

Satellite-Derived Bathymetry:

Industry update for the Southwest Pacific Hydrographic Commission
(SWPHC20)

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EOMAP

Germany | Australia | United States | Abu Dhabi

www.eomap.com



The SDB journey so far

- ♦ 1980s-2000's: R&D
- ♦ 2005: First commercial SDB project: (environmental management)
- ♦ 2012: NOAA and UKHO evaluate SDB
- ♦ 2013: Used by marine professionals (e.g. SHELL)
- ♦ 2014: Pilot project with AHO
- ♦ 2015: UK Hydrographic Office puts EOMAP SDB in chart
- ♦ 2019: NZ Hydrographic Authority puts EOMAP SDB in charts
- ♦ 2019: IHO S-44 updated for SDB
- ♦ 2020: 2 hydrographic agencies with commercial SDB software
- ♦ 2021 AHO signs extended contract for EOMAP software services
- ♦ 2021 IHO HSWG establishes SDBPT, chaired by EOMAP COO
- ♦ 2022 UKHO selects EOMAP as primary SDB provider for next 3-5 years
- ♦ 2022: SDB part of AGO GeoPanel (5 years)



SDB Topics

Selected highlights

SDB across the Pacific
Monitoring bathymetry

Technology developments

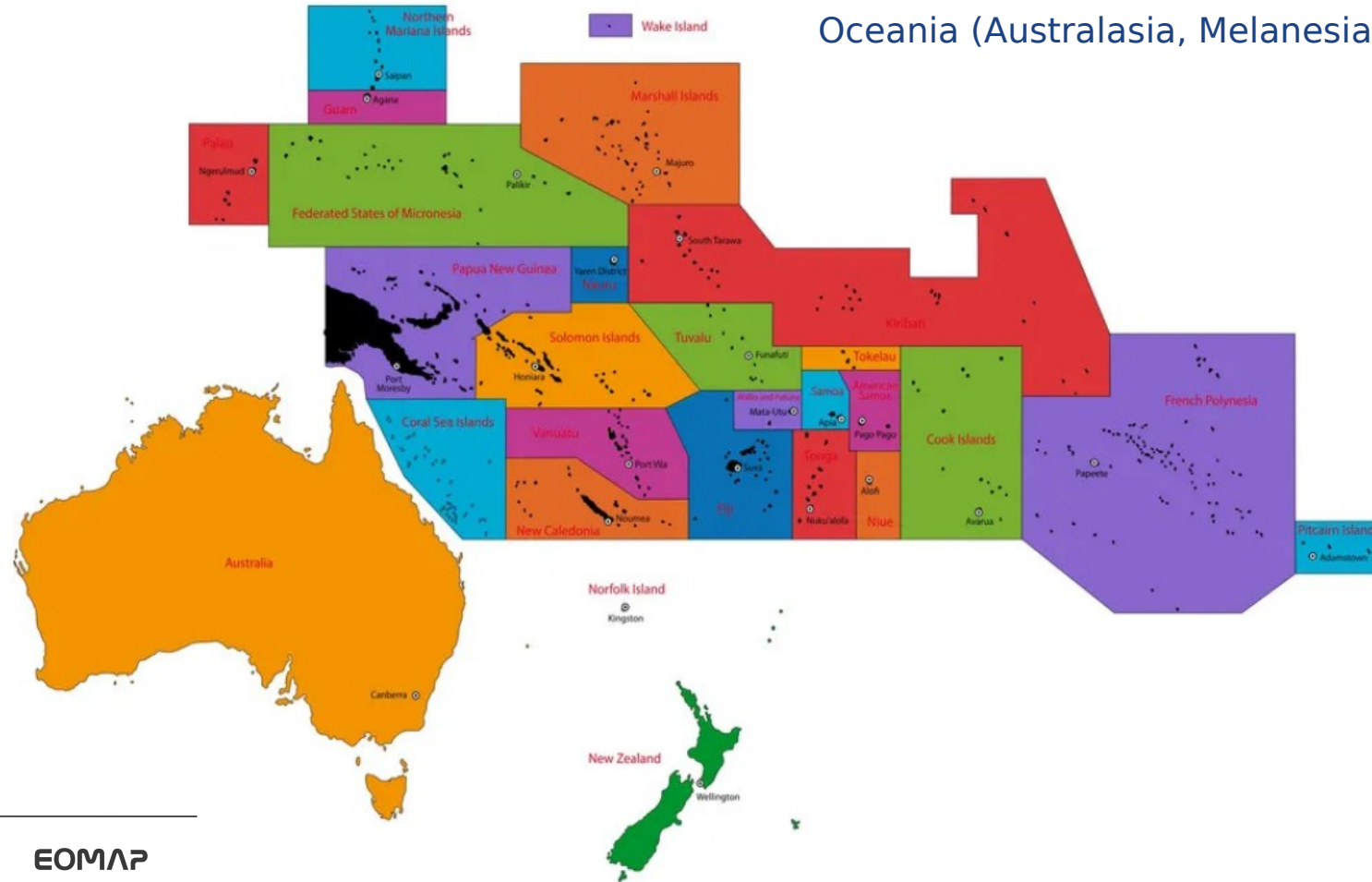
Multi-image parallel processing
SDB Online

Capacity Building, Standards and Best Practice

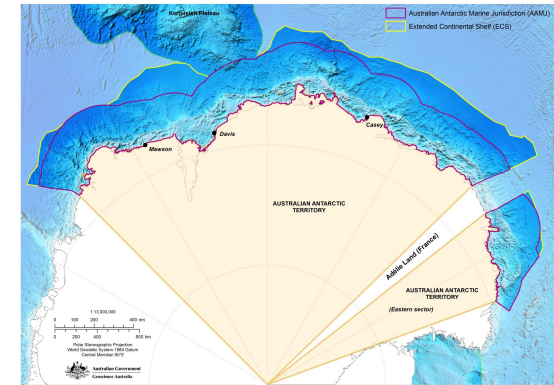
SDB Training
IHO SDB Working Group

(EOMAP) SDB across the Pacific

Oceania (Australasia, Melanesia, Polynesia, Micronesia)



Australia's Antarctic Marine Jurisdiction



MAPPING THE GAPS

THE NIPPON FOUNDATION-GEBCO

SEABED
2030

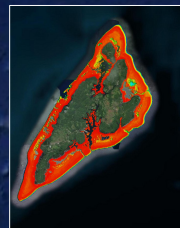


NIWA
Taihoro Nukurangi

South and
West Pacific
Ocean
Regional
Centre



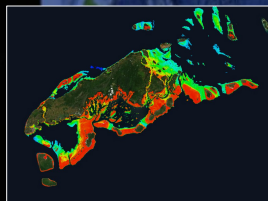
2m, 10m and 30m SDB



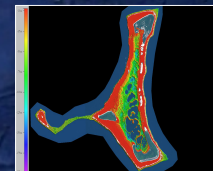
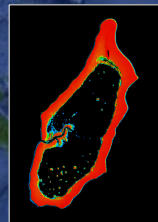
Entire Federated States of
Micronesia (2021-22)

Cook Islands
Atolls, (2021)

Tawi-Tawi,
Philippines (2022)

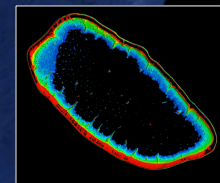
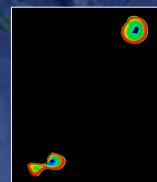


Helen Reef, Palau
(2022)



Manihi and Katiu
Atolls, French
Polynesia
(2022)

Minerva Reefs,
(2021)



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Image IBCAO

EOMAP

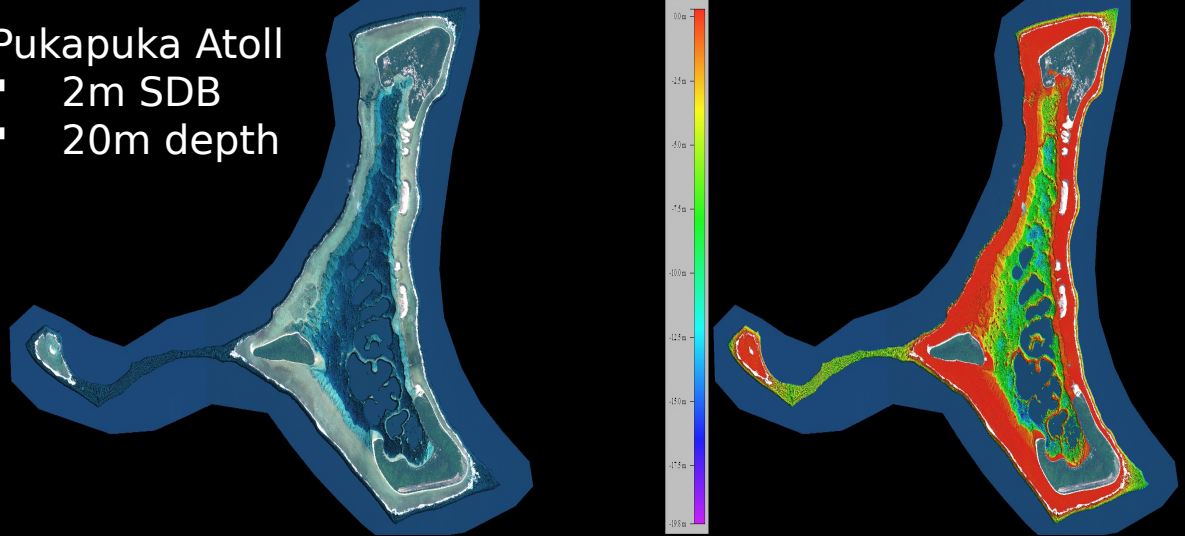
MAPPING THE GAPS

Seabed 2030 and Charting

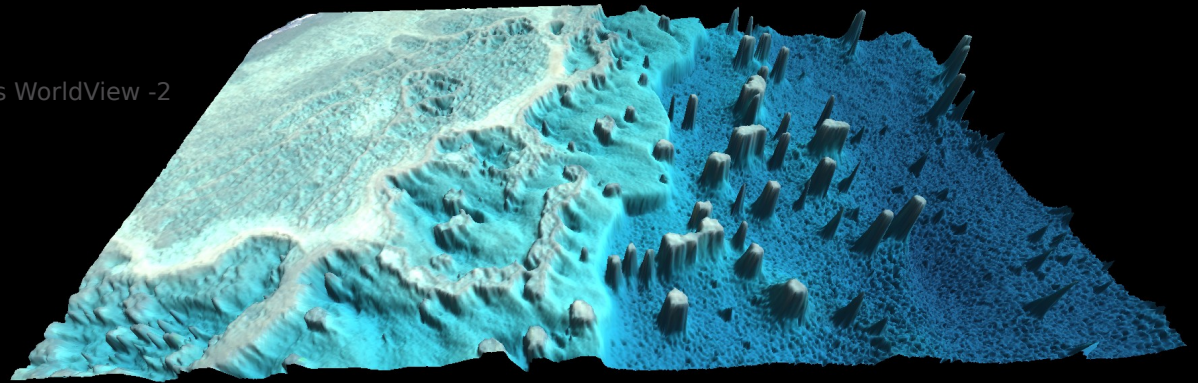
- 2018 - 6,500 km² (Tonga, Tokelau, Niue and Cook Islands) for the Pacific Regional Navigation Initiative (PRNI) via LINZ
- Sites not previously covered including 2 atolls, Pukapuka and Suvarrow
- 2m and 10m SDB, archived and tasked WorldView-2
- Very remote and at-risk reefs
- Etc...

Pukapuka Atoll

- 2m SDB
- 20m depth



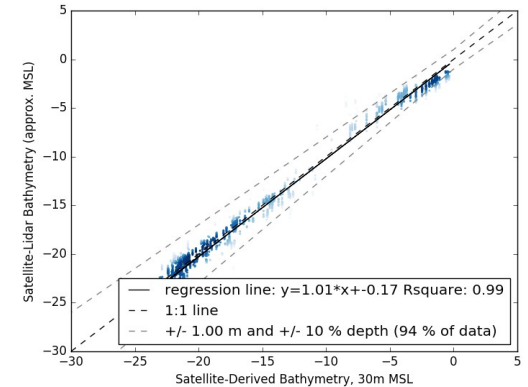
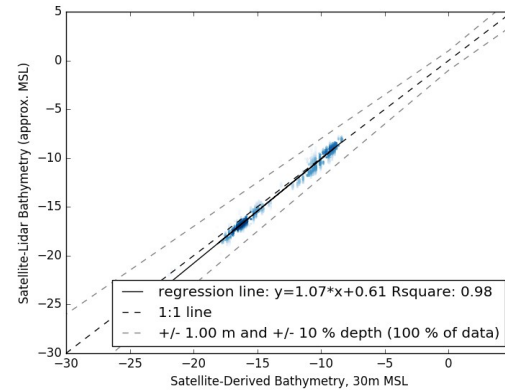
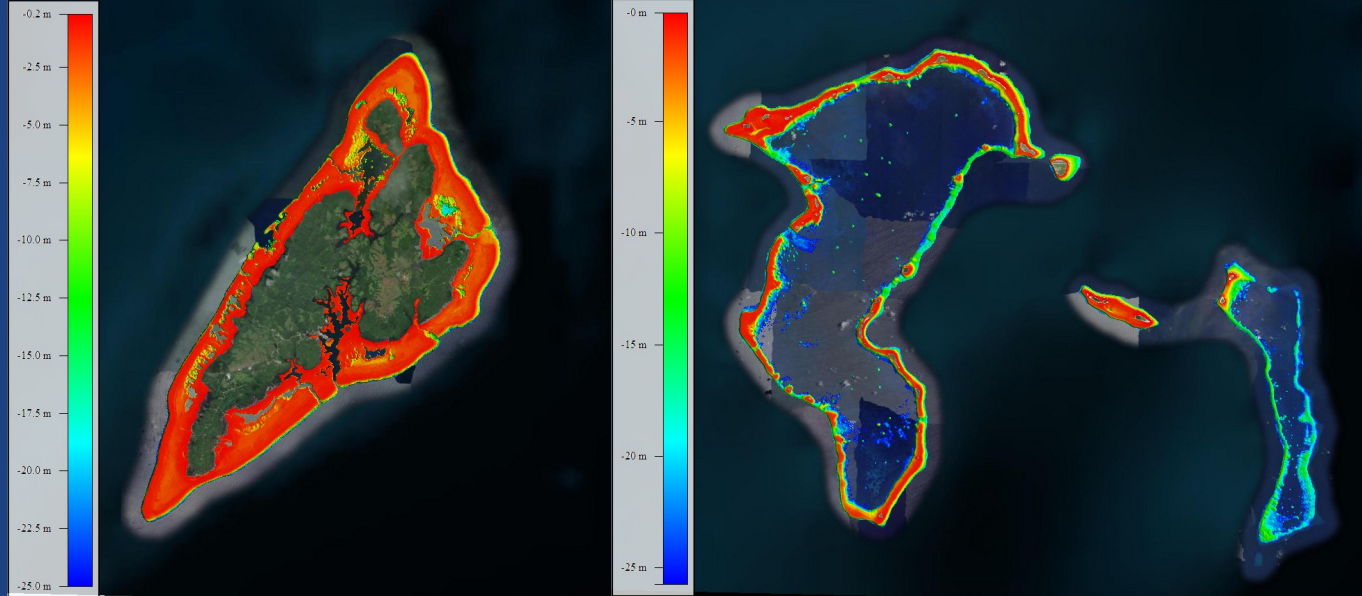
Maxar's WorldView -2



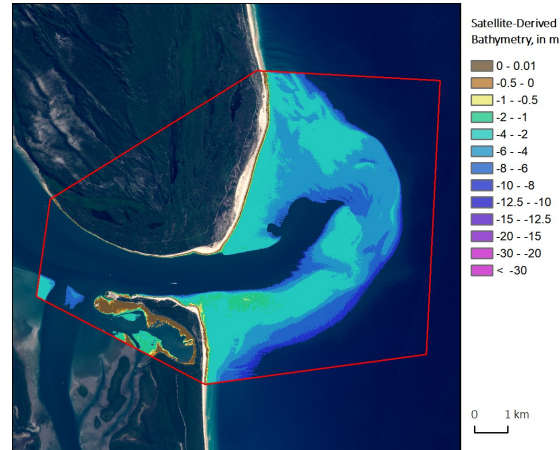
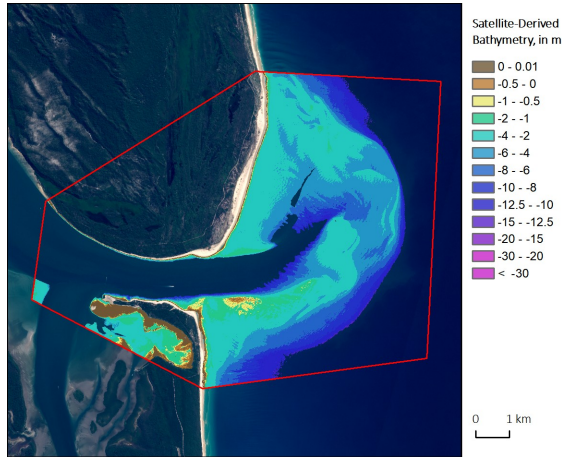
MAPPING THE GAPS

Federated States of Micronesia, Seabed 2030 (2021-22)

- Shallow waters down to a depth of ~25m (depending on clarity)
- ~7,500km²
- Sentinel-2 (10m) and Landsat-8 (30m) bathymetry grids depending on coverage
- Multiple images 2015-2021



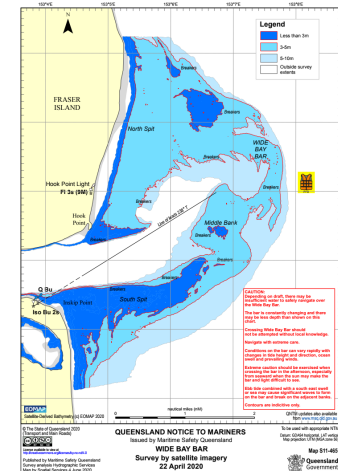
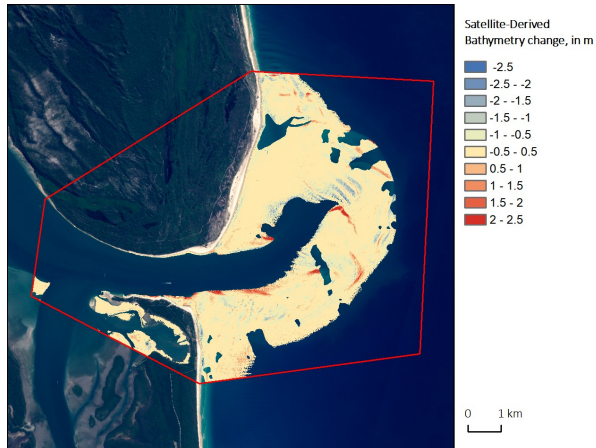
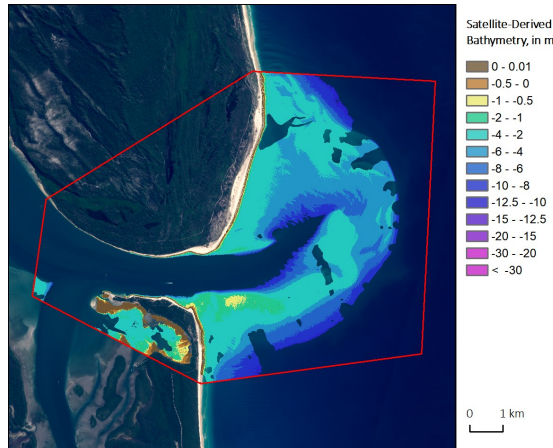
Monitoring Bathymetry for Navigation, WideBay Bar, QLD



Commissioned by Marine Safety Queensland (State Government)

Cost effective and fast in rapidly changing environment

Renewed for 2 more years



Monitoring Bathymetry for Coastal Resilience

COASTS

Coastal Change Observation Analytics
(multi-)Source (multi-)Technology System

Satellite data: bathymetry, shoreline change, turbidity

+

Drone Data: terrestrial topography

+

Hydrodynamic modelling

+

Web-based delivery system with fit-for-purpose analytics

=>

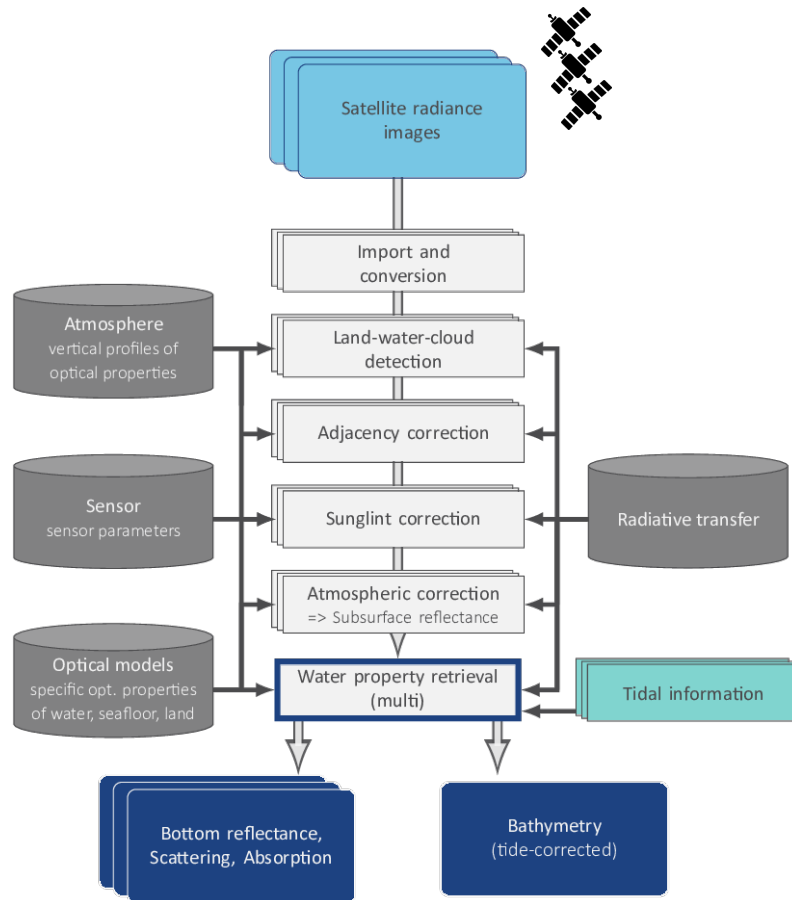
erosion, deposition, storm events, forecasting, planning

=>

Near-real time management, coastal hazards, coastal resilience, beach safety, inundation, climate change



Physics-based multi-scene processing: SDB 2.0



Fully physics-based

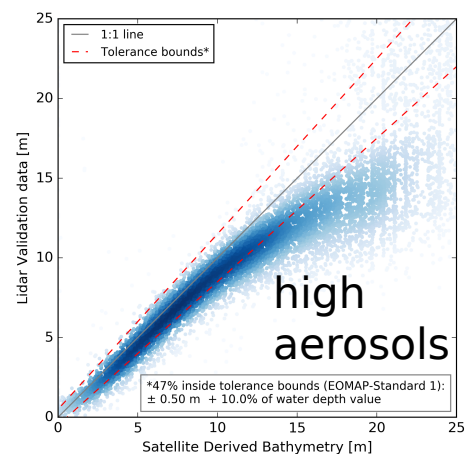
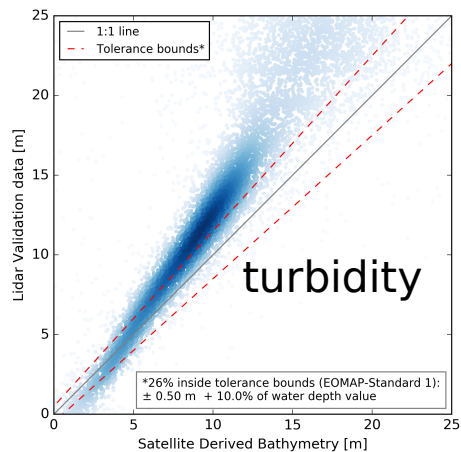
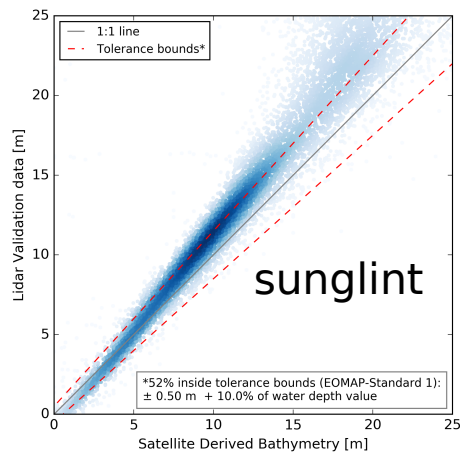
$\text{pixel} = f(\text{aerosol properties, adjacency, sunglint, water surface, absorbers and backscatterers of the water column, full bidirectionality from sun and sensor geometry})$

$\text{pixel} = f(\text{depth, absorbers and backscatterers of the water column, seafloor reflectivity, full bidirectionality from sun and sensor geometry})$

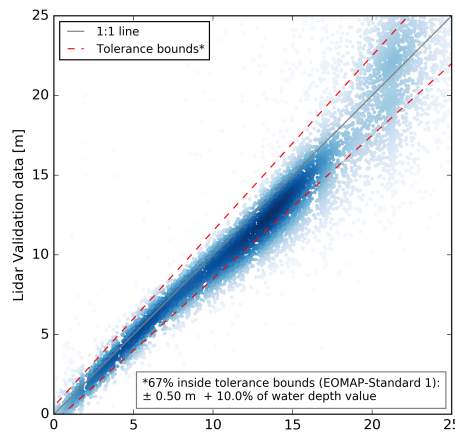
condition: depth $z_i = z$

US Patent 2017, No 9613422
Realization funded by BMVI

Physics-based multi-scene processing

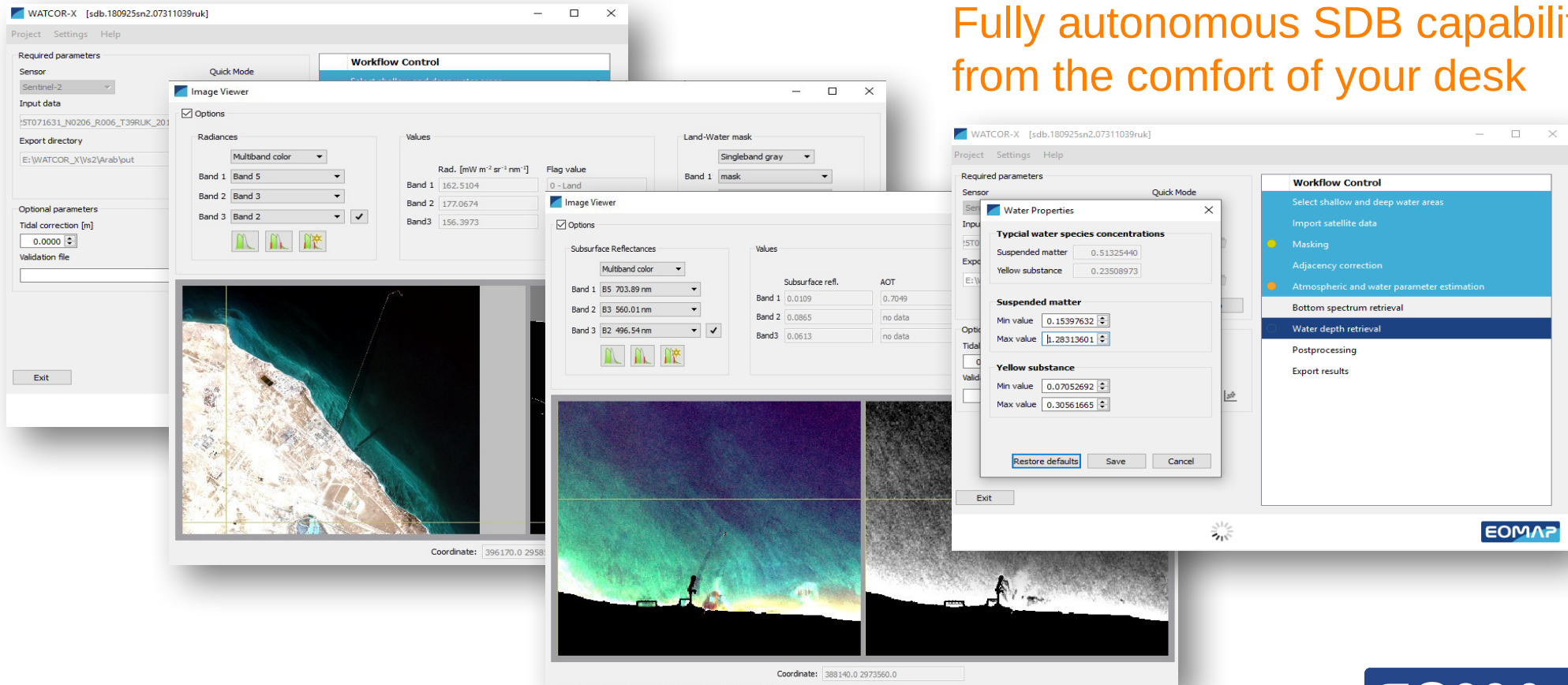


➤ Absolute accuracy increases



WATCOR-X: sophisticated, stand-alone SDB software

Fully autonomous SDB capability
from the comfort of your desk

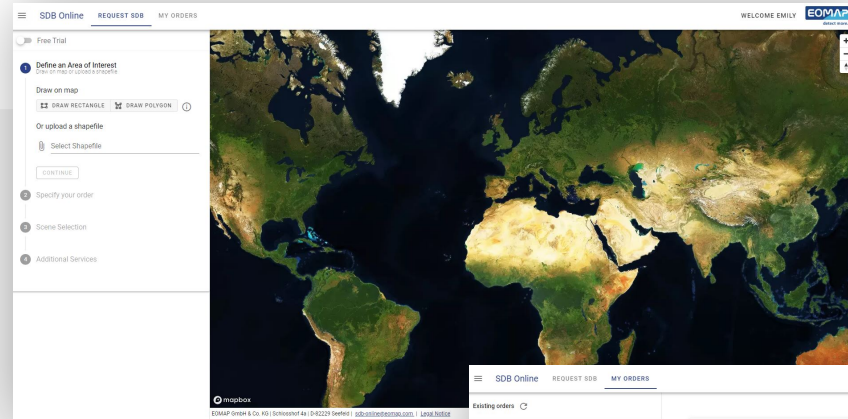


SDB SaaS:

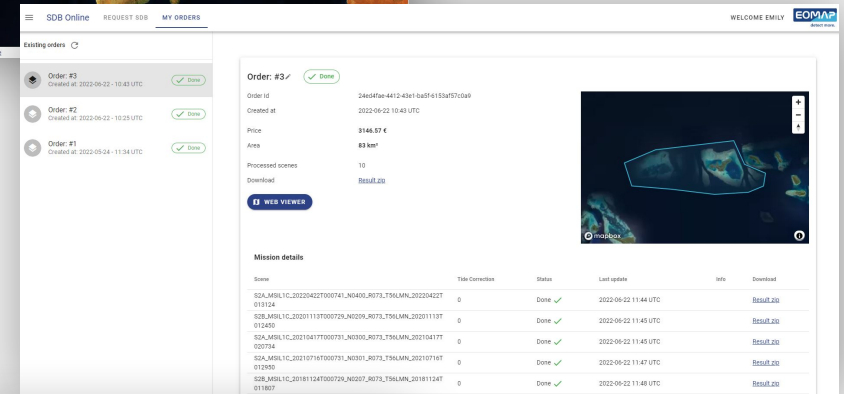
SDB-ONLINE

- **Powerful cloud backend**, fully **scalable**
- **Ultra easy to use**
- **Physics-based SDB** concept (radiative transfer inversion)
- **Coupled** with satellite archives (currently Sentinel-2)
- **Automatic** mode (image selection, full processing workflow)
- **Calibration/validation**: optional fine tuning with own survey data
- **Multi-image** mode (US patent)
- **Webapp** user interface, any browser
- **Pay-per-use**
- Machine-to-machine (**API**)

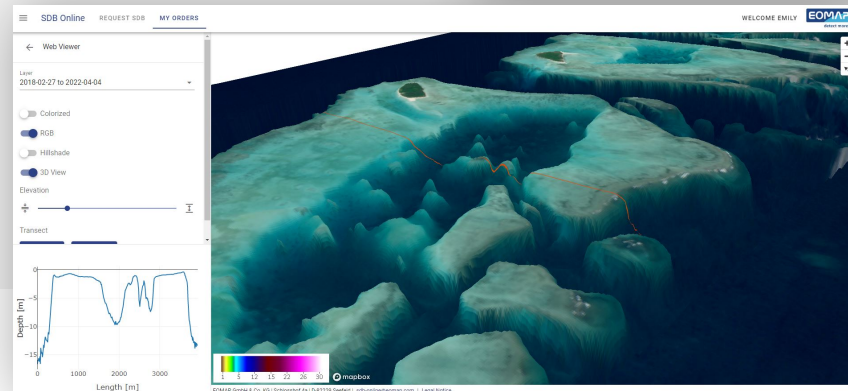
Define your site



Download data



Visualise data online



SDB Capacity Building

4th International SDB Day (October 2022)

2 day conference

SDB training at EOMAP HQ

- Image selection and pre-processing
- Creating SDB
- Post-processing and quality control
- Handling and interpreting SDB data
- SDB software and GIS, etc.



SDB Best Practice Project Team (SDBPT) - IHO

SDBPT is a supporting body of IHO HSWG
(Hydrographic Surveys Working Group)

Commenced in April 2021, chaired by EOMAP

40+ members: member states, experts, academia, users

SDB Standards and Best Practice

Proposed as a 'B-13' document to HSSC
(Hydrographic Services and Standards)



8.13. Satellite-Derived Bathymetry Best Practice Guide

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IHO FORWARD ON SATELLITE-DERIVED BATHYMETRY

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3.4.3 Vertical datum

3.4.4 Water refraction and off-nadir correction

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4 Chapter 4: Uncertainty

4.1 Introduction

4.2 Vertical uncertainties

4.2.1 Modelling and estimating vertical uncertainties

8.13. Satellite-Derived Bathymetry Best Practice Guide

is rarely collected looking vertically downwards, but has an off-nadir view. Typically lat asymptotes between 0 and 30 degrees but may be as low as 10 degrees. As the off-nadir view angle increases, the path length from the satellite to the water surface increases, and the path length from the water surface to the sensor increases. This results in a longer path length and a longer time delay. The longer path length and longer time delay result in a longer time delay. The longer path length and longer time delay result in a longer time delay.

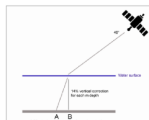


Figure 5: Vertical correction of depth due to off-nadir view and refractive water column. Image credit: EOMAP

Observed depth points will likely need to be corrected to give offshore for diagonal view-angle geometry and refraction effects. For [ICESAT-2](#) slant-range off-nadir angles there may also be a need to correct for the observed depth. These corrections will need to be carried out as a depth retrieval, which is a relatively simple trigonometric problem. Such as Sentinel-2 does not require these corrections of resolution and their corrected vertical viewing geometry. A further important consideration when using [SLB](#) is that the off-nadir angles will likely have been projected into a 2D image. At off-nadir angles a further horizontal displacement which can be very significant in the local vertical suspension between ground and observed heights is added here is to consult with the satellite image vendor to ensure the projected into a suitable ground model such as EGM2008. Translation of data by means of HBM as it has been described in the previous section.

2.4.5 Filtering

Data filtering is applied mainly in the QC processes for the purpose of noise or unwanted signals. The criteria might be based on the

8.13. Satellite-Derived Bathymetry Best Practice Guide

Individually for the action of wind on the water surface. The main factor influencing the time delay is the wind speed. When wind speeds are high, the time delay is significant, then the reflected signal is significant noise, thereby affecting the accuracy of the data.

A visual example of each of these factors is provided in the following figures.

Table 3. Image examples of satellite records negatively affected by different



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8.13. Satellite-Derived Bathymetry Best Practice Guide

- **Satellite sensors**, WTR can be based on **multispectral** and **radar** acquisitions at a very short time delay. A sensor **spatial resolution** is required.
- **Need for a reference data** not required
- **Others**
 - Potential challenge to identify the 'real depth' at deeper water.

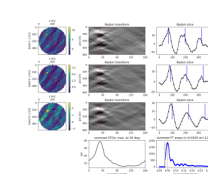


Figure 2: Concept of WTR. Image sensors (left) are analysed with a Transformation or radiance transformation (mid-left) and it's wavelet (mid-right), the time delay between - in this example - three effects, quantify the period (right) and a depth estimation is provided (bottom) EOMAP

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8.13. Satellite-Derived Bathymetry Best Practice Guide

2.3.6 Satellite-Lidar Bathymetry (SLB) from ICESAT-2 ATLAS

NASA's ICESat-2 satellite launched in Sept 2018 features ATLAS, a green photon-counting lidar with a 100kHz pulse repetition rate and nominal 17m diameter footprint. It records photon returns in discrete track lines covering the entire globe that are capable of measuring bathymetry. ATLAS by itself cannot create a dense spatial grid as each trackline can be up to hundreds of kilometres apart. A proprietary cluster algorithm separates seafloor photon returns from both the water column and water surface. Correction routines need to be applied to the ICESat-2 seafloor photon returns to account for the water refraction and recording geometry as well as effects on water heights. SLB information extracted along each trackline serves as a valuable check and as a training dataset for other SDB methods.

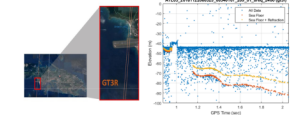


Figure 4: Left: ST Thomas ship, crossing Runway 0028 at the St. Thomas airport (STT). Right: profile of processed photon returns, with the bottom return photons, both pre-refraction correction (dark orange) and post-refraction correction (light orange). (Parrish et al., 2019)

Cost assessment

ICESat-2's green laser is reflected by the seabed and the time delay between the emission and return provides information on ground height of the seabed.

Resolution

Satellite acquisition SLB data cannot provide a spatial coverage, depth information can be provided for single tracklines. Each trackline might be up to several 100m apart.

¹Neumann T, Brenner A, Hancock D, Robinson J, Silva J, Hattwick K, Gibbons A, Lee J, Lublin S, Deibel T. 2021. ICESat-2 Algorithm Theoretical Basis Document for Global Oceanic Photosynthetically Active Radiation (GOCAR) Retrieval. Version 1.0.0. [https://nasa-icesat2.gsfc.nasa.gov/icesat2-atlas/ATLAS_ATLAS_ATLAS.pdf](#)

²Parrish, C.E., Maynard, L.A., Neumann-Tschaplitz, A.L., Fortson-Gibson, N., Alpar, M., Jorjani, M. Validation of ICESat-2 ATLAS Bathymetry and Mapping of ATLAS Bathymetry Mapping Performance. Remote Sens. 2019, 11, 1634. [https://doi.org/10.3390/rs11101634](#)

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EOMAP

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SDB Topics Summary

Selected highlights

SDB across the Pacific - continues with Seabed2030 et al
Monitoring bathymetry - hydrographic data with temporal
dimension: navigation, coastal resilience

Technology developments

Multi-image parallel processing - accuracy and autonomy
SDB Online – SaaS and AWS power

Capacity Building, Standards and Best Practice

SDB Training – all welcome
IHO SDB Working Group – document in progress

Thank you

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