GREAT BARRIER REEF BATHYMETRY

First high resolution map of the entire reef from the world's biggest high resolution satellite bathymetry survey

GREAT BARRIER REEF, Australia

350 000 sqkm

Published Nov. 18th 2013

Content

Executive Summary

EOMAP GmbH & Co.KG has mapped the shallow water bathymetry (~ 0-30 m depth) and seafloor reflectance of the entire Great Barrier Reef (~ 19,000 km^2 of reef surface area), using data from the Landsat 7 satellite. Physics-based inversion algorithms running through a standardized processing chain, the Modular Inversion Processor produced digital map products at 30 m horizontal resolution, with a nominal vertical resolution of 10 cm. The bathymetry results have been independently assessed.

The following document is intended to introduce and describe the project, the products and the technology.

For even more information, please visit www.eomap.com.

Disclaimer

Earth observation data are in general recorded under changing environmental conditions. EOMAP value adding software corrects for most relevant environmental conditions. However, with respect to the physical nature of the remote sensing method the achievable product quality can differ due to varying observation angles, varying atmospheric, surface and in-water conditions or changing sensor raw data quality with each scene. Therefore, EOMAP cannot take any responsibility caused by the usage and interpretation of the remote sensing products. Of course, EOMAP will undertake all possible efforts to assure a constant product quality.

Project Partners

EOMAP GmbH & Co. KG

Biophysical Remote Sensing Group, University of Queensland

James Cook University

Cooperative Research Centre for Spatial Information

The Great Barrier Reef High Resolution Satellite Bathymetry Project

Concept

The Great Barrier Reef (GBR) is of international importance. Despite the need to monitor, manage and protect this World Heritage Area, only approximately half of all the reefs in the GBR have been mapped or surveyed in some form. The challenge lies in the in-accessibility and remoteness of these shallow reef environments, particularly for traditional survey methods.

Satellite-derived bathymetry (SDB) technology can in theory overcome these challenges, but it has never before been applied at this combination of scale and resolution.

> For an introduction to this technology, you may want to first read the section 'Satellite-derived bathymetry (SDB): what is it and what can it do for you?'

Method

The data used for processing were from the Landsat 7 satellite. The GBR was separate into 26 areas of interest (AOI) according to Landsat tiles. For each AOI, the most suitable scenes were selected (1-5 images). In total, 52 scenes were processed, dating from between 1999-2003 (SLC 'on').

All processing was done using EOMAP's Modular Inversion Processor (MIP). Essentially, EOMAP's proprietary algorithms are bundled into function specific modules. These modules are connected through a semi-automated processing chain. In turn, the processing chain interrogates various databases for additional input. Figure 1 illustrates the MIP schematic for bathymetry and seafloor reflectance retrieval from satellite image data.

As shown in Figure 1, the image data were first pre-processed for land-water-cloud-masking, adjacency correction, sun glitter correction and atmospheric correction. The processing stage involves the definition of water and bottom types and a couple retrieval of water depth based on the subsurface reflectance image.

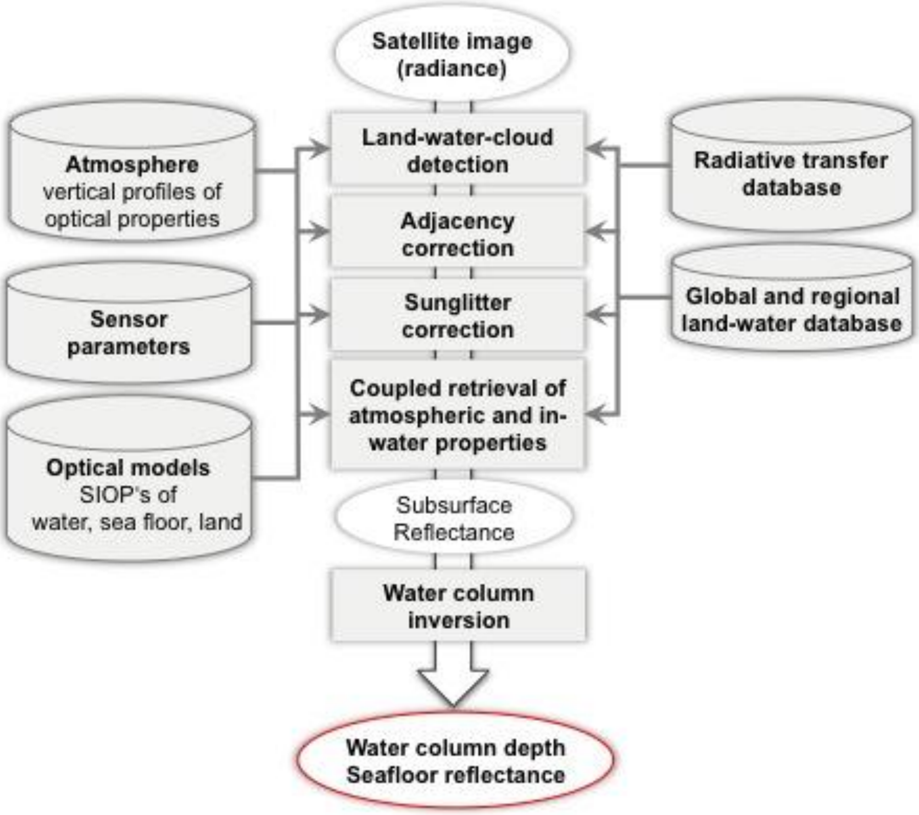


Figure 1. Schematic of the MIP modules for water depth and seafloor reflectance processing.

Post processing includes tide correction to lowest astronomical tide and a semi-automatic selection of correct depth retrievals (avoiding clouds, cloud shadows, turbidity, sun glint, etc.). Finally any false positive identification of shallow depths (e.g caused by highly turbid waters) were identified and removed (these were very few in number).

All of the depth retrievals were given a quality rating of quality 1-3 (quality 1 being the most reliable). These ratings were based on objective analysis of the input imagery based on the presence of turbidity in the water column, or sun glitter on the water surface.

The resulting products, at 30 m horizontal resolution, were also down-sampled to 150 m and 500 m horizontal resolution versions.

Finally, the flagship high resolution 30 m bathymetry product was also converted from lowest astronomical tide (LAT) to mean sea level (MSL) and highest astronomical tide (HAT) datums. These conversions were performed by the Cooperative Research Centre for Spatial Information (CRC SI) using their in-house technology.

Results and Output

Primary product outputs are as follows

- A digital, shallow water bathymetry map for the entire Great Barrier Reef, at 30m horizontal resolution (available in LAT, MSL and HAT)

- A digital, seafloor reflectance map for the entire Great Barrier Reef, at 30m horizontal resolution

Secondary outputs include:

- Digital, shallow water bathymetry maps for the entire Great Barrier Reef, at 500 m horizontal resolution (available in LAT)

- Digital, seafloor reflectance maps for the entire Great Barrier Reef, at 500 m horizontal resolution

Additional outputs include

- An objective quality assessment rating for every pixel in the data, where Q1 pixels are considered the most reliable, and Q3 pixels are considered the least reliable.

All bathymetry products are at nominal 10cm vertical resolution. Depth estimates are provided down to approximately 30 m of depth, depending on environmental conditions during image capture.

Assessment

The bathymetry product has been independently assessed by Dr. Robin Beaman of James Cook University for both horizontal and vertical accuracy. The following is a summary of his findings:

Horizontal accuracy

The horizontal accuracy was assessed using Geoscience Australia ALOS PRISM mosaics of the GBR. The ALOS PRISM mosaics have a 2.5 m-resolution with RMS horizontal error estimates of individual scenes typically reported as 3 to 5 m, thereby providing a high confidence in their positional accuracy 32 reefs were selected for validation across the entire GBR,. For 21 of the selected reefs there was no detectable horizontal offset, while 11 reefs had offsets of between 30 to 40 m, or about the width of one Landsat pixel. Therefore it is considered that the bathymetry data have an overall maximum horizontal positioning error of 40 m.

Vertical accuracy of the bathymetry product

The vertical accuracy was assessed using using 11 Australian Hydrographic Service lidar surveys collected from the Torres Strait to SE Queensland. The lidar surveys are IHO S44 Order 1 compliant using the LAT vertical datum. Scatterplots of the bathymetry data against the lidar data were grouped according to quality Class 1-3 (from the EOMAP objective image quality assessment processing done prior to this validation assessment), and the number of pixels were counted within an absolute error of 1 m, plus a relative (i.e. depth dependent) error of 25%. For Class 1 pixels, 75% of pixels are within +/- 25% (with +/- 1 m offset), e.g. at 10 m true depth, 75% of pixels lie within an error band 9-11 m +/- 2.5 m.

For further details on this independent assessment, please see Dr. Beaman’s formal validation letter review, included in this booklet. You can learn more about Dr. Beaman’s research at http://www.deepreef.org/

Classification potential

The bathymetry and seafloor reflectance products have been preliminarily assessed by Dr. Chris Roelfsema (Biophysical Remote Sensing Group) University of Queensland for the purpose of classifying the geomorphic zonations and, ultimately, the benthic assemblages in these shallow waters. This is an ongoing area of research and development between EOMAP and the Biophysical Remote Sensing Group.

The bathymetry data were used together with the Landsat image data to create geomorphic zonation maps for Capricorn Bunker Group in the southern Great Barrier Reef. This approach mapped reef zones based on geomorphological processes that are driven by water depth. The results are very promising relative to approaches based on subsurface reflectance imagery alone.

The seafloor reflectance product shows new details over reef areas in water depths of 5 m to 15 m. Previously discriminating reef features at these depths was very difficult. The reflectance product provided more detail for information extraction at depth.

For further context on these initial findings, please see the accompanying summary letter from The Biophysical Remote Sensing Group, included in this booklet. You can learn more about Dr. Roelfsema’s research at http://www.gpem.uq.edu.au/brg

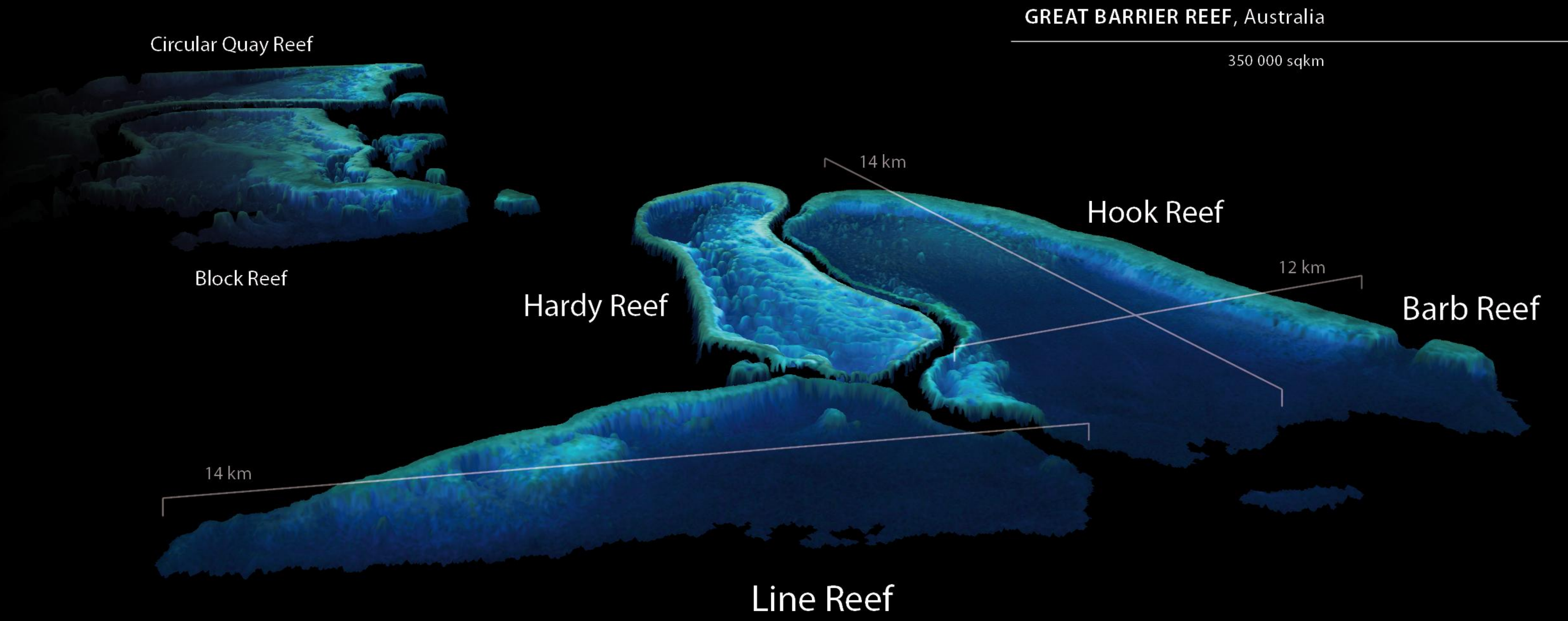
Concluding remarks

> "*Baseline mapping of natural environment and resources is fundamental requirement for understanding what an environment is made up of and how it is changing over time. This information is regarded as essential data for any government or company responsible for or managing the environment.*
>
> *We have this for our terrestrial environments down to the level of trees, yet for one of our most valuable assets, the Great Barrier Reef we still do not have the baseline information at a suitable level of detail, nor do we have the ability to assess how it changes over time. This applies to the depth or bathymetry of the entire reef, and the type of environments or communities present on reefs.*
>
> *The reflectance and depth products will form the fundamental baseline data able to be used by government monitoring agencies for monitoring and management planning, research institutions for monitoring and modeling, and private industry to build their own applications for the data. This will provide the basis for a range of derived map products and the need for higher spatial resolution versions of these data.*"

Professor Stuart Phinn
School of Geography, Planning and Environmental Management ,
Centre for Spatial Environmental Research,
University of Queensland

GREAT BARRIER REEF BATHYMETRY

First high resolution map of the entire reef from the world's biggest high resolution satellite bathymetry survey



Satellite Data Source: USGS Landsat

Satellite-Derived Bathymetry (SDB)

What is it and what can it do for you?

What is it? Satellite-derived bathymetry (SDB) is the mapping of water column depth using imagery collected from space-borne satellites. Since this imagery is typically densely packed with information in every pixel, SDB effectively provides a continuous 3D model of seafloor topography. For those familiar with geospatial information products, this is the equivalent to an underwater digital elevation model (DEM).

What does it look like? The image below shows SDB derived by EOMAP for Ningaloo Reef. SDB is typically delivered as a digital, high resolution map of water depth, or if you prefer, as a digital, high resolution 3D model of seafloor elevation. It can also be visualized in more traditional cartographic or hydrographic formats.

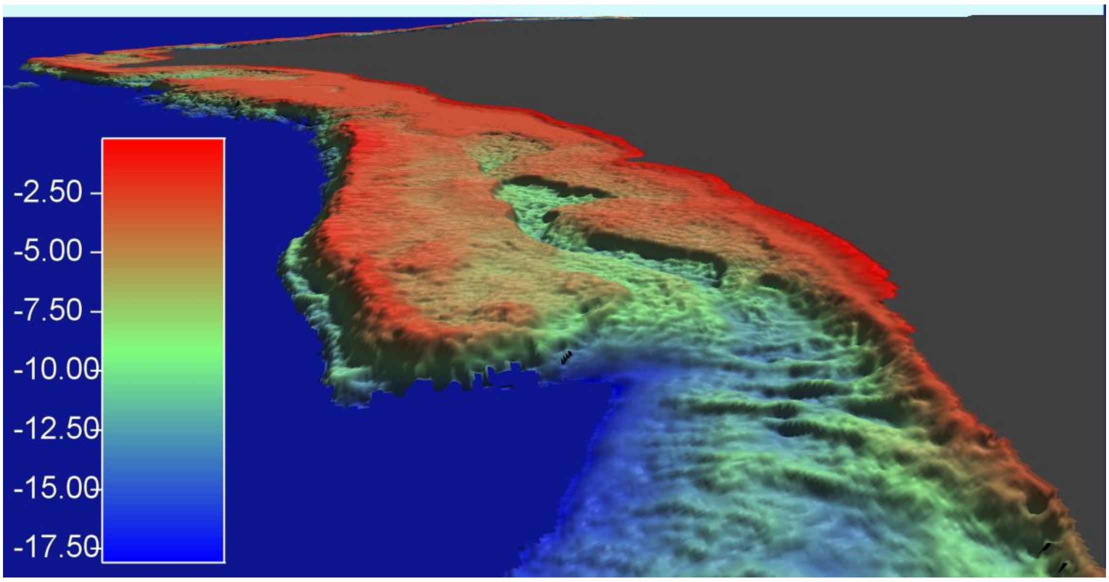


Figure 2. EOMAP SDB of Ningaloo Reef using the Landsat 8 sensor, at 30 meter horizontal resolution, down to a depth of 17.5 m.

What is it for? SDB is seeing increasing uptake across a range of uses. These include: environmental monitoring, modeling and baseline derivation; construction and development planning; exploration, and to some extent, navigational applications.

A complimentary product to SDB is the seafloor reflectance, or seafloor color map. This can be interpreted into ecological information (e.g. maps of coral and sea grass distributions) which has important uses in environmental applications such as establishing baseline information and monitoring change.

How does it work? Briefly, SDB relies on 1) satellite sensors that detect sunlight reflected from the seafloor, and 2) algorithms that use this sunlight information to calculate water column depth (as well as seafloor reflectance, or color).

As an aside, this means that SDB is dependent on water clarity, and typically only retrieves depths down to approximately 30 meters. As it happens, this is the depth interval that is the most challenging and costly for traditional, ship-based bathymetry surveying.

We elaborate a bit more on how SDB works further below, in the section '*The mechanics of SDB in more detail*'.

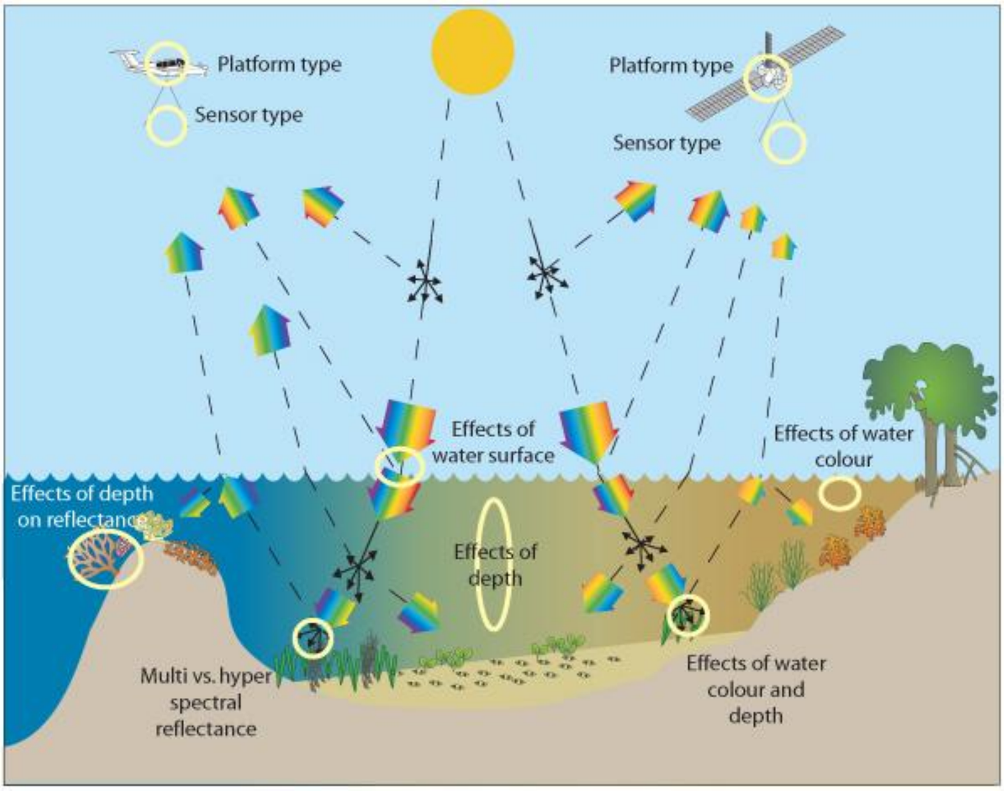


Figure 3. Schematic illustrating the path of the sunlight signal, interacting with the atmosphere, water column and seafloor, and finally being measured by a space-borne or airborne sensor. Image courtesy of the Centre for Spatial Environmental Research, University of Queensland.

What are the pros and cons? SDB is experiencing increased uptake because it is now becoming an operational and robust technology. Its primary advantage is that it offers the ability to rapidly and non-intrusively survey remote, extensive, or in-accessible areas at between 5-10 times less cost than most traditional methods.

There are limitations to SDB. The accuracy of the depth retrieved is, as already mentioned, dependent on a range of external factors. If the water in the image is turbid, or if the atmosphere is hazy, SBD will be negatively affected. Although these factors cannot be controlled, they can be accounted for. Still, SDB is typically not recommended as a standalone tool for applications requiring nautical-grade precision.

Having said this, SDB is very effective when used as a complementary tool, also referred to as a 'layered approach'. SDB can indicate where further, in situ sampling is required, and can also then be fine-tuned using this in situ data, in order to provide the dense, continuous coverage typical of SDB, but with even better accuracies.

The shallow, coastal zone is the most costly and challenging for ship-based bathymetric surveys, and this zone is where SDB typically outperforms; creating a continuous depth map as opposed to point measurements or transects which need to be interpolated.

We conclude this introduction to SDB by re-iterating its primary advantage: the ability to rapidly and non-intrusively survey remote, extensive, or in-accessible areas at between 5-10 times less cost than most traditional methods.

The mechanics of SDB in more detail

A tale of two methods The science of deriving water depth from satellite data has been in researched and developed for over 30 years. Initially, empirical methods were used. The advantage of these methods is that they are relatively straightforward, and computationally fast. The primary drawback of these methods is that they require known depth information for the area being studied in order to 'tune' the satellite information into retrieving accurate depths.

> In conclusion, the Landsat satellite bathymetry data are an innovative solution to providing a dramatic improvement on the foundational spatial data used for the GBR.
>
> Dr Robin Beaman, School of Earth and Environmental Sciences, James Cook University

Physics-based methods on the other hand, require no known depth information for the study area, and can therefore be applied independent of satellite type and study area. These methods rely on fully describing the physical relationship between the measured light signal and the water column depth, and require more sophisticated algorithms and powerful processing capacity. In deriving the shallow water bathymetry for the entire Great Barrier Reef, EOMAP used its proprietary physics-based method, the Modular Inversion Processor (MIP).

The sensor compromise Along with water clarity, the other critical factor in SDB is the choice of satellite sensor used. Simplifying a little, we consider sensor choices in terms of horizontal and vertical resolution. The horizontal resolution is the size of each pixel in the satellite image, which is closely related to the size of the smallest detectable object in the image. In order to detect a 5 meter boat, you would need to use a satellite with approximately 5 meter horizontal resolution (or better).

The vertical resolution, together with maximum depth of penetration, is determined by the satellite's radiometric sensitivity, signal-to-noise ratio, and spectral resolution. These concepts are beyond the scope of this text, so we will lump them into the term vertical resolution - as applied to SDB here - and resort to a relative estimate of this parameter.

The choice of satellite sensor is usually a compromise between cost and fit-for-purpose. For SDB projects requiring high levels of spatial detail, 2 meter horizontal resolution and good vertical resolution imagery is recommended. Not surprisingly, these types of data have the higher price tag. By contrast, data from the Landsat satellite series have a horizontal resolution of 30 meters, with a relatively average vertical resolution. The advantage of the Landsat imagery is that it has historical global coverage, is very low cost, and offers a spatial resolution suitable for producing baseline bathymetry maps over very large areas, such as the Great Barrier Reef.

Physics and the environment The overall accuracy of SDB is often quoted in percentage terms. As an example, EOMAP's WV-2 data SBD products typically have an accuracy of +/-10% (by the way, this is industry-leading for SDB). The reason for using a percentage term is that SDB absolute accuracy decreases with increasing water depth, as the signal gets weaker. Using the above example, the accuracy would be +/- 0.5 meters at 5 meters of depth, and +/-2 meters at 20 meters of depth.

SDB is affected by a number of factors. By no means exhaustive, the following list outlines some of the more important factors that negatively impact water depth retrieval:

- Sun glint on the water surface
- Turbid, or murky waters, preventing detection of seafloor
- Clouds or haze in the atmosphere
- Significant waves on the water surface
- Sensor signal-to-noise
- Sensor calibration and radiometric sensitivity
- Sensor view angle

Factors such as these are often beyond the control of persons creating SDB. However, it is possible to estimate these factors. As an example, EOMAP provides a quality indicator value for each pixel in its SDB map, based on a combination of factors such as outlined above. Specifically for the Great Barrier Reef Landsat SDB, EOMAP created three, objective quality classes, where Class 1 pixels are considered the most reliable.

For further reading and a practical introduction to mapping aquatic environments using satellite data, we recommend the University of Queensland's CSER Marine Remote Sensing Toolkit.
(http://ww2.gpem.uq.edu.au/CRSSIS/tools/rstoolkit_new/html/marine/marine.html)

The layered approach and very high resolution mapping

SDB is very effective when used as a complementary tool, also referred to as a ‘layered approach’. SDB can indicate where further, in situ sampling is required, and can then be further fine-tuned using this in situ data. This offers the dense, continuous coverage typical of SDB, but with even better accuracies.

But it is not only the accuracy it is also the smallest mapping unit, the spatial resolution of the satellite data which characterize its’ applications and mapping potential. The Great Barrier Reef is now mapped in 30m resolution, which is by at least one order of magnitude the highest resolution mapping which exists for the entire shallow reef. However the potentials for SDB mapping are even greater, both in terms of accuracy and spatial resolution. The very high resolution mapping using imagery from commercial satellite data providers can be seen as the premium SDB product.

EOMAP has been previously contracted to conduct very high resolution bathymetry and seafloor mapping throughout the world, maintaining a unique methodology to extract information from all the important available satellite fleets.

> The WV-2 bathymetry data look very clean (no noise that I can see) in my visualisation software. Well done to the EOMAP team and you set a very high bench-mark for others to follow using these SBD methods.
>
> Dr Robin Beaman, School of Earth and Environmental Sciences, James Cook University

For the Great Barrier Reef, EOMAP processed Digital Globe's 2m World-View 2 data for a seleceted area, in order to provide users the opportunity to freely access demo material for very high resolution bathymetry and seafloor mapping. This 2m mapping can be seen as the highest and most accurate mapping method currently possible with SDB.

EOMAP offers the following bathymetry products, with the number corresponding to the horizontal resolution of the product: eoBATHY 2, eoBATHY 5, eoBATHY 30, eoBATHY 150, and eoBATHY 500.

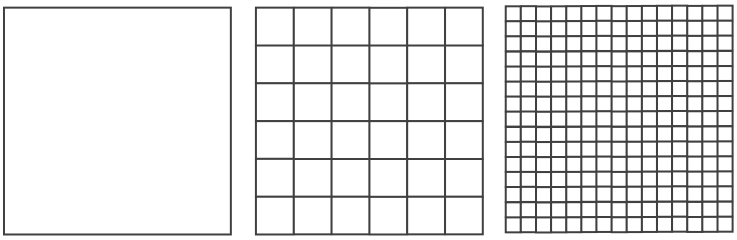


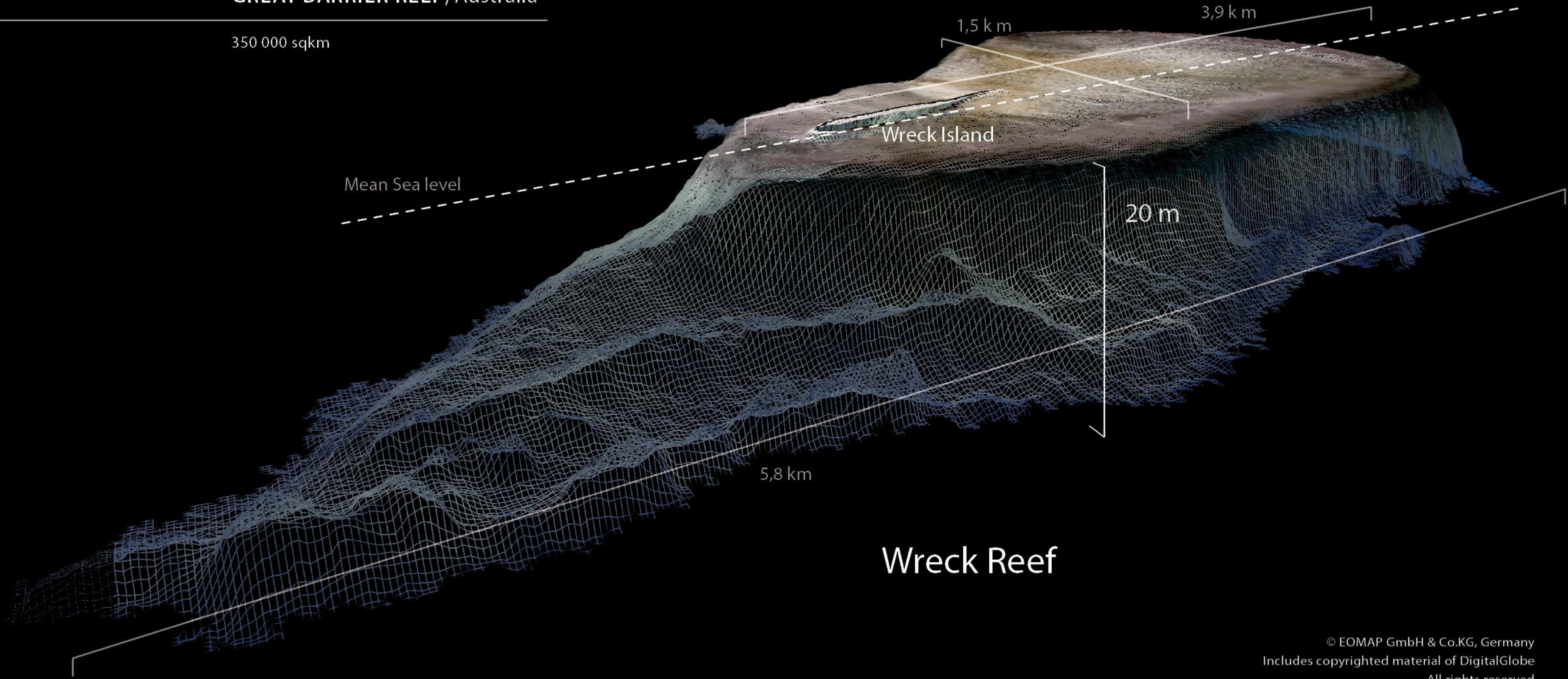
Figure 4. Left to right: Spatial resolution of eoBATHY 30 compared to eoBATHY 5 and eoBATHY 2.

GREAT BARRIER REEF BATHYMETRY

Very high (2m) resolution mapping
of bathymetry and seafloor

GREAT BARRIER REEF, Australia

350 000 sqkm



Wreck Reef

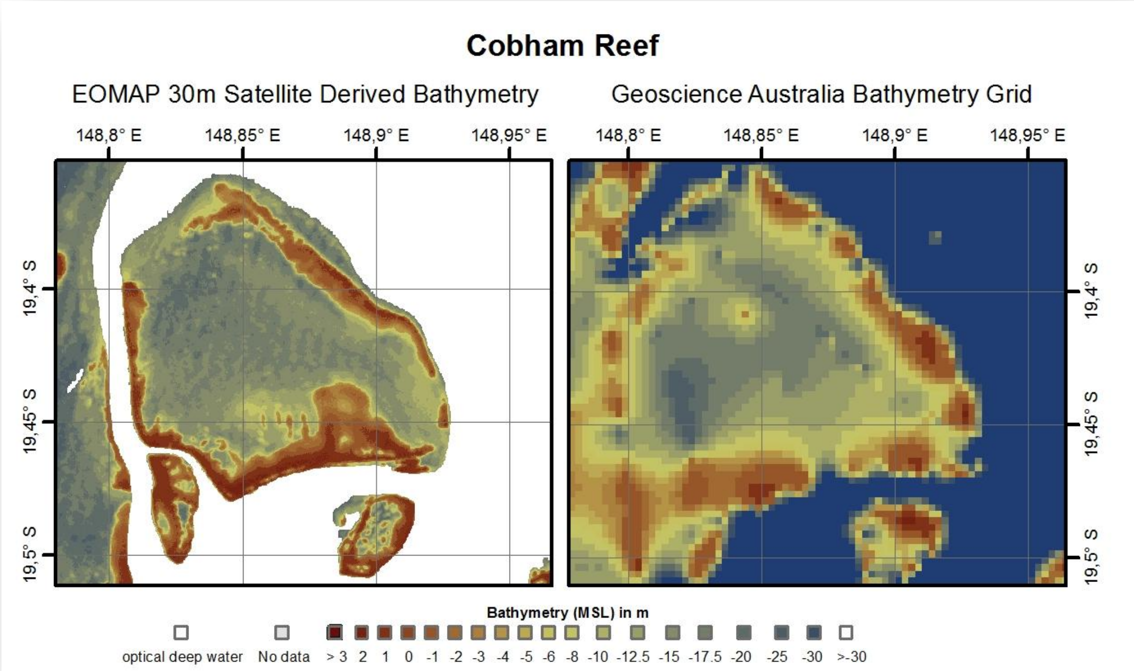
Comparison of EOMAP Satellite Derived Bathymetry 30m product vs. the Geoscience Australia Bathymetry grid

Since the launch of EOMAPs Satellite Derived Bathymetry Great Barrier Reef (GBR) Survey in 2013 and Geoscience Australia's' Bathymetry grid in 2009, two datasets now exist which cover the whole of the GBR. These differ significantly in methods, resolution, accuracy, data acquisition and other characteristics. The following table gives an overview of the two datasets, and the accompanying figures, further below give a visual impression of the comparison.

> *EOMAP's satellite image based reef products are a step change in enabling Australian agencies and industry to map and monitor changes to GBR. This also demonstrates how private industry and government can work together to deliver the best solutions for the government and draw on our expertise in private industry..*
>
> Stuart Phinn, Professor School of Geography, Planning and Environmental Management Centre for Spatial Environmental Research, The University of Queensland Brisbane, Queensland, Australia

	EOMAP Satellite Derived Bathymetry Product	**Geoscience Australia Bathymetry grid**
Producer	EOMAP GmbH & Co. KG (GER) EOMAP Asia Pacific (SIN)	Geoscience Australia (AUS)
Date of release	Nov. 2013	June 2009
Methods	Satellite derived Bathymetry, based on Landsat 7 data	Various different methods and datasources: • Multibeam • Fairsheets and 1:250,000 Series • Laser Airborne Depth Sounder (LADS) • Satellite altimetry measurements • Australian topography • New Zealand topography • SRTM DEM
Purpose	Providing the first complete moderate resolution bathymetry dataset for the GBR for scientific and industry projects. Raise awareness to technique of Satellite derived bathymetry.	Providing regional and local broad scale context for scientific and industry projects, and public education

Data acquisition	1999-2003	1963-2009, based on various dataset acquired during the last decades
Data Extent	North latitude: -9° 14'19 South latitude: -24° 50'37 East longitude: 153° 48'21 West longitude:141° 31'15	North latitude: -8° South latitude: -60° East longitude: 172° West longitude: 92°
Spatial Resolution	30 m	• 250 m (0.0025 decimal degrees) in areas with direct bathymetric observations • 1500 - 3500 (1-2 arc minutes) for the remaining area of the Australian shelf
Vertical accuracy	Varying with source image quality, in the range of 0-30% of depths.	Unknown, function of methods used
Horizontal accuracy	0-40m	5 – 2 000m, depending the method used.
Depth range	+4m – - 40m	+ 3 000 - -9 000 m
Metadata	Detailed information available for every reef	General metadata for all the overall dataset
Water reference level	LAT, MSL, HAT	MSL


Cobham Reef
EOMAP 30m Satellite Derived Bathymetry
Geoscience Australia Bathymetry Grid
148,8° E
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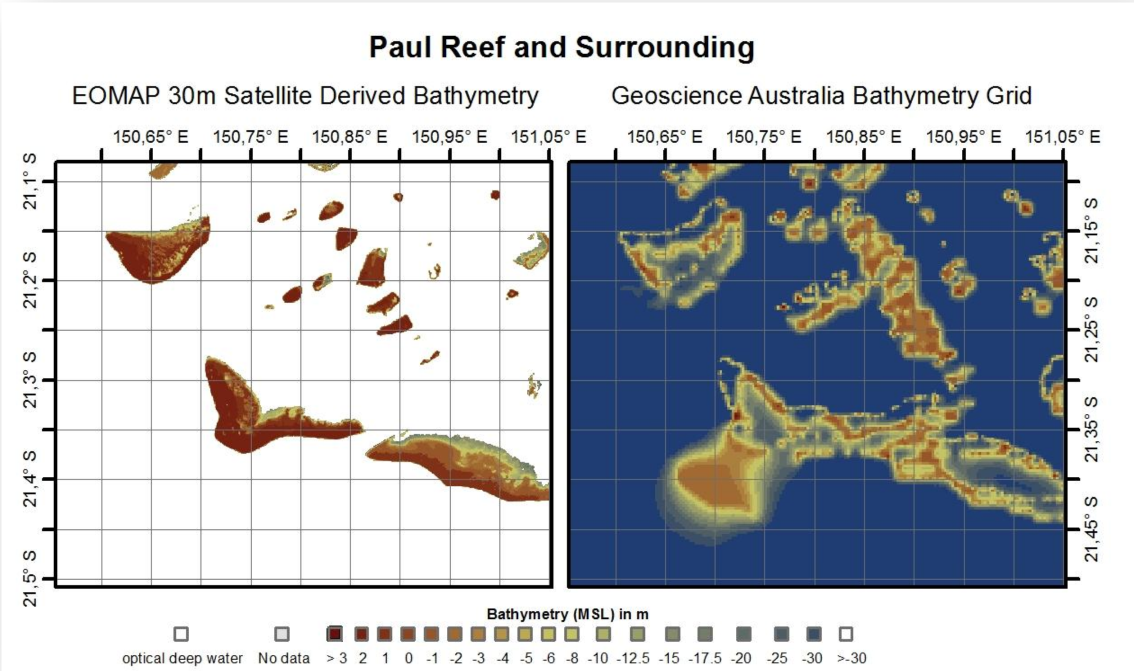
Paul Reef and Surrounding
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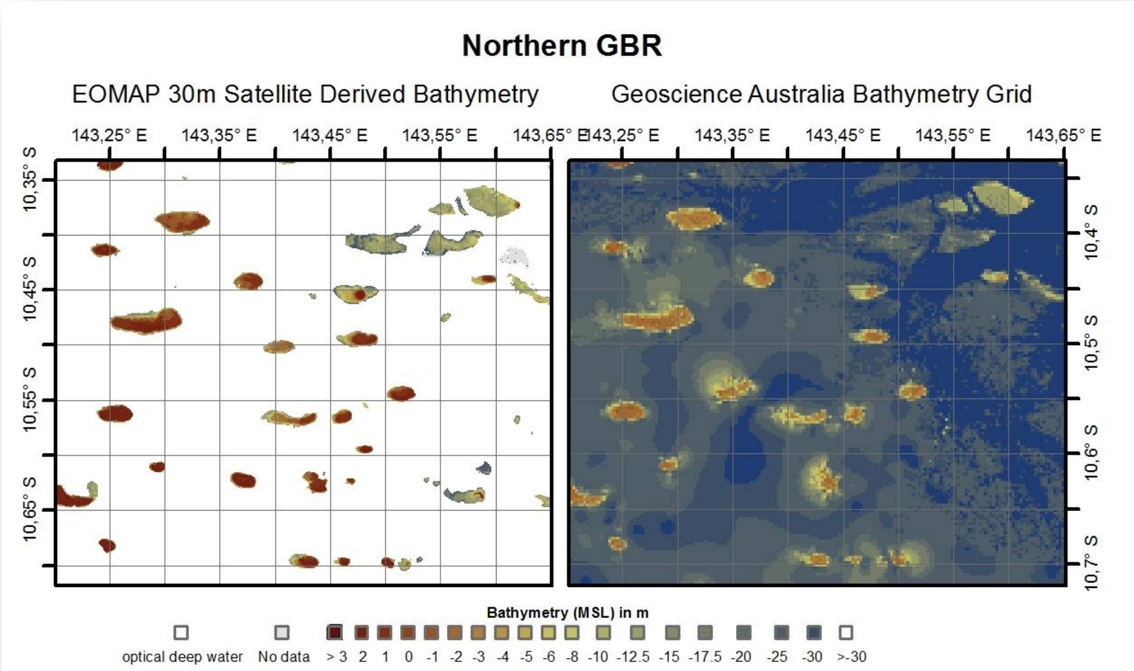
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EOMAP 30m Satellite Derived Bathymetry
Geoscience Australia Bathymetry Grid
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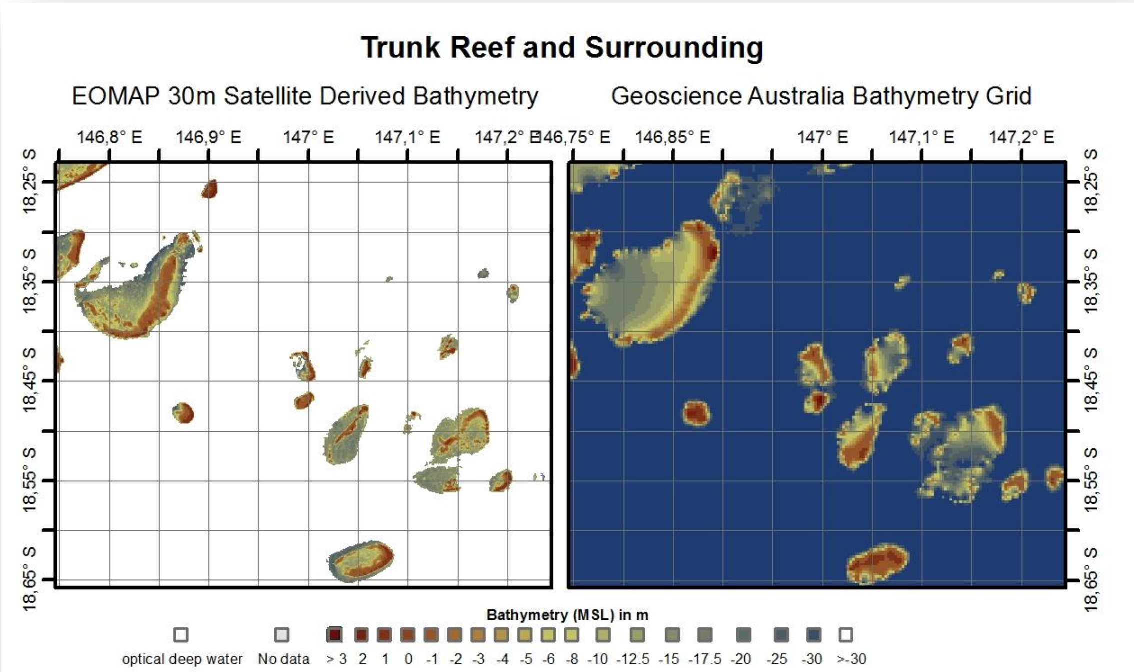
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Bathymetry (MSL) in m
optical deep water No data > 3 2 1 0 -1 -2 -3 -4 -5 -6 -8 -10 -12.5 -15 -17.5 -20 -25 -30 >-30

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Data access

Access the free available datasets through:

www.eomap.com/great-barrier-reef

contact info@eomap.com for data ordering or general inquiries

> *The reflectance and depth products will form the fundamental baseline data able to be used by government monitoring agencies for monitoring and management planning, research institutions for monitoring and modelling, and private industry to build their own applications for the data. This will provide the basis for a range of derived map products and the need for higher spatial resolution versions of these data.*
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> Stuart Phinn, Professor School of Geography, Planning and Environmental Management Centre for Spatial Environmental Research, The University of Queensland Brisbane, Queensland, Australia

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Re: Great Barrier Reef revised digital bathymetry from EOMAP

Dear Magnus,

The following letter outlines a few thoughts on the EOMAP product we have been working with you on which may be useful for demonstrating its value.
.
Baseline mapping of natural environment and resources is fundamental requirement for understanding what an environment is made up of and how it is changing over time. This information is regarded as essential data for any government or company responsible for or managing the environment.

We have this for out terrestrial environments down to the level of trees, yet for one of our most valuable assets, the Great Barrier Reef we still do not have the baseline information at a suitable level of detail, nor do we have the ability to assess how it changes over time. This applies to the depth or bathymetry of the entire reef, and the type of environments or communities present on reefs.

EOMAP's satellite image based reef products offer Australian government and scientific agencies, and private industries the ability to access state of the art and accurate baseline maps of the Great Barrier Reef. Agencies can then link these to ongoing field surveys and build a more accurate base for monitoring, understanding changes to the reef, assessing disturbance impacts (e.g. tropical; cyclones, crown of thorns, ship groundings..), and predicting likely impacts of climate change effect, such as sea-level rise and increased tropical cyclone frequency .

EOMAP's satellite image based reef products are a step change in enabling Australian agencies and industry to map and monitor changes to GBR. This also demonstrates how private industry and government can work together to deliver the best solutions for the government and draw on our expertise in private industry.

EOMAP's satellite image based reef do not replace the need for detailed fieldwork to assess the state and condition of the GBR, especially such critical activities as the AIMS long term

EOMAP

monitoring program. It does however enable a significant advance in the level of mapping and monitoring possible by combining ecological field surveys and image data sets to map reef features indicative of the amount of coral and algae present.

It is interesting to note that all state and commonwealth agencies, including Wet Tropics Management Authority have baseline maps of the extent and composition of the environment they are responsible for. This data set will enable agencies responsible for GBR to develop these key data sets and monitor change over time.

Extensive work done in BRG over the past 14 years, has focused on developing, testing and delivering maps of coral reef environmental properties , with extensive focus on the Capricorn Bunker Group, a s well as other environments around the world. The group has extensive field, airborne and satellite archives and derived maps. This experience was used to assess EOMP's products on several of the groups mots intensively studies sites which are surveyed and mapped on an annual basis.

EOMAP Bathymetry data were used with Landsat image data to create geomorphic zonation maps for Capricorn Bunker Group in the southern Great Barrier Reef. This approach maps reefs zones based on geomorphological processes that are driven by water depth, hence the EOMAP product was essential for it to work. The results are very promising relative to approaches based on subsurface reflectance imagery alone.

EOMAP Bottom reflectance products, show new details detail over reef areas in water depths of 5 m to 15 m. Previously discriminating reef features at these depths was very difficult. The EOMAP products provide more detail for information extraction at depth.

The reflectance and depth products will form the fundamental baseline data able to be used by government monitoring agencies for monitoring and management planning, research institutions for monitoring and modelling, and private industry to build their own applications for the data. This will provide the basis for a range of derived map products and the need for higher spatial resolution versions of these data.

Please contact us at the numbers below if you require additional information.

Yours sincerely,

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08 Nov 2013

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To whom it may concern,

Ref: Validation of EOMAP Landsat satellite derived bathymetry of the Great Barrier Reef

During October 2013, I conducted a validation of the Landsat satellite derived bathymetry of the Great Barrier Reef (GBR) supplied to me by EOMAP as a Project Swordfish product. The bathymetry data comprised of two 32 bit floating point geotiffs ranging from the Torres Strait and Coral Sea, to Fraser Island in SE Queensland:
(A) Northern GBR at 30 m-resolution, UTM54S WGS84 horizontal datum, Lowest Astronomical Tide (LAT) vertical datum, depth in decimetres, general depth range +2 to -34 m, and 10,624 km^2 area coverage;
(B) Southern GBR at 30 m-resolution, UTM56S WGS84 horizontal datum, LAT vertical datum, depths in decimetres, general depth range +2 to -33 m, and 8,166 km^2 area coverage.

Horizontal validation. Using Geoscience Australia ALOS PRISM mosaics of the GBR, I compared 1 m-interval contours derived from the Landsat satellite derived bathymetry in ArcMap. The ALOS PRISM mosaics have a 2.5 m-resolution with RMS horizontal error estimates of individual scenes typically reported as 3 to 5 m, thereby providing a high confidence in their positional accuracy. I selected 32 reefs for validation, spaced about 60 nm apart across the entire GBR, looking for cloud-free ALOS PRISM data with sharp edges on shallow reefs to line up against the contour data. For 21 of the selected reefs there was no detectable horizontal offset, while 11 reefs had offsets of between 30 to 40 m, or about the width of one Landsat pixel. Therefore I consider the Landsat bathymetry data to have an overall maximum horizontal positioning error of 40 m.

Vertical validation. Using 11 Australian Hydrographic Service lidar surveys collected from the Torres Strait to SE Queensland, I selected two Landsat bathymetry reefs from within each lidar survey for vertical validation. The lidar surveys are IHO S44 Order 1 compliant using the LAT vertical datum. EOMAP supplied an accompanying shapefile of quality, where Class 1 pixels are assumed to contain the most reliable information by assessing the sunglint on the sea surface and level of turbidity in the water column. Scatterplots of the Landsat data against the lidar data were flagged as quality Class 1-3, and the number of pixels were counted within an absolute error of 1 m, plus a relative (i.e. depth dependent) error of 25%. For Class 1 pixels, 75% of pixels are within +/- 25% (with +/- 1 m offset), e.g. at 10 m true depth, 75% of pixels lie within an error band 9-11 m +/- 2.5 m.

LAT datum validation. Using the 22 linear regression equations from the vertical validation scatterplots, I calculated the equivalent Landsat bathymetry depths when the lidar data were set at 0 m, i.e. LAT. This method checked the ability of the Landsat bathymetry to approximate LAT as a result of the tide model used in the processing. The equivalent depths ranged from -0.93 to +3.08 m, with an average of +0.3 m. Therefore I consider that the Project Swordfish data closely approximates LAT, with a slight (~0.3 m) positive bias.

False positives. Using GBRMPA Landsat classified imagery of reefs in the GBR, I examined the Landsat bathymetry data for areas that could be false positives, i.e. areas falsely selected as reefs but actually due to oceanographic phenomena. I only detected very minor false positive areas in the vicinity of some narrow channels, likely caused by sediment plumes. These were highlighted to EOMAP and I have been advised that they have been removed. Therefore, I consider the Landsat bathymetry data to have no false positive reefs.

Sincerely,

R. Beaman

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