Pacific Islands
GIS&RS *news*

The Newsletter of the GIS&Remote Sensing Users in the Pacific
Issue 1/2008
February, 2008

Pacific Islands GIS&RS User Conference: Marked a great Success

The pacific Islands GIS and RS User Conference was held in Suva from the 4th to the 7th of December, last year at the lower campus of the University of the South Pacific. An independent conference committee made up personnel from SOPAC, USP, FLIS, FEA, NLTB and Forestry Department organised the conference.

Over 220 people registered on the conference website with about 200 turning up to the conference from more than 20 different countries. During the four days about 60 power point presentations and verbal speeches were given.

The conference attracted presenters from as far as the America's and Europe. This includes presenters from Australia, Canada, Cook Islands, Fiji, France, Germany, Hawaii, Ireland, Kiribati, New Caledonia, New Zealand, Papua New Guinea, Samoa, Solomon Islands, Tonga and Tuvalu.

On the final day of the Conference approximately 100 Pacific Islanders discussed about 17 different subjects relating to GIS and RS applications and the methods to be developed or adapted for Pacific Island Countries.

During the evenings, a number of meetings took place for the conference committee or the special interest group GIS&RS of PICISOC.

Every evening a social program provided the avenue to network between Pacific Island GIS officers and between software, hardware and image data provider and users.

An exhibition room was set aside to give space for the display information about hardware, software, image data and applications. This room was also doubled as a meeting during the coffee breaks.

Prior to the conference a workshop was conducted for GIS officers of utilities and another workshop as introduction to ESRI GIS products. This effort was greatly welcomed by the participants and their organisations as a way to move forward.

This and following issues of the GIS&RS Newsletter will publish articles provided by the presenters of the Conference.

Wolf Elizabeth

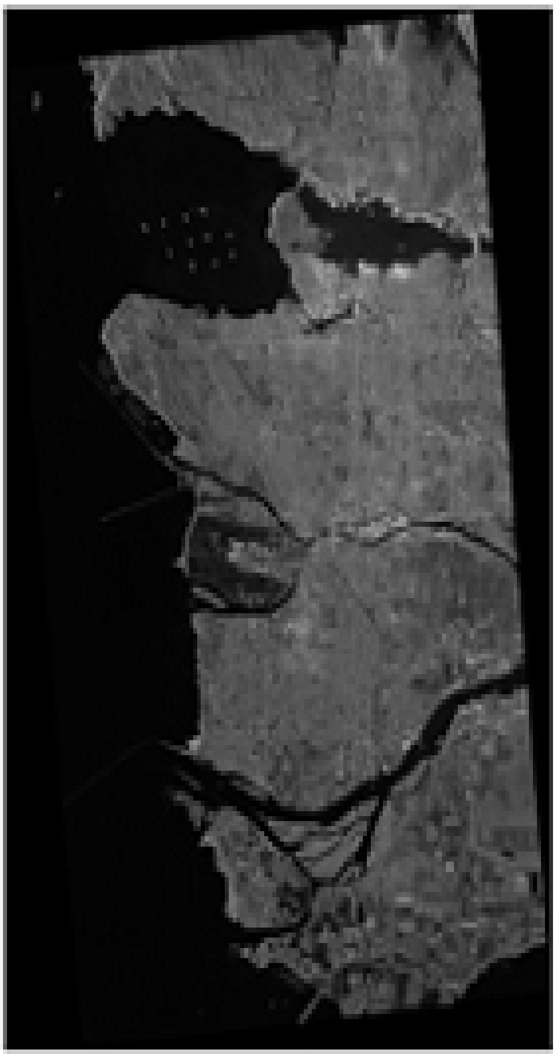
ISSN 1562-4250

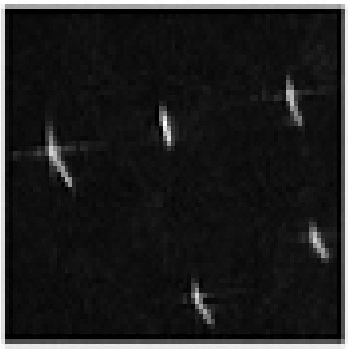
Content

MDA Geospatial Services Inc. has released the first delivered images from the RADARSAT-2 radar satellite, launched on 24th December 2007.

The three call-outs to the right of the image demonstrate the increased information content provided by high-resolution radar imaging. The top call-out shows five cargo ships in English Bay - structural detail of the cargo holds is evident. The bright return from the stern is due to the strong radar response from the superstructure of the ship.

The middle call-out shows the increased detail available over the Vancouver Airport. The thin bright line feature coming in from the right hand side is the new rapid transit Canada Line currently under construction for the 2010 Olympics. More information can also be extracted from the airport terminal buildings and loading gates.





The bottom call-out shows the added detail provided by 3m imaging, which enables greater differentiation of the agriculture fields under different management practices and moisture conditions.

This image was acquired early in the commissioning phase, prior to any adjustment of the radar gain settings.

Sattellite Image Data Preprocessing

Joy Papao

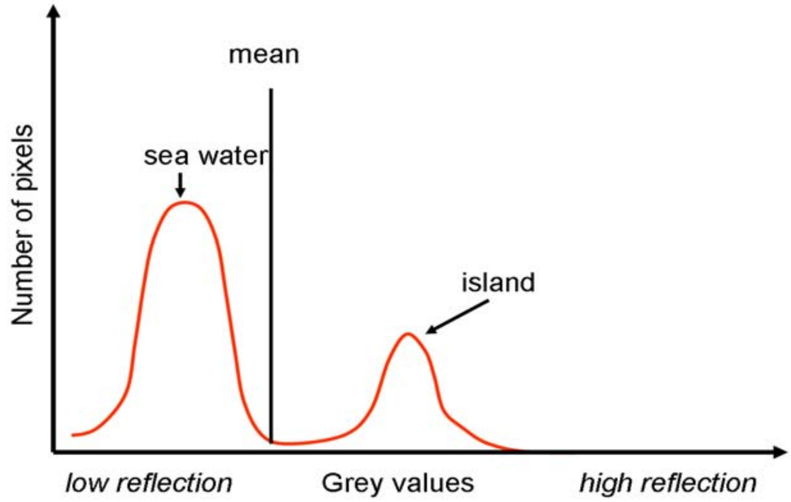
Introduction

Today, most digital image data is received from the satellite image distributing companies as 16bit GeoTIFF and in different scenes according to capture date for the most frequently used, which are pan-sharpened QuickBird and multi-spectral IKONOS images. This data cannot be directly displayed in most image software products and SOPAC provides the service to its member countries of converting the image data to backdrops ready to be used GIS software.

Image Stitching

Software used for this process is ERDAS Imagine version 8.4 and 9.0. FWTools - GDAL (open source) is also used when images are greater than 2GB which ERDAS v 8.4 cannot handle.

In most cases the high-resolution image satellites record the target area not in one go but in tiles of several over flights. Each of these tiles arrives as different file and the image has to be stitched together. In addition, the image tiles often arrive as different file for every image band. The pre-processing therefore joins in one go the different bands together to multi-band image files. Then, target areas, which are mostly the land areas of islands are cut out of these files if they cover large areas of off shore water bodies. In a further step these subsets are stitched together to a new image file, which is a semi automatic process if the images are geo-coded.



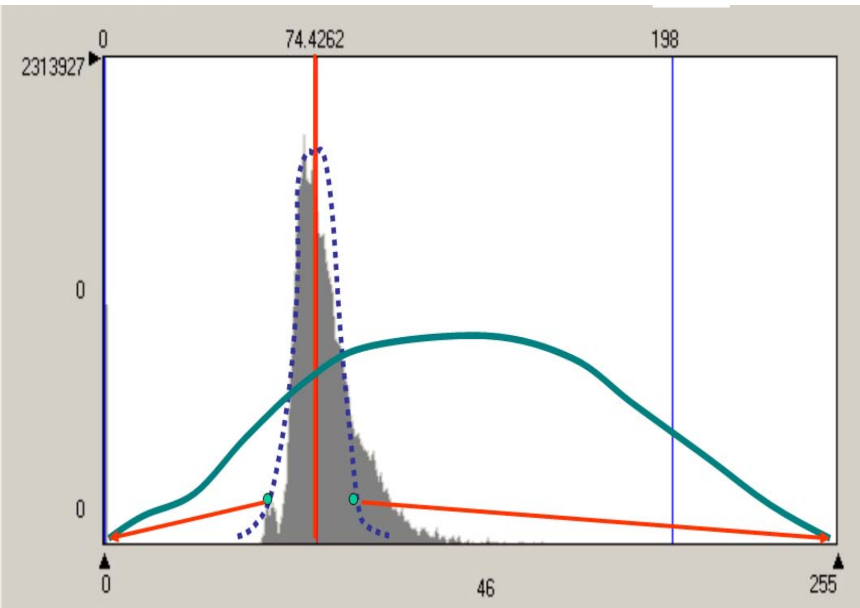


Figure 01: *Grey value distribution of a "normal" image shown as grey background. The software assumes a bell shaped normal distribution (blue dotted line) from the calculated mean of the image data (red line) and recalculates a distribution (green line), which sets all pixels lower than two times standard deviation from the mean to 0 and all pixel values greater than two times standard deviation plus the mean to 255.*

Band Selection and Object specific Contrast Enhancement

Depending on the later use of the backdrops band selection and combination has to be performed, as multi-spectral data arrive as 4 band images (QuickBird, IKONOS or OrbView-3) or seven to more band images (Landsat TM) and MapInfo software only displays a combination of three bands. In most cases onecombination is supplied as blue, green, red and another combination as green, red, near infrared. Image analysis software such as Adobe Photoshop or also ERDAS stretches the image automatically. The software therefore assumes that the image is a "normal" image with the usual distribution of grey values forming a bell shaped distribution curve. All pixel values are then re-calculated through the Look Up Table (LUT), which transforms all grey values minus 2 times standard deviation from the mean grey value to 0 and all grey values plus 2 times from the mean to 255, see figure 01. Thus the display of the monitor, which has also the range from 0 to 255 is optimal utilised. In reality the pixel data is not changed the LUT stores the re-calculationowever, the assumption of a normal distributed grey value distribution is not always the case for Pacific Island Countries. Often a two bell shaped curve is a reality with one peak for the low reflecting off shore water bodies and one peak for the bright reflecting island. The statistical mean is located between the two bell shaped curves and the automatic stretch does not enhance the image contrast, see figure 02.

To overcome this problem an "Area of Interest" (AOI) has to be delineated manually excluding the water as the image stretch is calculated using pixels of the AOI only, see figure 3. This creates one bell shaped pixel value distribution with a mean grey value in the centre of interest and increases the contrast between features on land while reducing the contrast of the off shore water at the same time see figure 04.

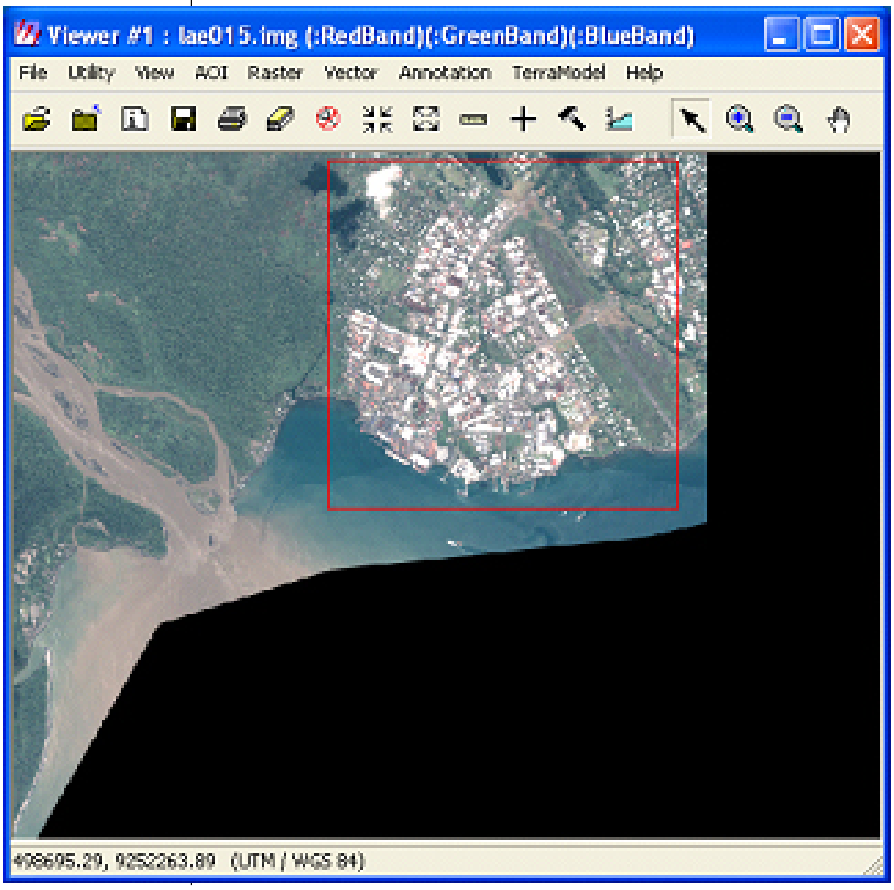


Figure 03: *An area of interest must be selected for a type of image with a two bell shaped pixel grey value distribution, which only includes pixels of the target area to be contrast enhanced. The red line in image above shows the area of interest.*

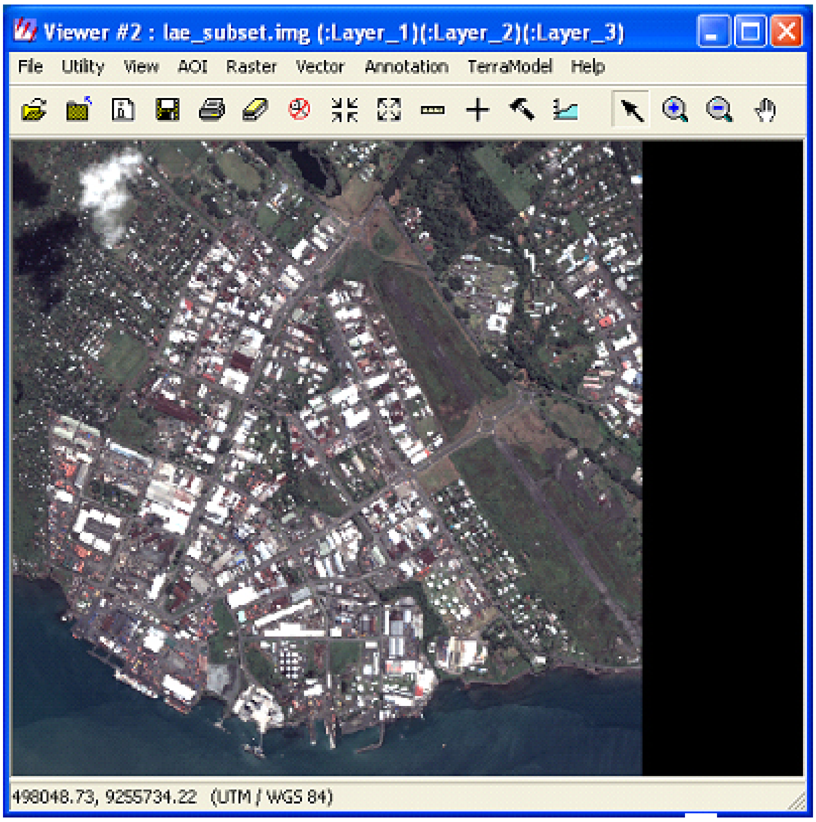


Figure 04: *Result of the enhancement, the target area has increased contrast.*

Conversion of 16 bit to 8 bit

Modern image data of high-resolution sensors is recorded in 11 bit and packed into 16bit GeoTIFF files. These files are converted by the software to ERDAS IMG image files and still have 16 bit data depth. These 16 bit image files have to be converted to 8bit because this not only reduces the unnecessary large file size, but also because MapInfo cannot read 16 bit data. As explained the image enhancement stretches the image between the values 0 and 255 for the display, which is exactly the 8 bit data range. ERDAS Image provides the possibility to store the re-calculated pixel values in a new image file, which keeps optimal image stretch and reduces the image to 8 bit data range.

Creating GeoTIFF Image Files

As MapInfo and most other GIS software cannot read ERDAS IMG files the image data has to be re-formatted to a compatible format. It is best to utilise the export format GeoTIFF, as MapInfo from version 6.5 upwards can read also the stored coordinate system in the image data and the user does not need to geocoded the image file again.

The new formatted images are stored on DVDs at the GIS&RS archives and copies are sent to member countries to be used as GIS Backdrop. The original files are also sent to the member countries after a safety copy is stored at SOPAC.

Summary

The image pre-processing at SOPAC allows "normal" users to utilise image data as GIS backdrops without going through image analysis processes. However, the user has to know that the image data has been changed and a permanent image stretch is fixed, which results in:

a) Loss of contrast if an additional image stretch in applied.

b) The need to go back to the original 16 bit image file if a special image enhancement is required for example to show different forest types or different agricultural crops within the land mass.

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SOPAC is equipped with a new scanner capable to scan up to A0 size, which can handle most maps in one go. The resolution is up to 600 dpi and the colour output file is real RGB 24bit (not pseudo colour).

SOPAC can service member countries to produce image files from available topographic maps (and other thematic maps) for subsequent GIS backdrop production. Image stitching of different map patches and successive colour adjustment can be avoided now.

The resolution is sufficient to carry out colour separation with ERDAS software available in all SOPAC member countries and separate village, road or river names as separate layer.

Coffee GIS

Mary Pati, PNG

Introduction

Papua New Guinea (PNG) relies very heavily on it's agricultural commodities. The government through the Department of Agriculture in collaboration with the Coffee Industry Corporation (CIC) initiated a Geographic Information System (GIS) pilot project on coffee in the Eastern Highland Province. This pilot GIS after completion was to be replicated for other agricultural commodities as a step towards establishing a National Commodities Management Information System (NCMIS).

Project Background

Within a time frame of six weeks, a MS Access database interfaced with MapInfo was delivered. Map Basic programs were also written to customise MapInfo to show locations of coffee plantations, blocks, small holder coffee growing villages in relation to coffee factories, roads and airstrips.

One of the objectives of the project has been to target small holder coffee growers to promote growing and exporting of organic coffee. One important factor that affected the rural coffee growing community has been transportation of coffee to factories for processing and manufacturing for export. With the pilot project, it has been difficult to show location on individual coffee gardens as there hasn't been any existing data, however, data collected for villages has been used to show coffee growing villages.

Data Capture Methodology

A week's Global Positioning Systems (GPS) training was conducted to train twenty six (26) Field Extension Officers from the various coffee growing provinces to use hand held GPSs (Explorist 400) to capture locations of small holder coffee gardens. Topograhic maps of a scale 1:100,000 were scanned and registered to enable the Field Extension officers to use as backdrops. Possible coffee areas as depicted by the legend on the topo map has also been digitised and confirmed by GPS, refer to *Figure 01*

The GPS data is downloaded using MapSend Lite in Excel format. This data is then opened into MapInfo and the GPS points are created as a points layer. A polygons layer is then created by joining the GPS points and attribute data entered and updated in the MS Access tables. An additional advantage in small holder data collection is knowing where the small holder coffee growing villages are as shown in the *Figure 02*

Aiyura Coffee Plantations

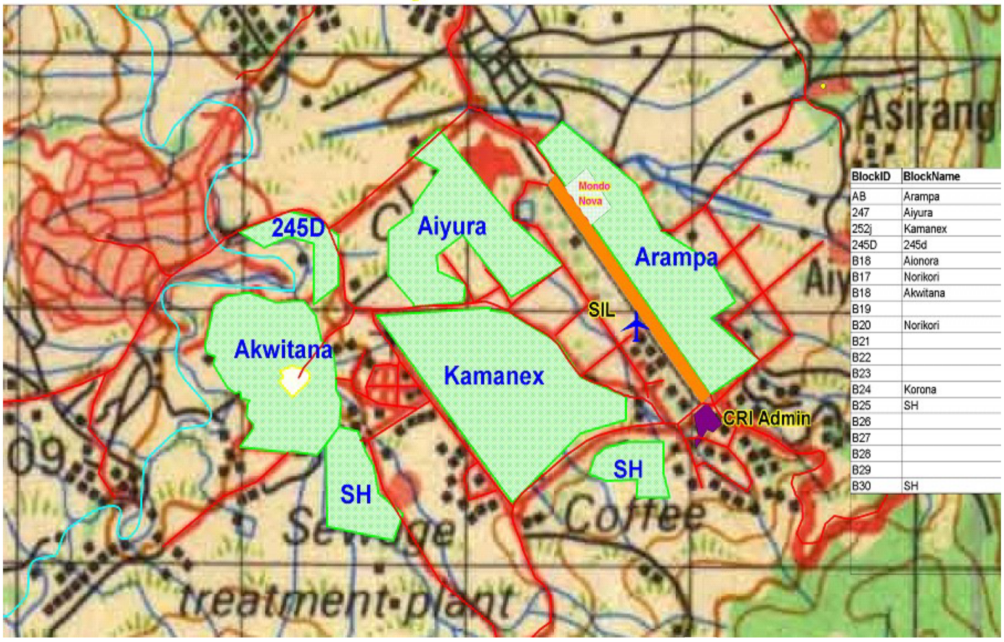


Figure 01: *The map shows the areas that may have coffee plantation*

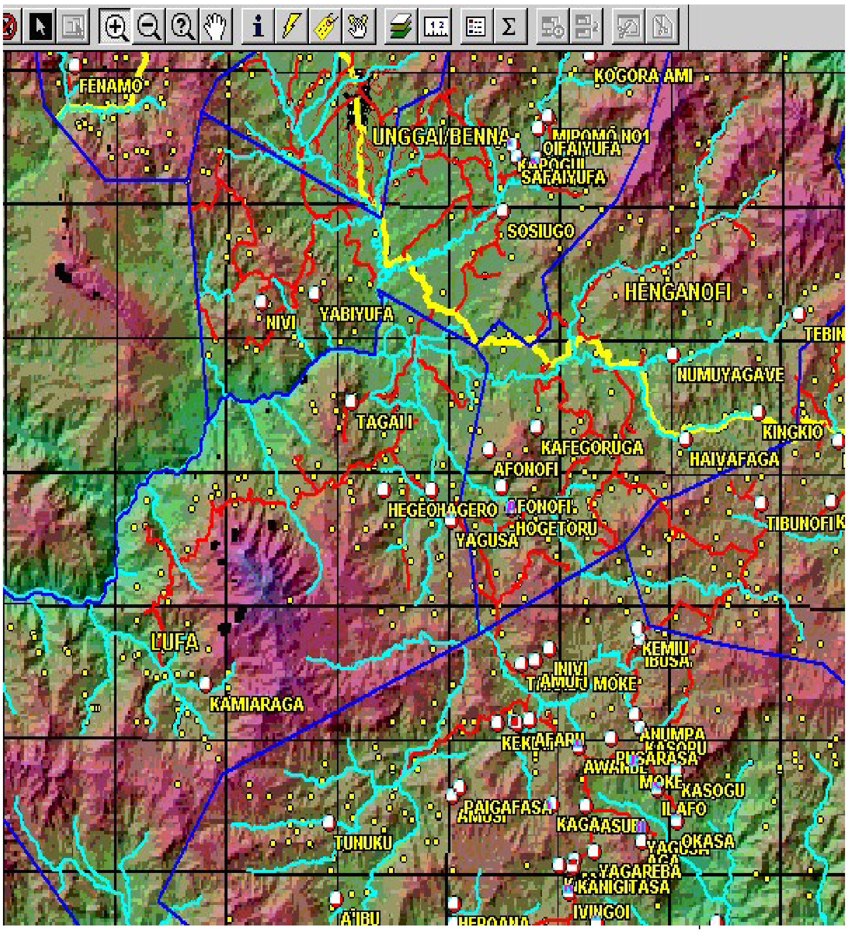


Figure 02: *Small coffee plantation holder is also depicted in the map*

The Pilot System

The Coffee pilot system has been designed to make it more user friendly. The MS Access forms has been divided into two sections; (1) enquiry and (2) update. In both sections; links are made to MapInfo for spatial displays for the particular data being queried or to be updated. Flexibility has also been made to the user for the user to design their own queries.An example of such a form is as shown in *Figure 03*

A particular interest by the Coffee Industry Corporation (CIC) is to know how much land area is being covered by coffee plantations, coffee blocks or small holder farms and the total coffee land area in percentage. This information and other statistical information are required so that a comparison can be made between the coffee growing provinces for planning and budgeting purposes. In knowing the total land area covered by coffee, a calculation can be made on standard spacing between coffee trees and rows and in knowing the type of coffee grown in a certain environment, an estimate can be made on how many tonnes of coffee can be produced by a plantation or block. In turn, an estimate can be made on how many tonnes a province can produce. An example of such a calculation is seen in Figure 04.The same formula will be used to determine the total produce of the various districts, particularly the remote areas so that, the Government of PNG through it's **Green Revolution Program** can assist the growers to airfreight their coffee to places where they can be able to sell their coffee.

This is a first step towards determining the yields of the different coffee types and the type of conditions that is conducive towards it's successful yield and also if these information and information on market demands is readily available, the coffee growing community can be encouraged and supported to grow highly demanded, high yielding coffee.

It is envisaged that with sufficient funding and support, a comprehensive data collection program can be the use of satellite imagery indicating patterns of vegetation cover can also be investigated.

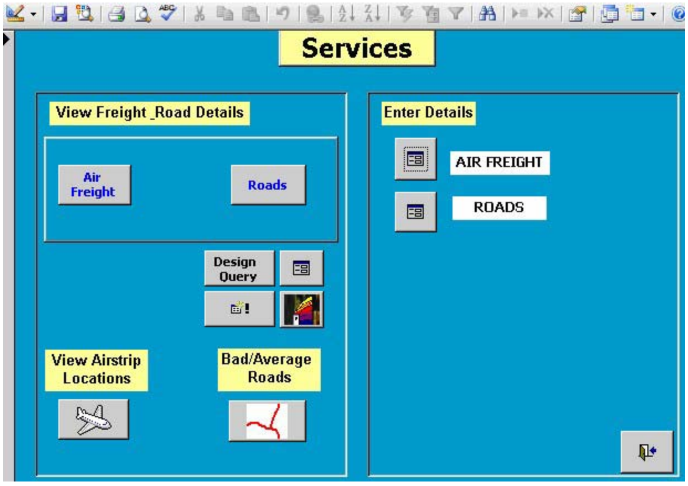


Figure 03: *Forms have been created to simplify user accessability*

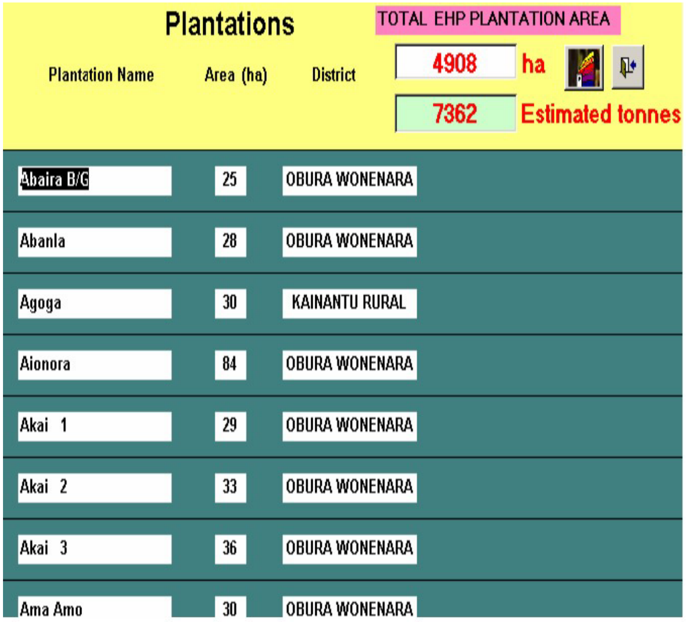


Figure 04: *Calculations of the total coffee produced in tonnes is done done automatically in Access*

Summary

This is a very important project. It is envisaged that over time the coffee data will eventually be captured and the Coffee Industry Corporation can use this system as a tool for management and planning of their coffee assets and their daily business operations. This type of project needs a champion to drive it in terms of securing funding and resources to sustain it. Information based planning is very crucial and is necessity and any resources spent on it will not be a waste.

This system can then be replicated for all other agricultural commodities such as cocoa, rubber, oil palm, spices, pyrethrum and etc. It will be cost savings for the Department of Agriculture and the National Commodities Board.

New Remote Sensing Satellites for Pacific Island Countries

Wolf Forstreuter, SOPAC

Introduction

Pacific Island Countries are outside the footprint of any ground antenna to receiving image data recorded by different satellites. Images have to be stored on onboard tape devices where the space has to be booked long time in advance. Often the target area is cloudy and the image data is not usable. In addition, the Pacific is sparely populated and companies do not record images in advance hoping that there will be a customer later.

In 2007 and 2008 new satellites are and will be in space, which could change the situation for 1:10,000 scale mapping. The data quality increased regarding the spatial resolution to 40cm instead of 60cm as the best option and more satellites record high-resolution image data. In addition, the onboard storage capacity increased due to improved equipment. Finally and the first high-resolution radar satellite provides image data, which can be recorded during nighttime and through clouds.

CARTOSAT-2

CARTOSAT-2 was launched in January 2007 and provides panchromatic (black and white) images of 80cm spatial resolution. The sensor can look 45 degrees in all directions, which allows stereo image production and ensures a high repetition rate of image recording. It is expected that this satellite provides low cost image data. The satellite is managed from India's National Remote Sensing Agency and the cost is not known yet.

EROS-B

EROS-B is an Israeli satellite, which was launched in April 2007. This satellite provides panchromatic images of 70cm resolution, just 10cm less than the best currently operating satellite QuickBird with 60cm resolution. A global network distributes the image data, where the point of contact for Pacific Island Countries is either the Center for Space and Remote Sensing Research in Taiwan or MDA in Canada as re-seller. It is expected that this image data will be distributed as low cost images as EROS-A data from the same company only cost USD 5 per square km while QuickBird data cost about USD 20.

WorldView-1

WorldView-1 will be launched in October 2007 and will provide 40cm resolution data in panchromatic mode. Although the data will be resampled to 50cm for customers outside USA it will be a further increase of spatial resolution, which e.g. might increase the stratification potential of coconut palm stands. Important is the increased onboard storage capacity of 750,000 km^2/day compared with 12,100 km^2 of IKONOS. DigitalGlobe handles the satellite and distributes the data.

WorldView-2

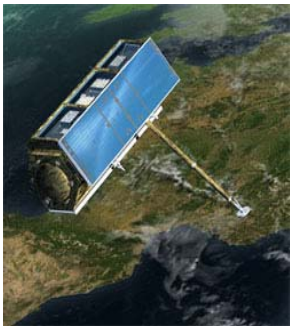
WorldView-2 will be launched in late 2008 and is also operated by DigitalGlobe. This satellite will record images of the same spatial resolution in panchromatic mode, but will have 8 spectral bands in multi-spectral mode. The coloured images will have a spatial resolution of 1.8m and will cover new spectral bands not covered in this form by current satellites IKONOS, QuickBird or OrbView-3. The onboard storage capacity will increase to 975,000 km^2/day.

GeoEye-1

The GeoEye-1 satellite was supposed to be launched beginning of 2008, now it is unlikely to be launched before 22 August. The satellite will be equipped with a sensor capable to record image with up to 41cm resolution in panchromatic (which has to be resampled to 50cm due to licensing issues) and 1.65m in multi-spectral mode. GeoEye-1 will be able to revisit any point on Earth once every three days or sooner. The satellite will be able to collect up to 700,000 km^2/day of panchromatic (and up to 350,000 km^2/day of pan-sharpened multi-spectral) imagery per day. The image data will be distributed through Satellite Imaging Corporation in Texas for GeoEye Satellite Imaging. GeoEye also manages the satellites IKONOS and OrbView-3, which are still fully operational.

TerraSAR-X

TerraSAR-X was launched in June 2007 and is the first radar satellite recording high-resolution image data of about 1m. The sensor also can record also while orbiting the earth on the shadowed side. Infoterra GmbH, a German company, distributes the data. Available radar satellites so far such as ERS2, ENVISAT, RadarSat-1, etc. recode with about 30m spatial resolution, where shipping vessel were difficult to detect. This data set allows the shape of the vessel to be recognised and the speed can be measured. The satellite will be also used for change detection of topography and high-resolution DTM production



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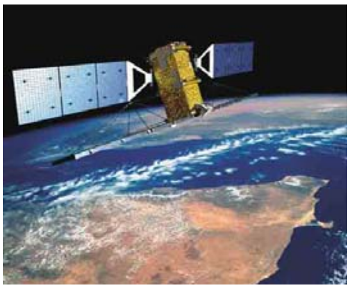
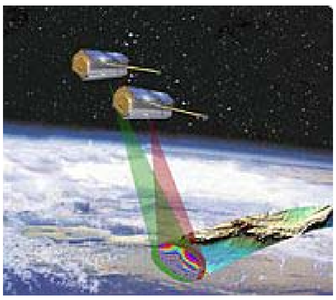


RadarSat-2

The RadarSat-2 radar satellite was launched on 24th December 2007. The first images were recorded in January 2008. The satellite is the product of a partnership between the Canadian Space Agency and MDA. The satellite can record with ground resolution between 3 to 100 metres and like TerraSAR-X the system can send and receive with different polarisations HH, HV, VV and VH.TanDEM-X



TanDEM-X

TanDEM-X consist of two high-resolution imaging radar satellites, which will be launched in late 2008. The systems are nearly identical to TerraSAR-X. The two satellites flying in tandem forming a huge radar interferometer capable of measuring terrain topography with 2 m height accuracy generate digital maps from any part of the world. Infoterra GmbH will distribute also the TanDEM-X data.

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Bathymetry of the Pacific Ocean

Franck Margron, SPC

Because of the increasing pressure on sedentary marine species - both in coastal areas and offshore seamounts - there is an increasing need for mapping the potential habitat of these resources so that fisheries managers and decision makers can make informed decisions about coastal resources.

Contrary to land resources, which can be mapped using satellite products, the marine environment is more difficult to map because water absorbs visible light and radar frequencies very quickly, and the ocean is basically opaque from the sky for depths beyond 50 m, even using airborne Lidar (laser bathymetry).

This paper is a revised version of two original articles published in the SPC Fisheries Newsletter N°117 and N°120. In the first part we describe the survey techniques and available datasets for deep water bathymetry, whereas we focus on shallow bathymetry in the second part.

Part 1 – General Bathymetry of the Pacific Ocean

Traditional oceanographic surveys of the oceans

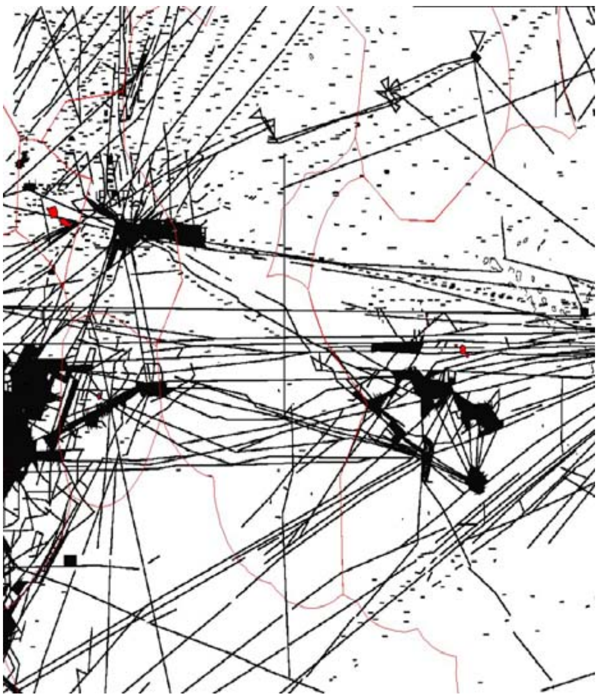


Figure 01: *Diagram of sounding line density of chart NZ 14606 and countries EEZ*

High-resolution mapping of the ocean floor requires expensive equipment (multi-beam and side-scan sonars), operated from oceanographic ships with high operational costs. For these reasons, direct ocean floor mapping is very limited, and traditional marine charts can miss important relief features outside the areas surveyed by hydrographic ships.

Figure 1 depicts the sounding lines used to produce the marine chart NZ 14606. It shows that some areas have been intensively surveyed, such as the Tonga Trench or Savannah seamount chain (French Polynesia), whereas there is much less information for the Cook Islands or Line Islands (Kiribati). This is not necessarily a problem when the area is a large abyssal plain, but it does not allow the systematic inventory of underwater features such as seamounts and ridges.

On a global scale, the International Hydrographic Organization (IHO) and the Intergovernmental Oceanic Commission (IOC) of UNESCO digitized available marine charts (contour and track lines based on soundings, coast-lines) to produce a global 1-minute bathymetric grid known as the General Bathymetric Chart of the Oceans (GEBCO). Because it was produced from marine charts, this grid will not provide more information than paper charts, but it is a convenient global digital grid of ocean bathymetry.

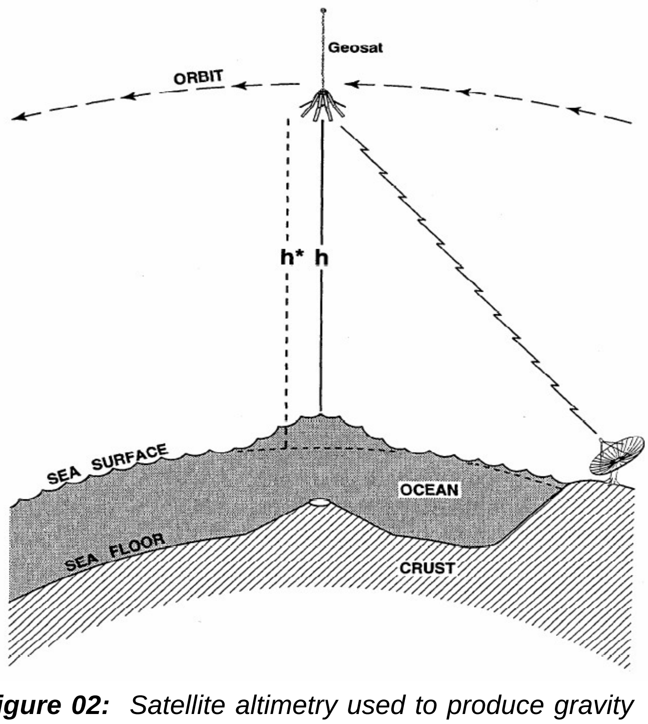


Figure 02: *Satellite altimetry used to produce gravity anomaly grid (reproduced from Sandwell and Smith 1997)*

Predicted bathymetry

Because mapping the ocean floor is difficult and onerous, oceanographic surveys target areas of interest such as trenches, ridges and seamounts. But it means the existence of these features must be known prior to the survey planning and it requires baseline information on the probable location of unsurveyed underwater features.

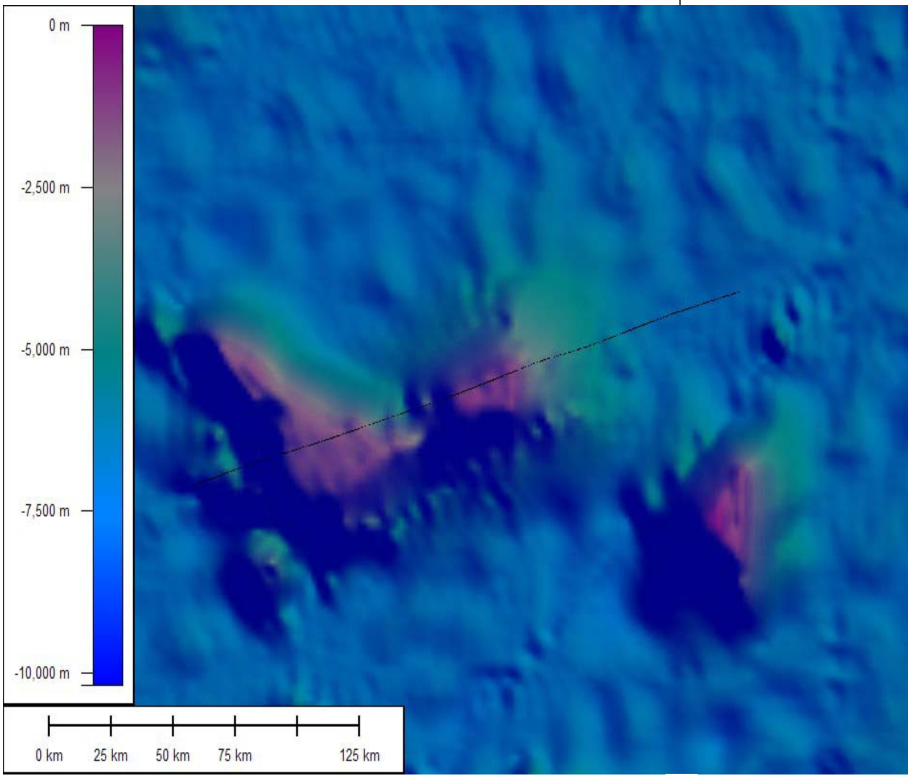


***Figure 03:** S2004 shaded relief and sonar sounding points from NOAA's National Geophysical Data Center (NGDC)*

to derive a map of marine gravity anomalies used later to predict the seafloor depth between the surveyed bathymetry tracks. In 1997, the authors produced a two-minute global map of predicted seafloor topography for latitudes between 72°S and 72°N (Sandwell and Smith 1997).

This initial work was later refined and several derived products are now available to the general public, combining the predicted bathymetry with other sources of information such as GEBCO or Shuttle Radar Topography Mission (SRTM) elevation data, and with various grid sampling (from 30 seconds to 5 minutes).

While Etopo2 is certainly the best known global seafloor predicted bathymetry product, the original Smith and Sandwell (S&S) data were slightly mis-registered in latitude and longitude when the grid was produced (Marks and Smith 2004), and this shift is apparent when comparing the predicted bathymetry with sonar data (see Figs 3 and 4), or when displaying atoll coastlines produced from Landsat 7 ETM+ (visible and infrared) or SRTM elevation data on top of shaded bathymetric data. Note that predicted bathymetry matches here the sonar data because the very same sonar data were used to produce the grid (and interpolated using gravity anomaly data).

The S2004 bathymetric grid produced by Walter Smith from the S&S data and blended with the GEBCO data is properly registered. It uses GEBCO data for depths shallower than 200 m, and a blend of the two datasets between 200 and 1000 m. That mitigates the fact that predicted bathymetry is less reliable for shallow water and the resultant grid is the best global bathymetric grid available at the moment (see Table 1).The shaded bathymetry produced from S2004 for PICTs can be found on the SPC PROCFish Portal in the GIS repository[1].

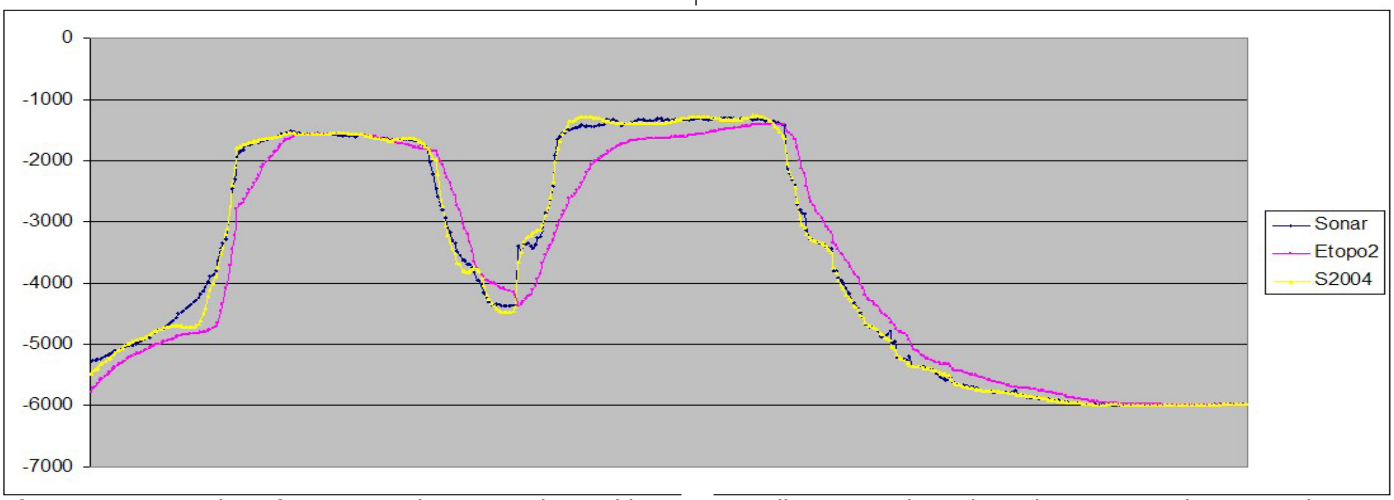


***Figure 04:** Extraction of Etopo2 and S2004 values with corresponding sonar data along the transect shown on Figure 3*

Grid	Resolution	Source	Comments
Etopo2	2 minutes	S&S, IBCAO, DBDBV, GLOBE	Mis-registration in latitude and longitude
GINA	30 seconds	S&S, IBCAO, GTOPO30	Correctly registered but smoothing effect observed (Marks and Smith 2004)

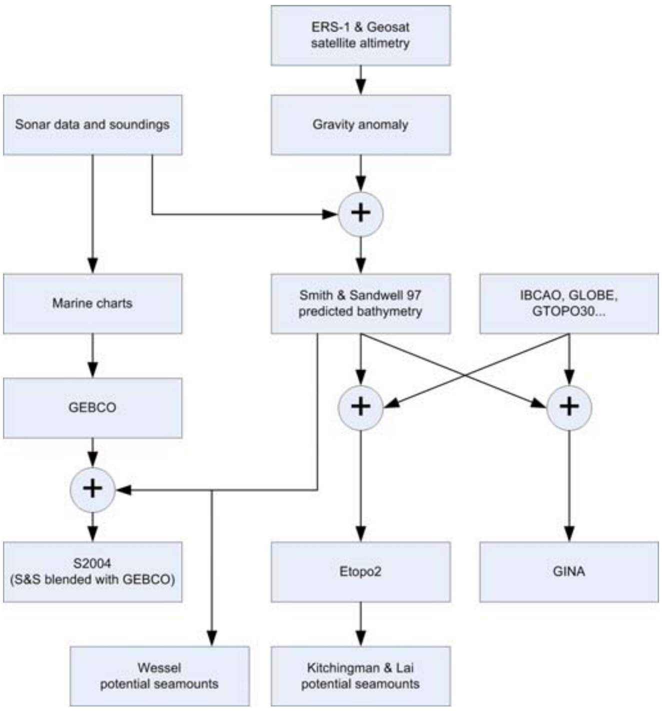


Figure 05: *Datasets and their relationships*

GEBCO 1 minute Charts contour lines Chart accuracy, smoothing effect

S2004 1 minute S&S, GEBCO Correctly registered

IBCAO: International Bathymetric Chart of the Arctic Ocean DBDBV: Digital Bathymetric Data Base - Variable Resolution GTOPO30: Global 30 Arc-Second Elevation Data Set Globe: Global Land One-kilometer Base Elevation

Table 1 Bathymetric grids and source data

The Figure 5 summarizes the various bathymetric grids and datasets cited and how they are related.

Inventory of seamounts

The availability of global bathymetric grids made it possible to conduct a systematic inventory of potential seamounts using a filter that detects peaks and searches for local rises of 1000 m or more from the seabed. Kitchingman and Lai (2004) used the Global Digital Elevation Model (Etopo2) grid and identified between 14,000 and 32,000 potential locations of seamounts, Wessel (2001) used the S&S grid to extract around 15,000 seamounts locations for the whole world.

The methodology (filter and thresh-olds) and source data grid used for the inventory of these potential seamounts have a significant impact on the results and their usability. Because the Etopo2 grid is mis-registered, so are potential seamounts (the distance between Wessel and Kitchingman seamounts can be up to 10 km).

Moreover, predicted bathymetry is less reliable in areas shallower than 200 m, around land masses, and is averaged because of the initial S&S two-minute resolution. As a consequence, atolls are often falsely detected as one or more seamounts, as depicted in Figure 6. Screening and cleaning of this data has been undertaken by the Pacific Islands Oceanic Fisheries Management project (SPC Oceanic Fisheries Programme/ GEF).

High-resolution mapping of seamounts. Once seamounts and other underwater features are identified, either from previous hydrographic surveys or using predicted bathymetry, they can be fully mapped by oceanographic vessels using multi-beam and side-scan sonars. Figure 7 shows the Capricorn Seamount as displayed with a one-minute resolution (S2004 grid) and with a 200 m resolution (multibeam data).

While the multibeam sonar captures bathymetry, a side-scan sonar captures texture and morphology. The side-scan sonar reflects the type of substrate and habitability of the area for deep bottom fish species and, when available, can be mapped on top of the bathymetry on a three-dimensional model.

High-resolution data for seamounts that have already been mapped is generally avail-able from the Internet, in particularly from the Seamount Catalog of the Seamount Biogeosciences Network (http://earthref.org), from where it is possible to download multibeam data, mixed with predicted bathymetry.

Part 2 – Shallow Water Bathymetry

While these maps are quite useful for the management of pelagic fishes and seamounts, they are generally

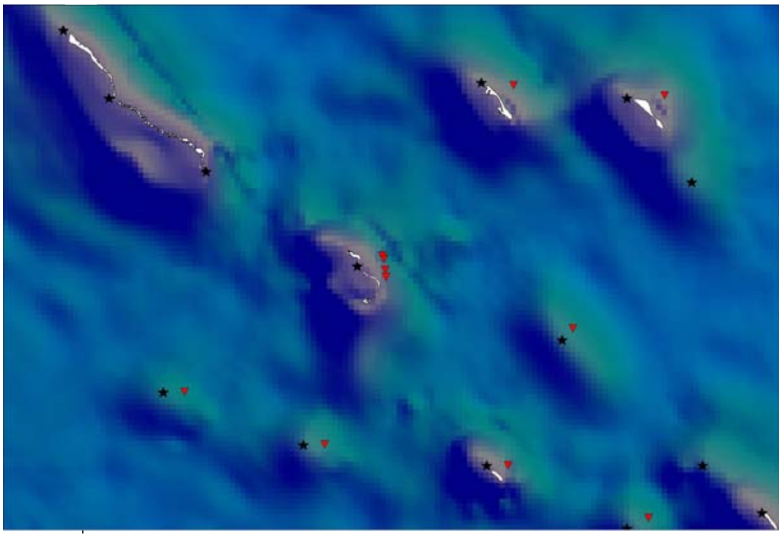


Figure 06: *Kitchingman (triangles) and Wessel (stars) potential seamount locations*

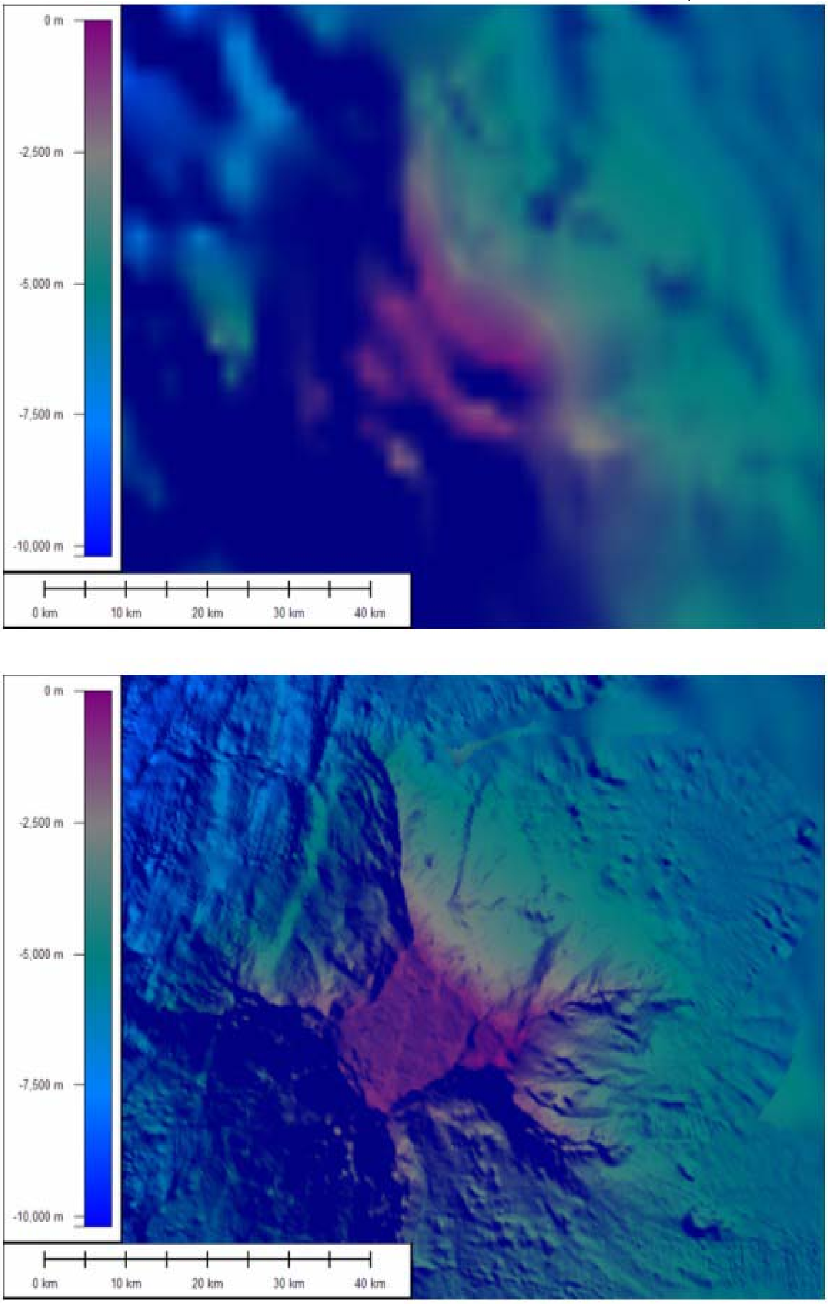


Figure 07: *Shaded relief of Capricorn seamount near Tonga trench at 1-minute (S2004) and 200 m (sonar) resolution*

unsuitable for nearshore and reef fisheries management, for which, higher resolution maps are necessary. This second part describes other sources of information for shallow water bathymetry, and how these can be used to produce bathymetric maps for coastal fisheries management purposes.

Nautical charts

Hydrographers and cartographers have produced nautical charts for the Pacific Islands region for centuries, and some of the charts available today are updated versions of 19th century original ones.

Nautical charts are generally available for the whole Pacific, but scale varies depending on the area. Because nautical charts have been created for navigational purposes, they emphasise hazards such as reefs, focusing on avoidance more than on the exact mapping of reefs. Nautical charts are generally quite detailed for approaches to harbours and passes, with additional detailed plans for these areas of interest.

Figure 8 shows that the bathymetry in the NZ 945 chart for Penrhyn is much more detailed around Taruia Passage and Gudgeon Bay, than in the rest of the lagoon and the passage is even more detailed because of its importance for navigators.

Importation of nautical charts in a GIS

For use within geographic information system (GIS) software, charts can be scanned and geo-referenced (raster image), or they can be digitized (on screen or with a digitizing board) and stored as points, contour lines and polygons. Spatial queries are possible with digitized charts, while raster images are generally used as backdrop.

Nautical charts have been digitized on a large scale by US federal agencies such as the National Oceanographic and Atmospheric Administration (NOAA), the National Geospatial-intelligence Agency (NGA), and the National Imagery and Mapping Agency (NIMA), but these products are generally not released to the public for copyright reasons, apart for US waters. Some private companies have also digitized charts to incorporate them in GPS plotters but these are generally encrypted and in a format incompatible with GIS software.

The projection and datum used to produce the chart must be known in order to geo-reference or digitize a chart, which is sometimes not the case for older charts for which adjustments for plotting GPS positions cannot be determined.

In conclusion, nautical charts are most often not readily available in vector format and often lack detailed bathymetry for reef areas and areas outside frequently used shipping lanes.

Hydrographic surveys of coastal waters

Depths between 30 m and 200 m are beyond remote sensing techniques (visible light is quickly absorbed and water is opaque to radar frequencies) and predicted bathymetry, using satellite altimetry, is not reliable for shallow water. Therefore, sonar and lead line remain the ways of measuring depths in the 30-200 m range.

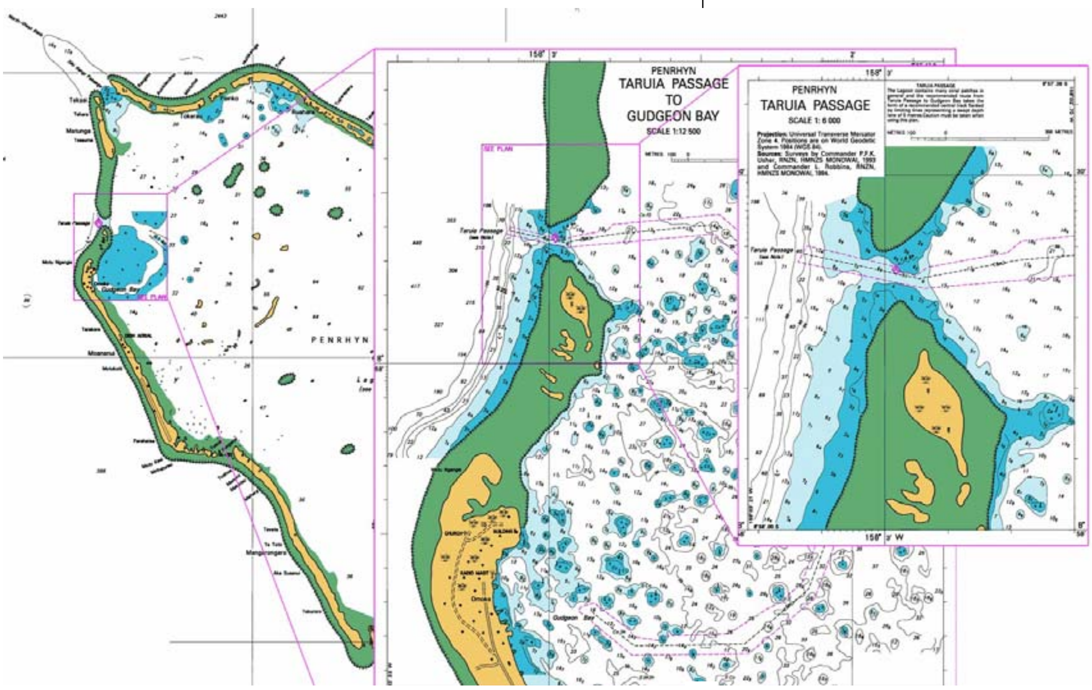


Figure 08: *Increasing level of details around passes and harbours for navigational purposes (from NZ 945 chart)*

A typical survey is done with a medium size boat equipped with a single-beam or multi-beam sonar that records depths regularly (every 20 m; see Figure 9) along the boat path (parallel transects). Very shallow areas (e.g. patch reefs or flat reefs) are generally not covered because they cannot be safely explored by the survey boat; therefore, holes in the dataset often correspond to shallow reefs.

Hydrographic surveys provide very accurate depth information, and additional data can be collected with additional sensors at the same time (e.g. acoustic signatures can be used to map bottom types). These types of surveys are done routinely by the South Pacific Applied Geoscience Commission (SOPAC) for ACP countries, and NOAA's National Ocean Service for US territories. An alternative method consists of digitizing individual soundings on nautical charts. This is a tedious process, but can make up for a lack of available sonar information for an area.

Use of hydrographic survey soundings

Each sounding point is stored as an XYZ position (geographic position and depth), and the dense set of sounding points is interpolated to produce a depth map (with isobaths at 5, 10, 20, 30 m), and determine the corresponding surfaces as in Figure 10.

It is noticeable on this figure that there are differences between what can be seen on the satellite image and with the isobaths, mostly due to the shallow areas excluded from the survey. The area circled in red for example is wrongly classified as a 20–30 m area while it is obviously much shallower. The actual error varies depending on the interpolation method and the pattern of data gaps.

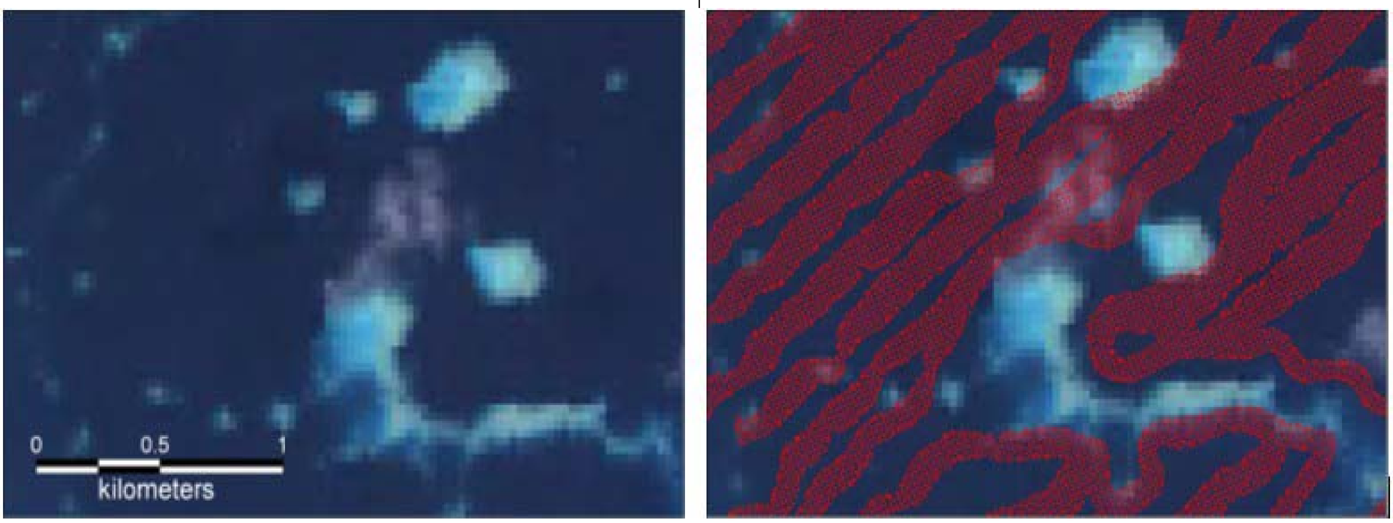
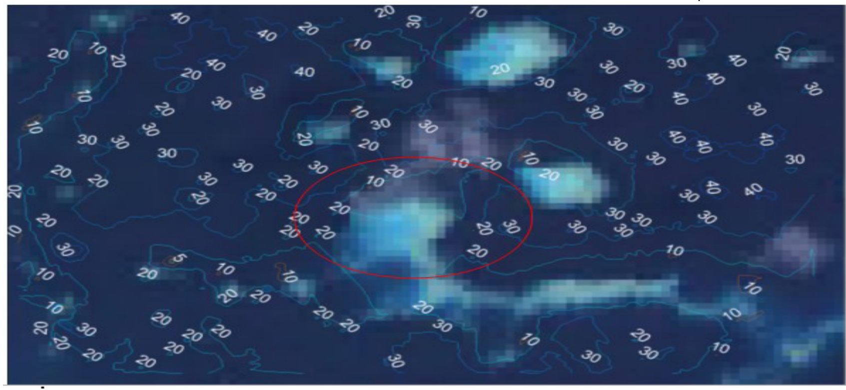


Figure 09: *Sounding points of a typical sonar survey (in re ver a Landsat image*

It is possible to set a maximum distance between interpolated points and leave holes as unknown, or unclassified areas. Figure 11 correspond to the same location as Figure 3 but no interpolation has been done for data gaps (in white). As a result, the area for which depth can be retrieved is about 50% of the previous one, and the proportion of 10–20 m surface areas compared with deeper areas has changed dramatically because shallow reefs are mostly unclassified.

Because of these differences and depending on the processing of data, it is important when using isobaths or depth grids to determine how they have been

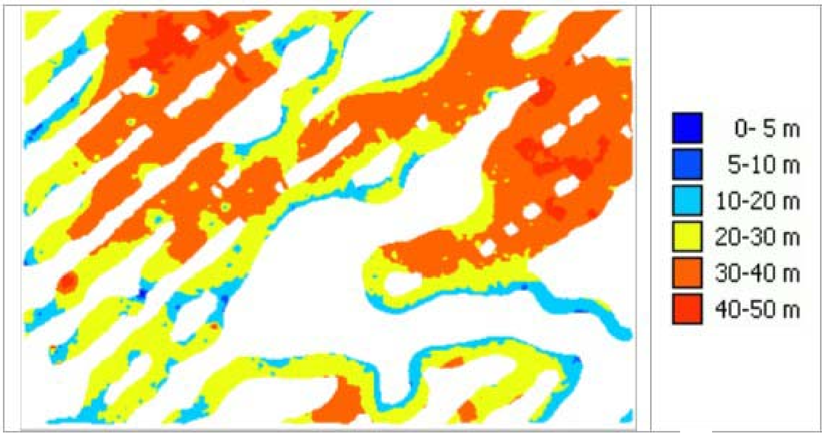


Depth (m)		Surface (km²)
From	To	
0	5	0.000
5	10	0.016
10	20	1.193
20	30	1.992
30	40	1.732
40	50	0.108

Figure 10: *Isobaths produced after interpolation of XYZ data (triangulation)*

produced (interpolation method and location of sounding points) and to compare the interpolated grid with available charts and satellite images.

Bathymetry of very shallow areas using remote sensing



Depth (m)		Surface (km²)
From	To	
0	5	0.000
5	10	0.009
10	20	0.297
20	30	0.972
30	40	1.279
40	50	0.104

Figure 11: *Depth classes with interpolation limited to a maximum distance of 50 m*

Pacific reef fisheries focus on depths between 0 m and 20 m, for which detailed bathymetry is often out of the scope of sonar surveys (reef areas dangerous for navigation). Yet these very shallow waters are not totally opaque to visible light and both passive and active remote sensing can be used to determine bathymetry.

Light detection and ranging (LiDAR)

A LiDAR is an active remote sensing equipment that uses time delay between a laser pulse and its reflected signal by the target to determine the distance of the latter. The SHOALS-1000 (Scanning Hydrographic Operational Airborne LiDAR Survey) system in particular uses a blue-green laser and can measure depths up to 60 m over a 200m swath width, a vertical accuracy of 15 cm and a distance of 8 m between sounding points (Wozencraft 2001). The SHOALS system is mounted on a Twin Otter aircraft and operated by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX).

This technique is complementary to the traditional sonar surveys and can be used to map very shallow waters and surf zones. It can also map the topography of the nearshore (beaches and dunes). LiDAR data is currently freely available from the NOAA website for US coastlines.

Unfortunately, the cost of airborne operations restricts its use for specific areas, and it is very unlikely that LiDAR data will be available in the near future for remote islands. According to the JALBTCX website, SHOALS surveys have or will be conducted in Majuro, Kwajalein, Kosrae, Pohnpei, Chuuk and Yap in addition to US territories.

Multispectral and hyperspectral images

This method is based on the optical properties of the water column: light absorption is exponential with depth and varies with wavelength (wavelengths corresponding to red colour are absorbed twice as

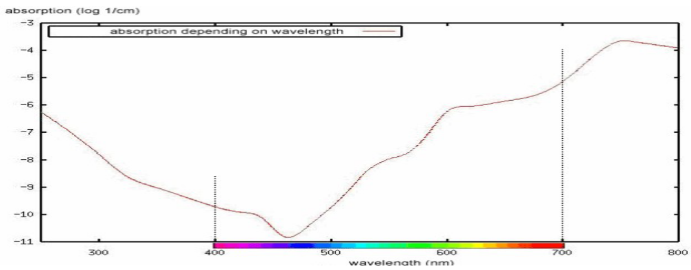


***Figure 12:** Absorption according to wavelength* (as per data from Shifrin 1988.)

fast as blue ones, see Figure 12). Compared with LiDAR, which uses laser pulses to illuminate the scene, passive remote sensing simply measures the sunlight reflected by the sea floor.

The difference between multi- and hyperspectral data is the number of sensors and their sensitivity a predefined range of wavelengths: Landsat and IKONOS satellites for example have four sensors (bands) for visible and near infrared spectrum, while the Compact Airborne Spectrographic Imager (CASI) can discriminate between 288 spectral bands.

Infra Rouges,Ultra Violets,Visible

The accuracy of depth as determined through passive remote sensing is far less than what can be achieved using sonar or LiDAR. The method often requires some kind of area specific calibration, using ground truth data and atmospheric correction to normalize the data. The advantage of this method is that it can use available images, and satellite images have a very large footprint compared with airborne and ship surveys, which are more localized.

Passive remote sensing can be used for depths up to 30 m, depending on water turbidity and atmospheric conditions. Numerous papers have been published on the use of satellite images for shallow water bathymetry (Ishiguro et al. 2001; Stumpf and Holderied 2003; Provost et al. 2004) and it is still an active research topic as there is still room for improvement. The main problem being that not only the water column absorbs light but also the atmosphere, particles in suspension in water and the sea floor itself, depending on substrate type. The resultant signal contains the depth information, but is mixed with the other components. Fortunately for fisheries management purposes, depth does not need to be known within a 15 cm accuracy. A rough mapping of depth classes (for example 0–5 m, 5–10 m, 10–15 m, 15–20 m, and 20 m+) is probably sufficient and can be obtained quite easily by using a ratio of blue and green bands if some soundings at various depths are available for the area and can be used to calibrate the image (Figure 13).

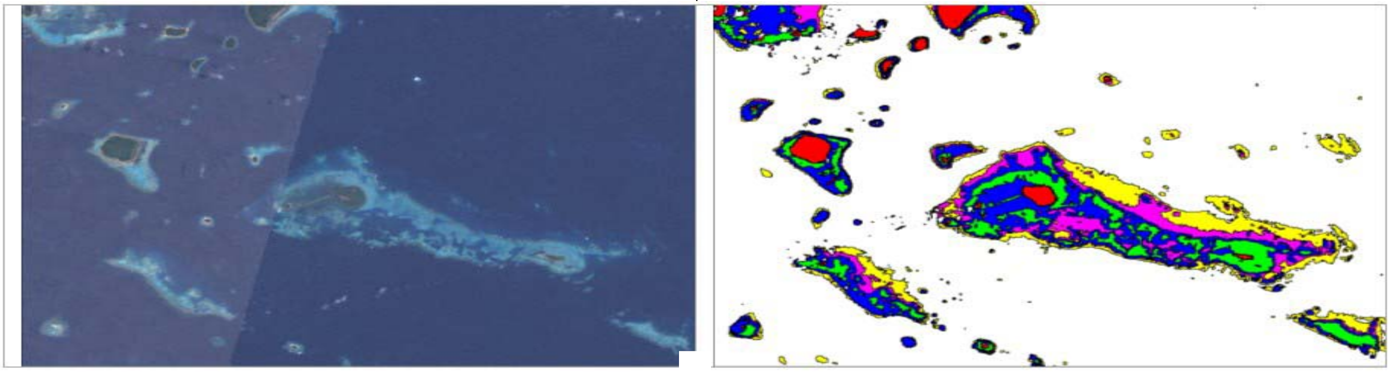


***Figure 13**: Satellite image (Landsat 7) and corresponding depth classes*

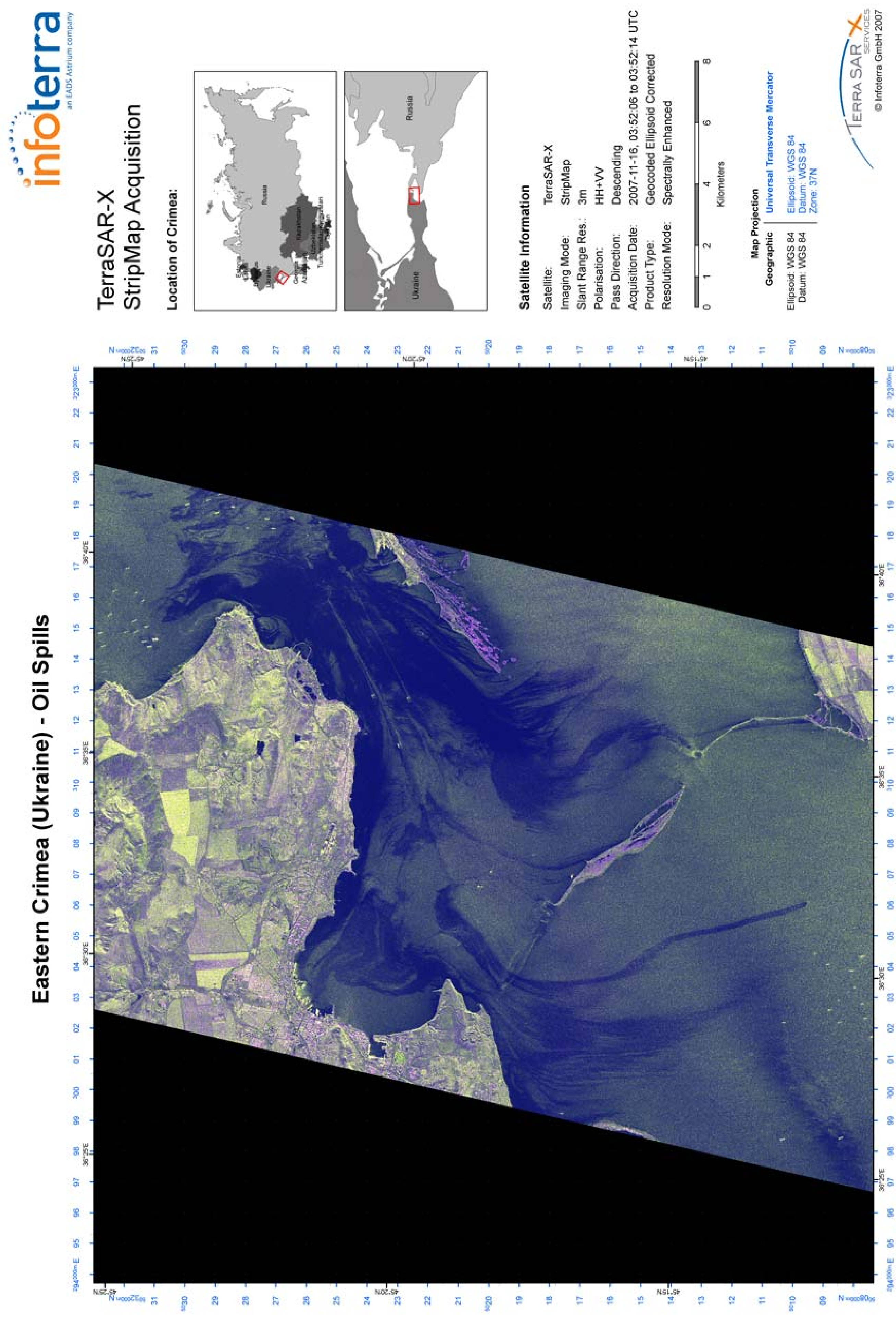
This method has been used to produce rough depth maps of Tonga's reefs, using available relatively cloud free Landsat images and sounding points from nautical charts.

Conclusion

While only a small part of the Pacific Ocean has been thoroughly mapped by oceanographic vessels, predicted bathymetry is available globally and allows the localisation of underwater features such as seamounts, which can be surveyed in detail at a later time using multibeam and side-scan sonars. Yet some caution is necessary when using S&S-derived products because of the mis-registration observed in some products and because of the limited resolution of these grids.

Sonar surveys have limitations in term of coverage of very shallow waters and are well complemented by LiDAR surveys but the operational costs of these types of surveys limit their use to specific areas. Passive remote sensing can provide a cheaper alternative but at the expense of accuracy and more robust methods, and models are still sought by researchers for improvement of current mapping.

When using a bathymetric map for coastal waters it is important to know how it was produced, for which purpose, and its limitations in order to determine if the map is suitable for the particular intended use.



TerraSAR-X acquires oil slicks in the Black Sea - Nov 16 2007: The StripMap image acquired 5 days after an oil tanker broke into two pieces shows massive oil slicks drifting on the surface. 3m resolution / dual polarisation.