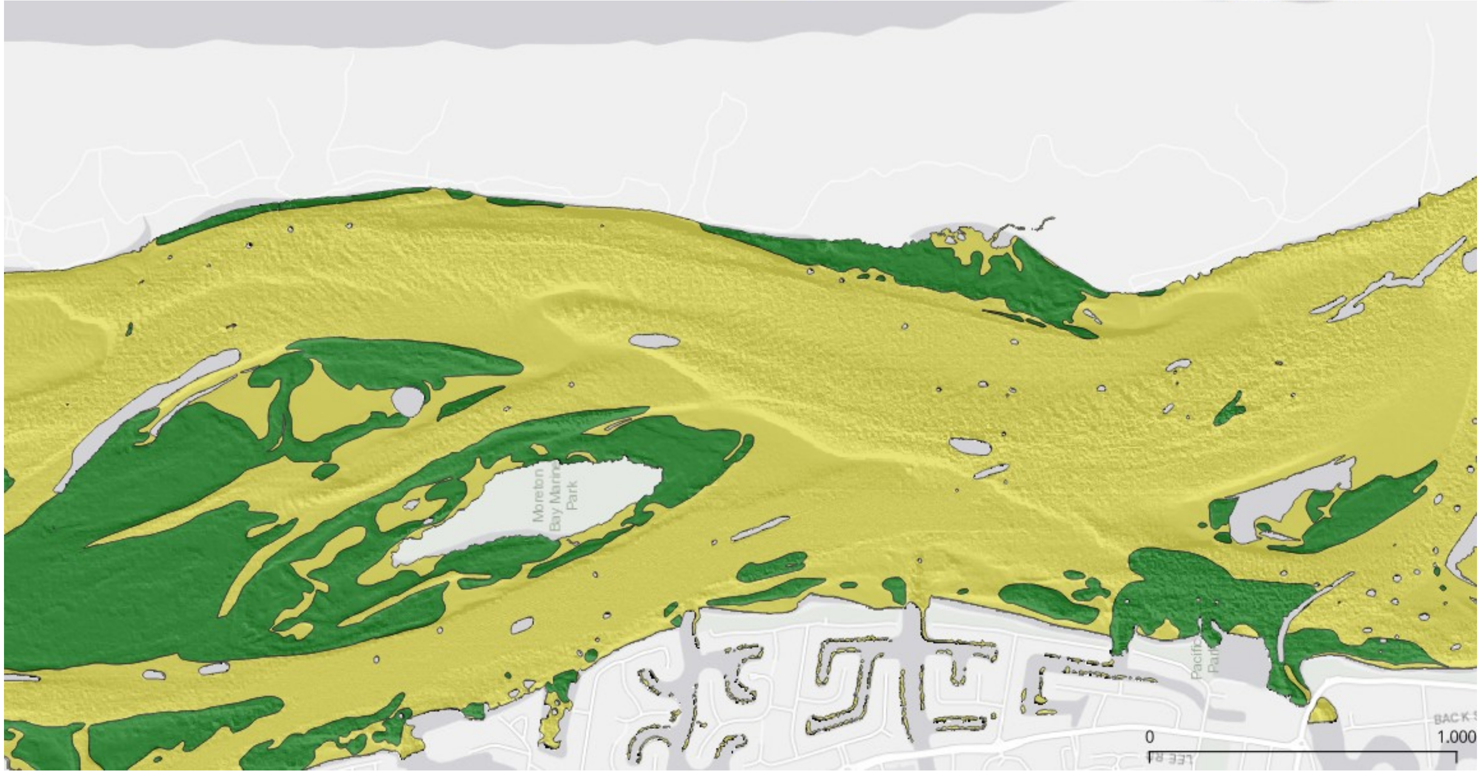
SDB of Gold Coast Waterways



SFC of Gold Coast Waterways



unconsolidated sediment

submerged vegetation

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EO-based monitoring of the Gold Coast Waterways

Initial conclusions

Complete, synoptic coverage of entire waterways and channel network at <u>one</u> point in time

Objective, quantitative data for monitoring change

Raster data sets with no interpolation: further analysis and value adding opportunities

Fit-for-purpose (e.g. z90)

Rapid turn around (weeks) = up-to-date dredging decisions, capture and adapt to events (e.g. storms)

Cost effective: ~~ 5 x 10 less than in situ survey methods

GOLD COAST WATERWAYS AUTHORITY

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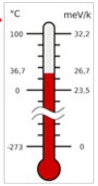
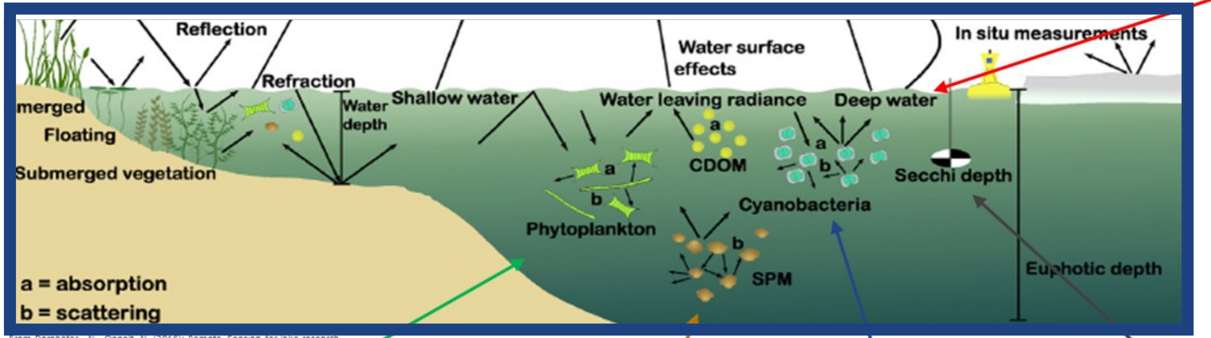
Water Quality from Earth Observation

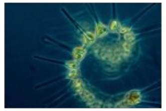
Surface Temperature

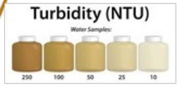




From Dornhofer, N., Oppelt, N. (2016): Remote Sensing for lake research and monitoring – Recent advances. Ecological Indicators 64

Chlorophyll-a





Turbidity/

Suspended Matter

Secchi Depth

Harmful Algae Blooms

Other Products:

- Coloured Dissolved Organic Matter
- Water extent
- Trophic State Index
- Evaporation
- KdPAR
- Inorganic and organic absorption
- …

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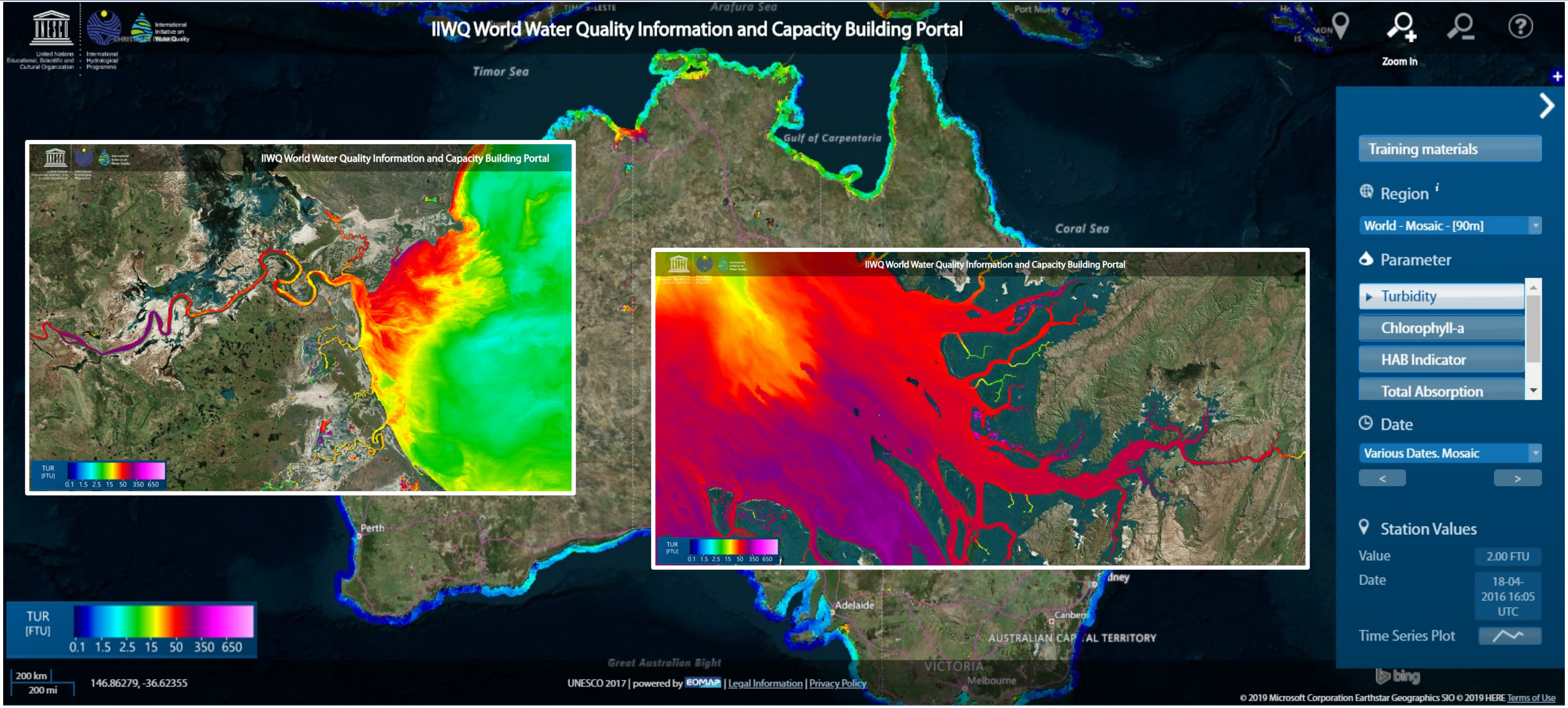
World Water Quality Information Capacity Buidling Portal for UNESCO



www.worldwaterquality.org

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Water Quality monitoring, Australia

Turbidity Monitoring:

Adaptive management for dredging program

Hay Point and Port Weipa

- Benthic turbidity loggers
- Surface near-real time measurements
- Synoptic satellite-derived turbidity maps

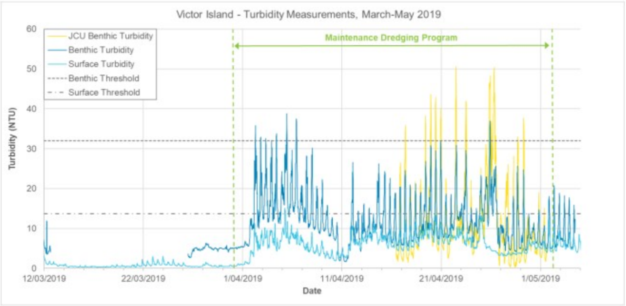
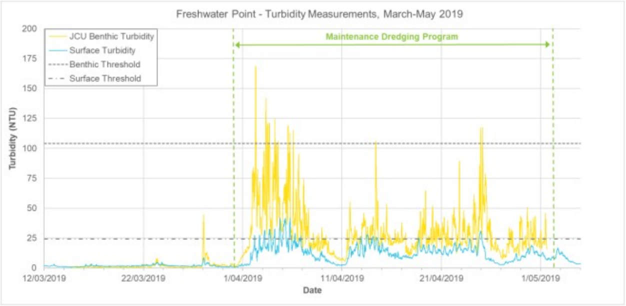
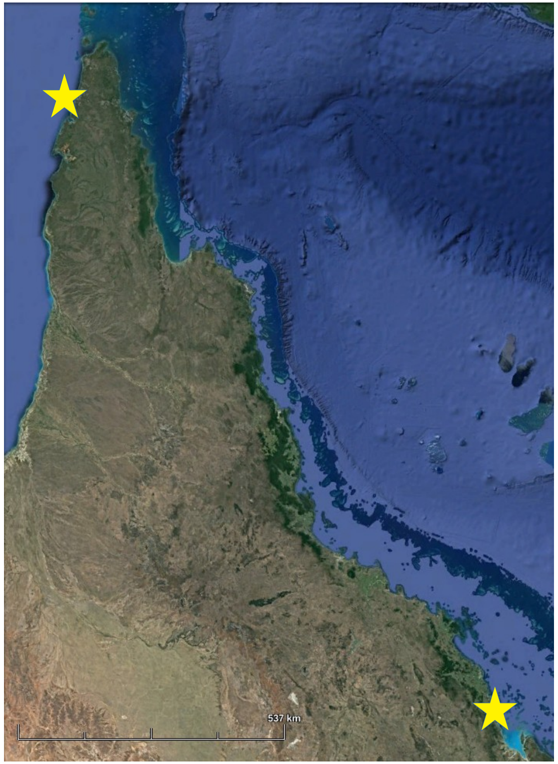


Figure 4. Hourly rolling average benthic and surface turbidity at Victor Island from 12th March to 5th May 2019. The data labelled Benthic Turbidity is the VE measured benthic turbidity data.





QUEENSLAND BULK PORTS CORPORATION

PORT & COASTAL SOLUTIONS

EOMAP

Water Quality monitoring, Weipa

Port of Weipa

2018/19 wet season:

> 2M m^3 sediment deposited in South Channel

~ 3X previous highest annual sedimentation volume

QUEENSLAND BULK PORTS CORPORATION

PORT & COASTAL SOLUTIONS

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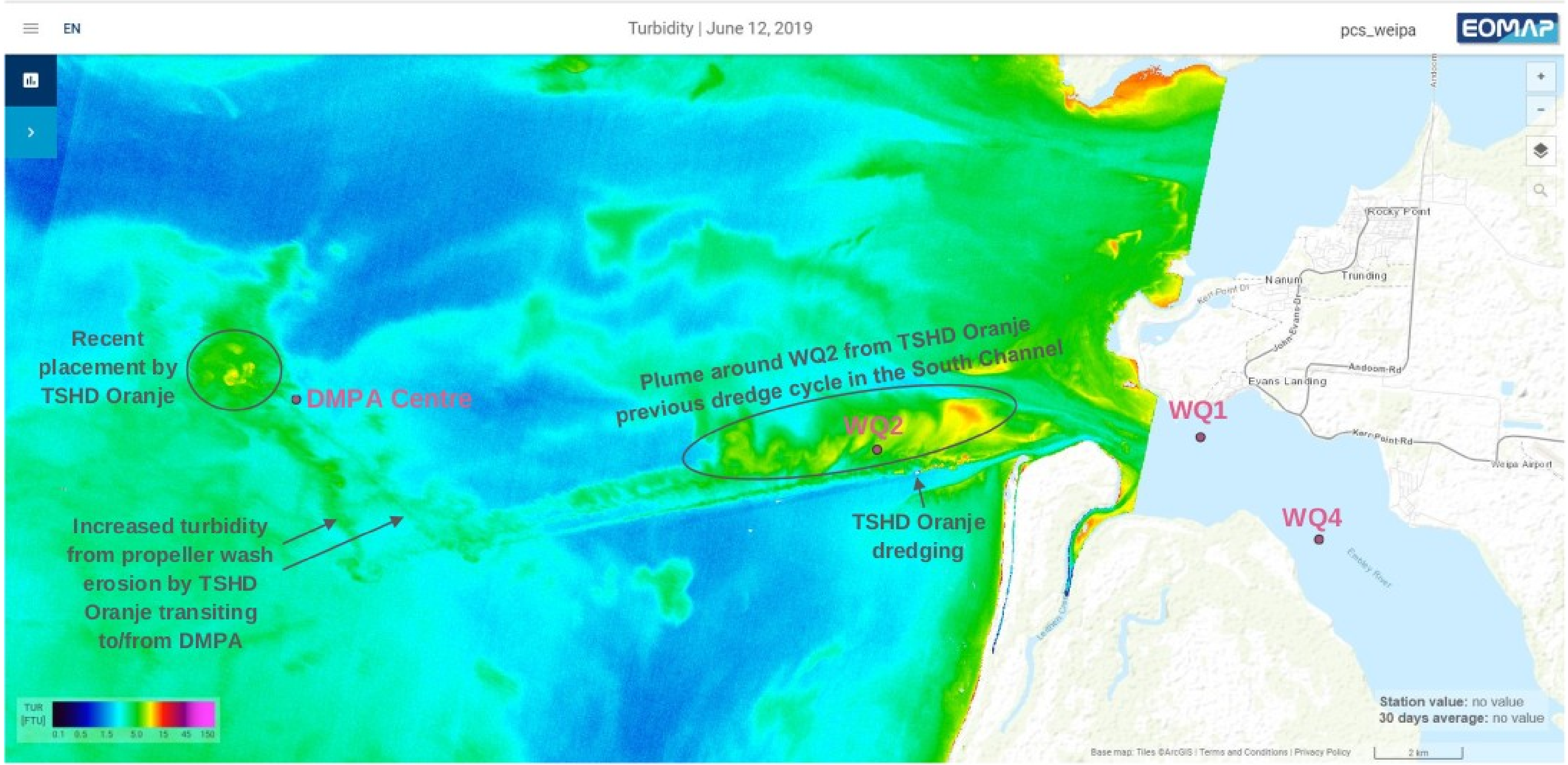
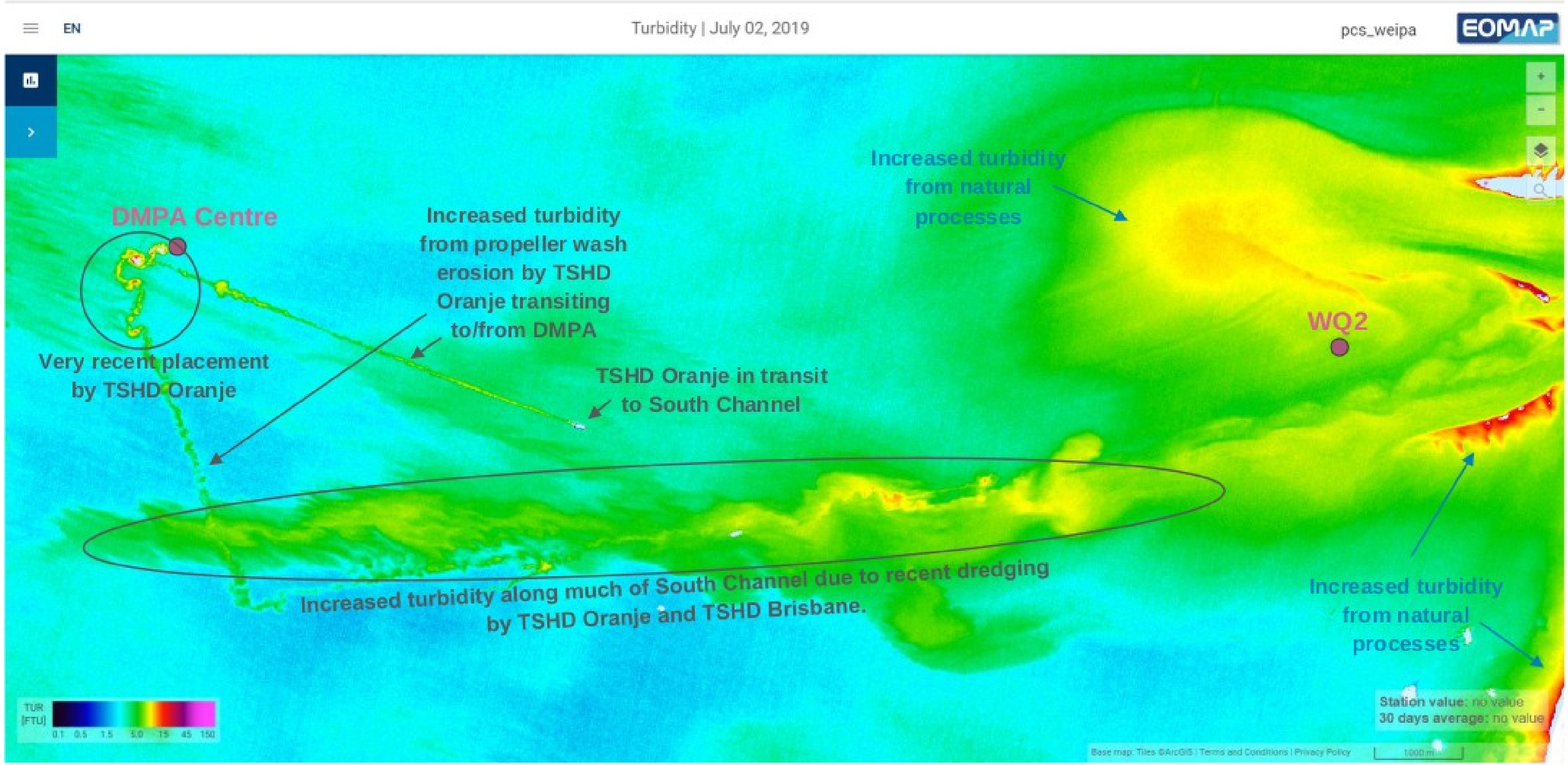
Water Quality monitoring



Port of Weipa

Water Quality monitoring



Port of Weipa

Water Quality monitoring

In summary

Weipa: Plumes visible, but limited transport. Remained close to where they were generated (South Channel or material placement site)

Satellite data offered

- ongoing spatial context for entire study area
- further insight into sedimentation mechanisms
- low cost alternative to monitoring entire area with in situ technology

Xylem eoPortal

WELCOME THOMAS

xylem

Visualize

Gridded EO Products

Temporal Resolution
All

Layer
Turbidity

Datetime
2019-10-24 15:40:16

Add RGB Background Layer

In-Situ and Model Data

Layer
Harbor Water Quality

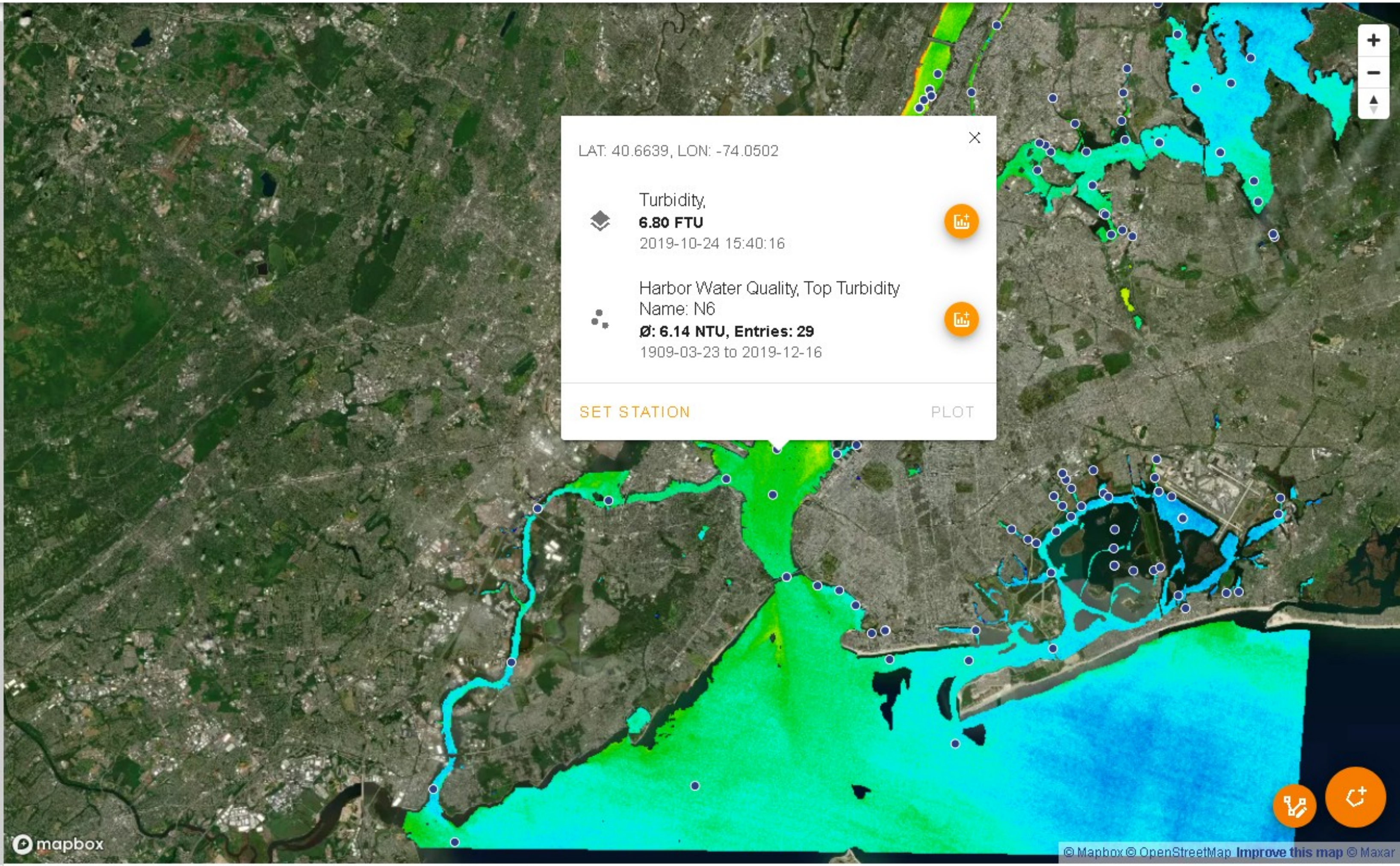
Category
All

Parameter
Top Turbidity

Start Date
1909-03-23

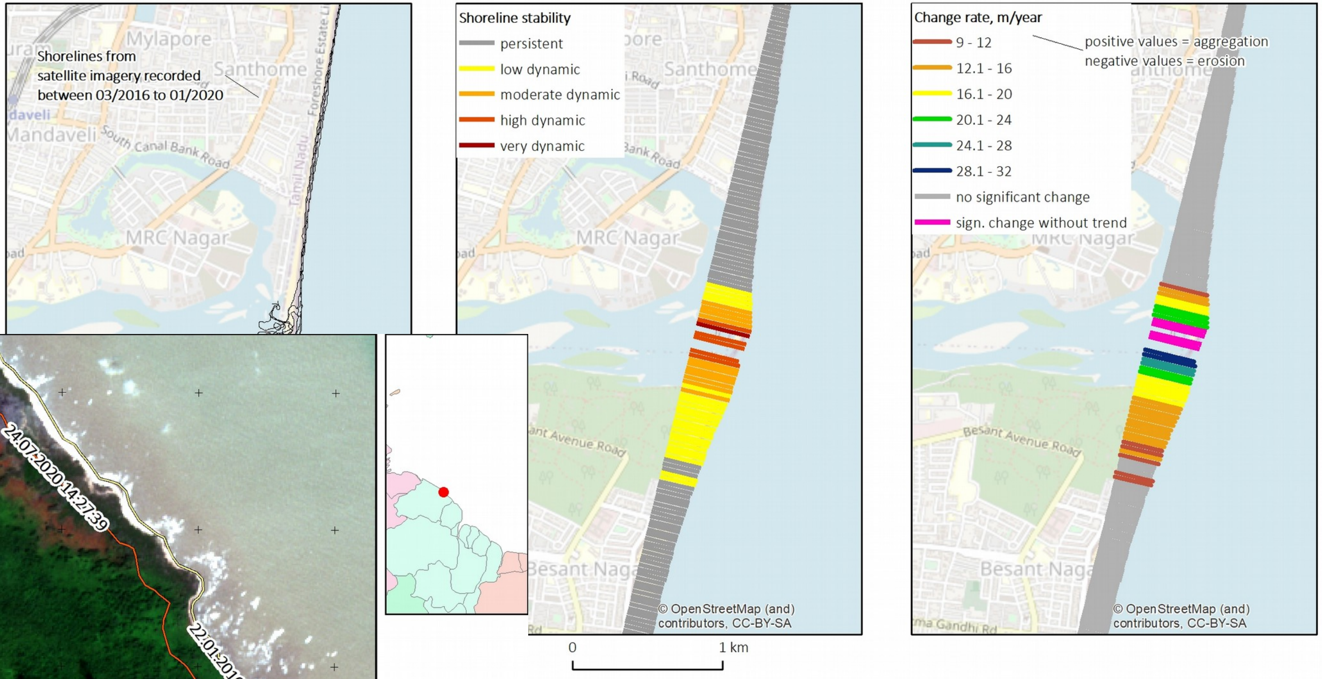
End Date
2019-12-16

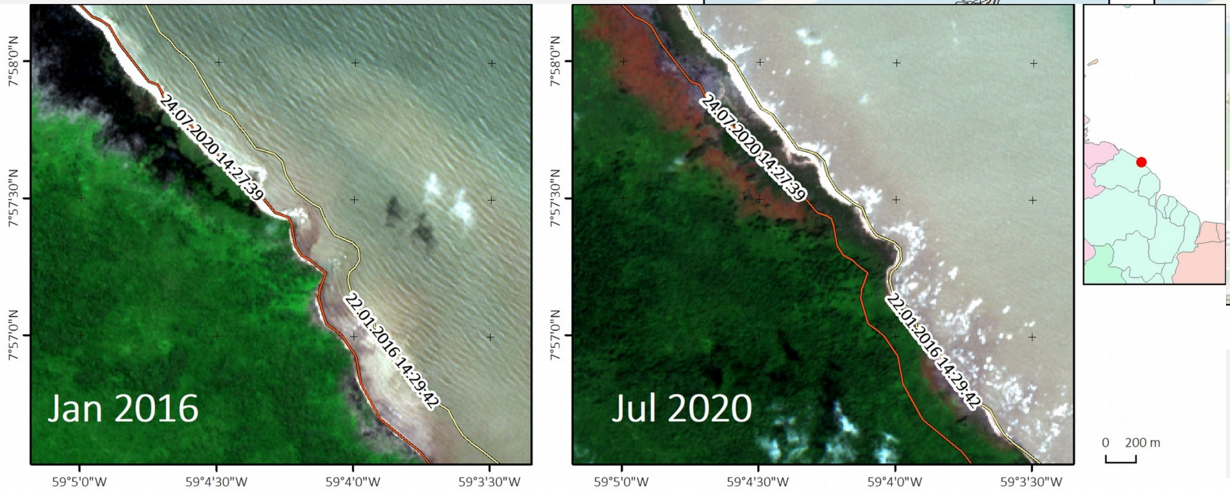
Virtual Stations



EOMAP Shoreline Stability Assessment

Satellite based mapping of shoreline change over time and quantification of shoreline erosion rate and stability.





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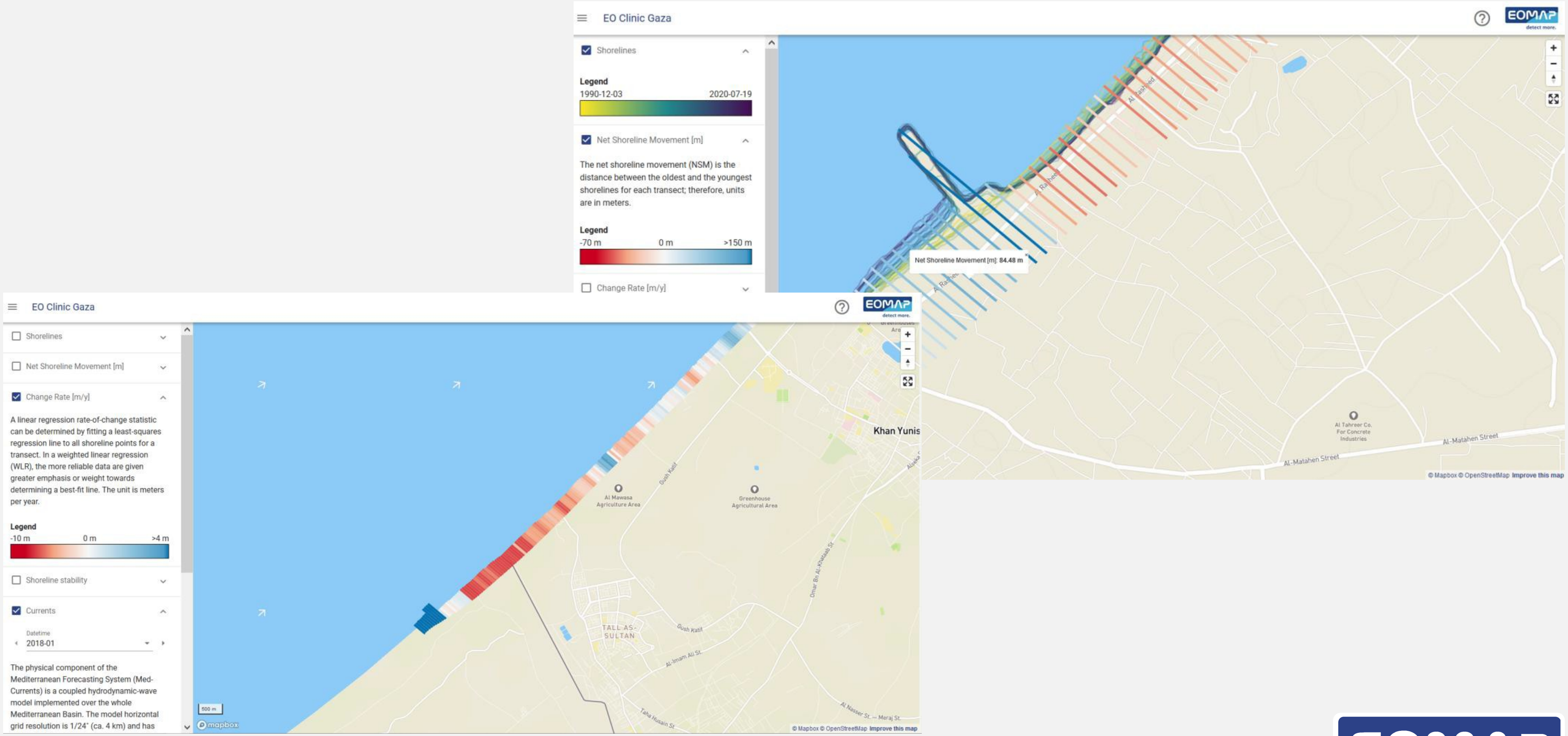
detect more.

Coastal WebApp : EO portal



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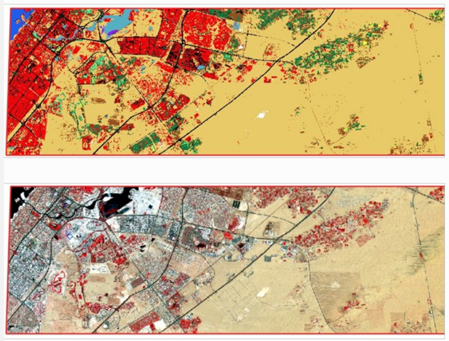
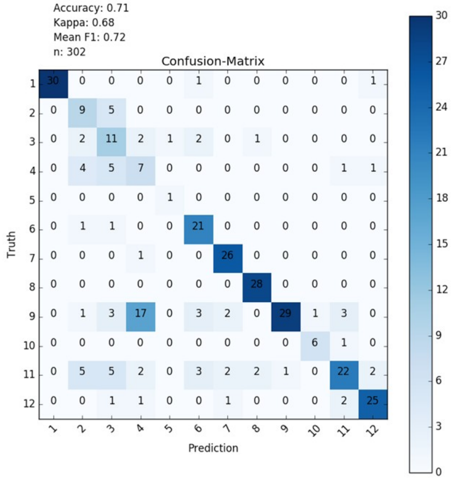
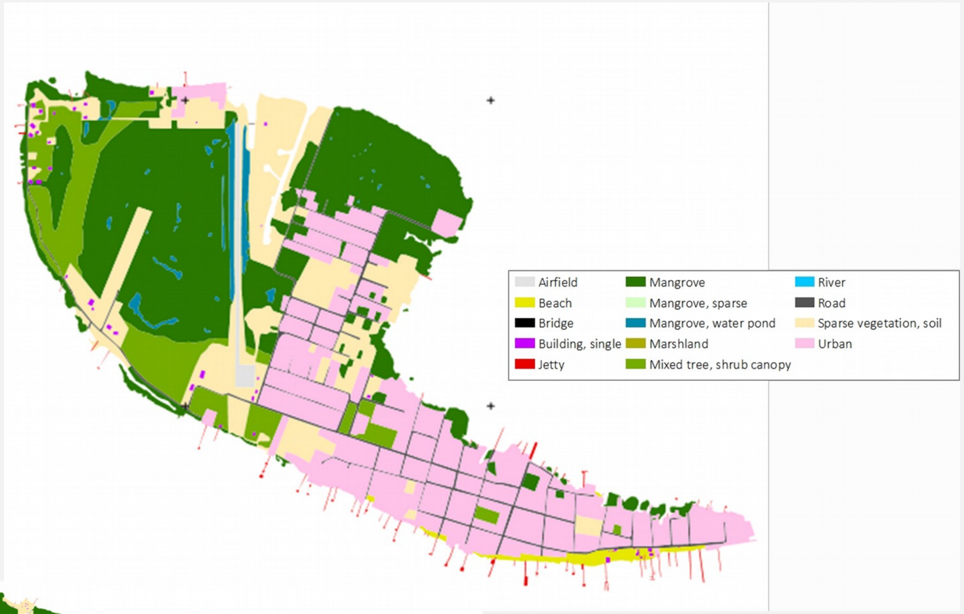
Thematic land cover map

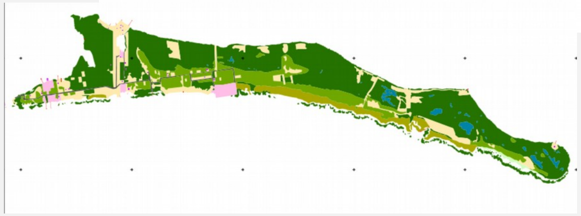
Cloud based workflows for continous mapping of land cover (below: Dubai)





“Standard“ thematic land cover map (below: Belize)

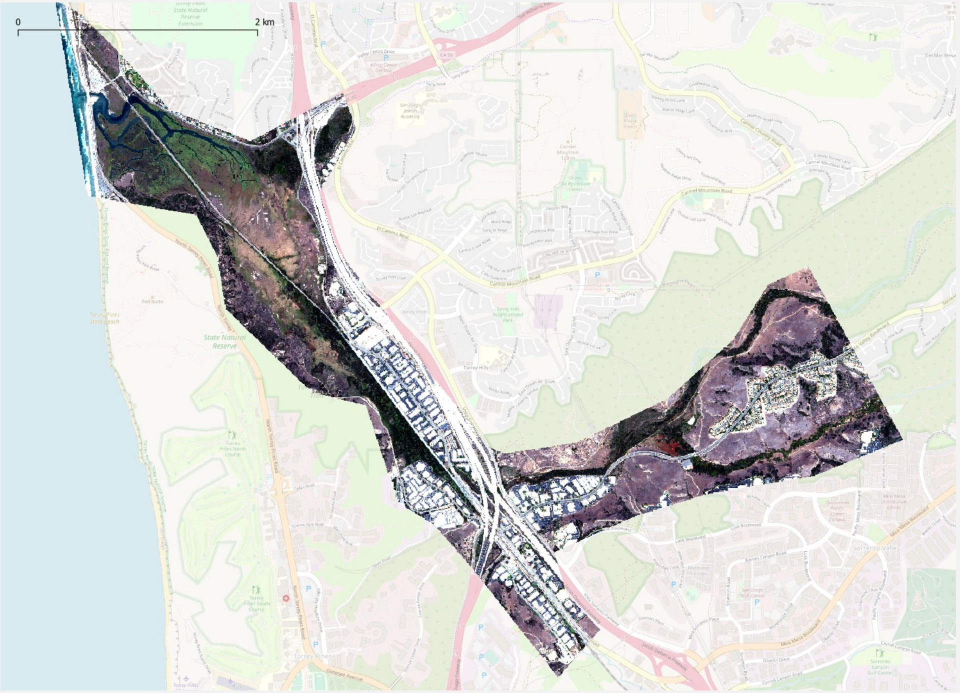




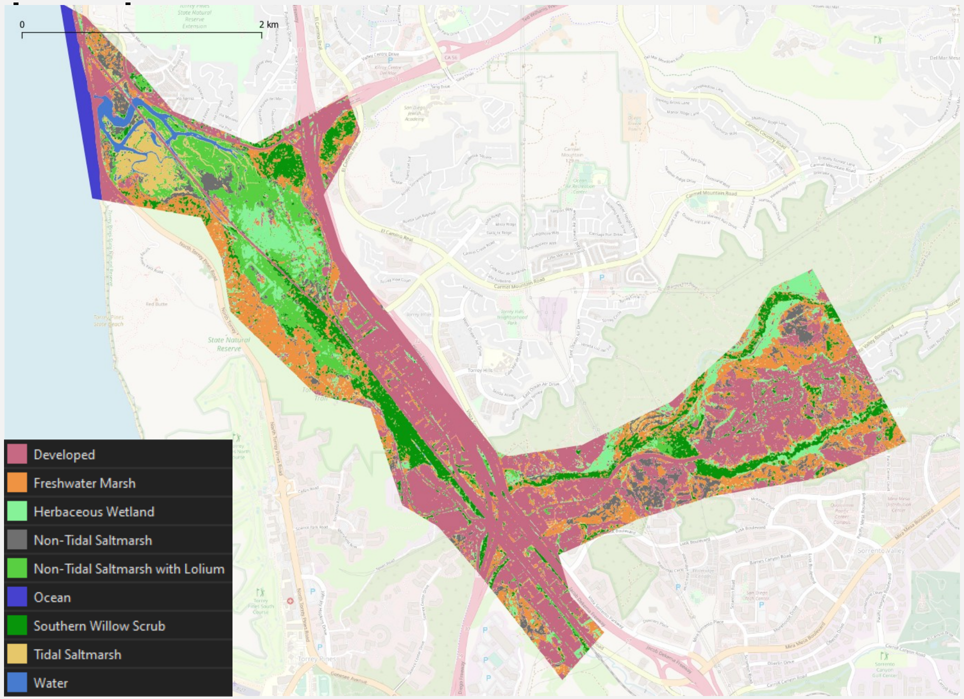
detect more.

Vegetation mapping, California

VHR satellite image



Vegetation classification species



detect more.

Finally here: SDB software for different needs

	software installation	calibration data	features
WATCOR-X	**local**	**independent**	transparent, accuracy assessment, sophisticated
LiteCOR-X	**local**	required	fast, easy
eoLytics-SDB	**online****	required	fast, easy
SDB-Online	**online****	**independent**	transparent, accuracy assessment, sophisticated
eoLytics-SWIFT, -WQ, -ICESAT …	**online***	-	Image finder, water quality analysis, ICESAT toolkit …

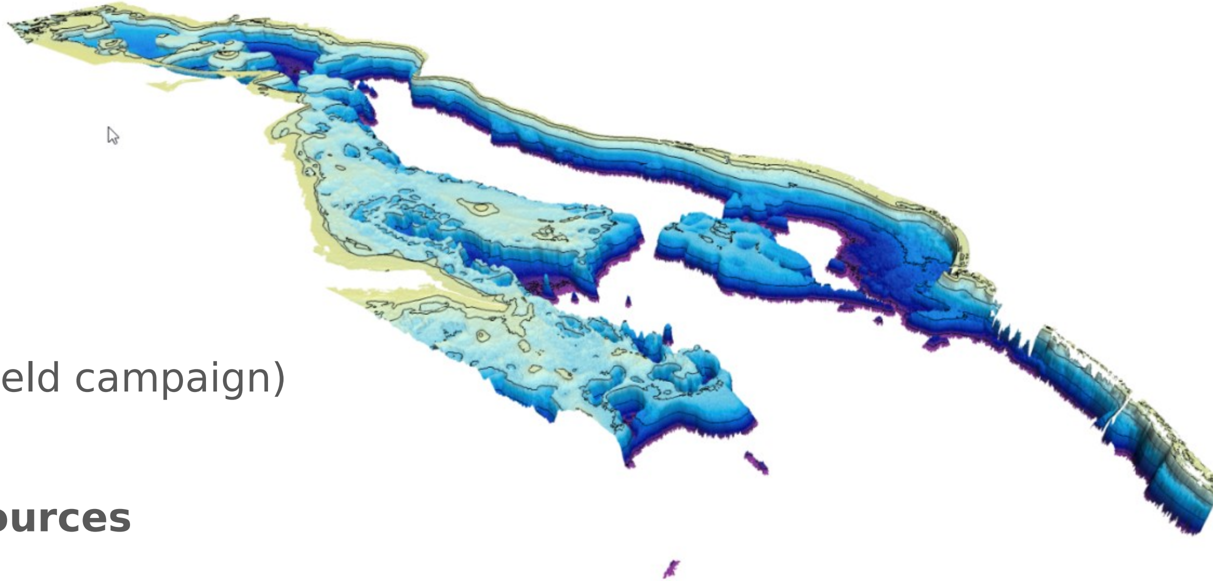
Concluding remarks on monitoring coastal system change using Earth Observation

Time travel with quantitative, inter-comparable data

Baseline and/or changes in depth, seafloor, water column, shoreline and land cover

Image archives going back 10+ years

Survey and monitor large, remote or in-accessible areas



Consider fit-for-purposeness

(e.g. typically less accurate than proper field campaign)

Cost savings and efficient use of resources

Synoptic coverage at 4-10x less cost

Optimise hardware deployment

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Concluding remarks on monitoring coastal system change using Earth Observation

Rapid, area-wide mapping

Capture events such as storms or construction at short notice

Health & Safety

Map previously uncharted or rapidly changing shallow water zone

COVID-proof: un-interrupted access to data from area of interest

Multiple, inter-related information layers from same image data

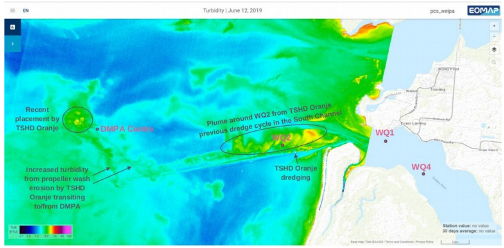
Bathymetry, seafloor cover, turbidity, land cover, shoreline change, etc.

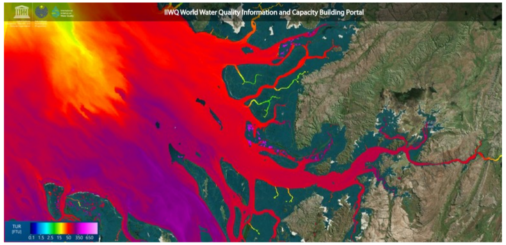
Holistic view, e.g. Environmental Impact Assessment

Latest development: software for in-house capabilities

Stand alone or cloud based SDB and WQ sofwtare

Application-specific data portals with fit-for-purpose analytics





Thank you

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