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Satellite-derived bathymetry of the Achziv coastal area, northern Israel

Shachak Pe'eri
University of New Hampshire, Durham, shachak.peeri@unh.edu

Gideon Tibor
Israel Oceanographic and Limnological Research

Brian Madore
University of New Hampshire, Durham

Tomer Ketter
Israel Oceanographic and Limnological Research

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Shachak Pe'eri (shachak@ccom.unh.edu)[1], Gideon Tibor[2], Brian Madore[1], and Tomer Ketter[2]

[1]Center for Coastal and Ocean Mapping University of New Hampshire Durham, NH 03824, USA

[2]Israel Oceanographic and Limnological Research, Tel-Shikmona, Haifa 31080, Israel

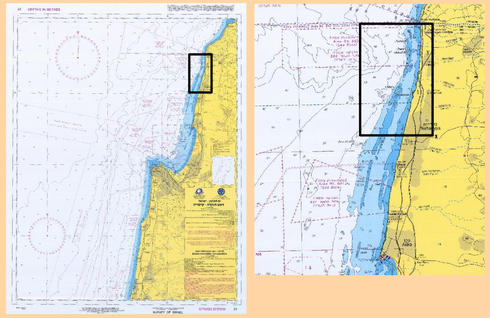
Abstract

Satellite-derived bathymetry provides a useful reconnaissance tool for hydrographic surveying offices in planning and implementing a prioritized survey program. Specific uses of the satellite-derived bathymetry include characterization of coastal areas and monitoring seafloor changes that have occurred since the last hydrographic survey. To be useful for hydrographic surveying offices in developing nations, the procedures must be based on readily-available data and software. In keeping with standard hydrographic surveying practice, the derived bathymetry must also be accompanied by uncertainty estimates. Recently a procedure was developed for the use of publicly-available, multispectral satellite imagery to map and portray shallow-water bathymetry in a GIS environment. Landsat imagery and published algorithms were used to derive estimates of the bathymetry in shallow waters. The most appropriate algorithm to derive bathymetry was determined in the study based on performance using different band combinations and spatial filters. This procedure was also applied over the coastal area of Achziv. The bathymetry will provide the first layer for the development of a coastal characterization procedure of the local benthic habitat. This study presents preliminary results of the satellite-derived bathymetry and a comparison with acoustic (multibeam echosounder) dataset.

1. Goal

1.1 Generate a shallow water bathymetry for habitat mapping

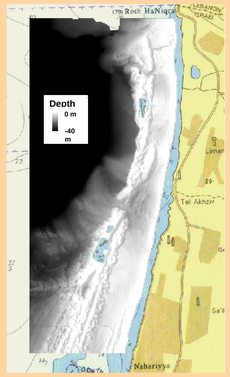
The current available bathymetry depicted from the chart is only on a scale of 1:100,000 and is based on dated surveys. A seamless bathymetric map was generated based on satellite imagery and multibeam datasets (deeper than 4 m).



Nautical chart produced by the Survey of Israel, where the significant depth areas are colour coded (5, 10, and 15 m).

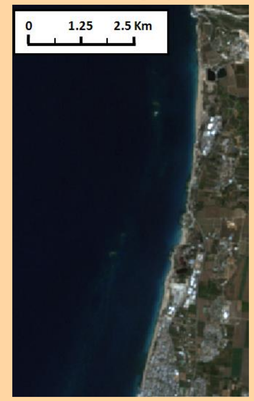
2. Available resources

Reference bathymetry



System: Kongsberg EM1002
Resolution: 2m

Landsat 7 imagery (May, 2002)

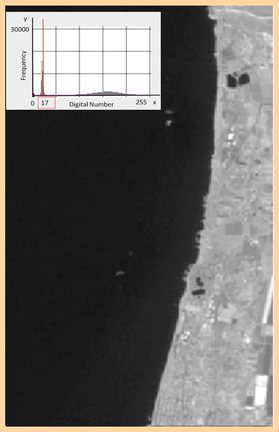


Bands: Blue (450 to 520 nm), Green (530-610 nm) and NIR (780-900 nm)
Resolution: 28.5 m

3. Procedure

3.1 Land/water separation

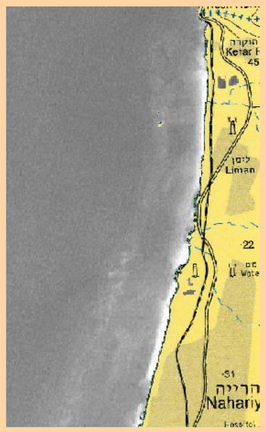
It is possible to extract the water areas from the dry land using Near Infrared (NIR) band.



The histogram of the NIR band over a coastal area is bi-modal with two modes corresponding to land and water regions.

3.2 Applying water mask

A mask polygon of the submersed areas is used to extract only the water body from the Landsat imagery in the Green and Blue bands.

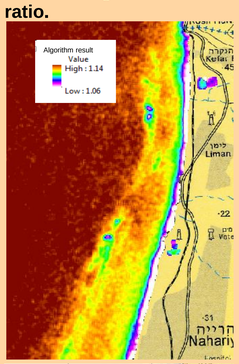


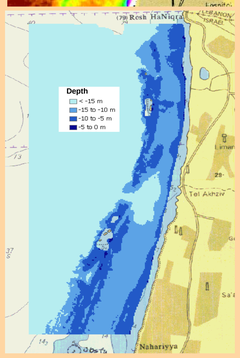
Masked Blue band

Masked Green band

3.3 Bathymetric algorithm

The Stumpf et al. (2003) was used to generate a bathymetric model using a Blue/Green band ratio.

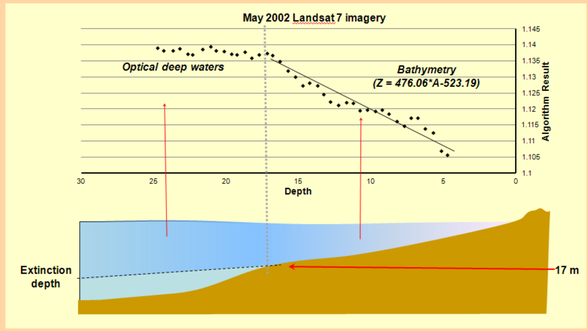




Reference bathymetry
(classified based on significant depths)

3.4 Referencing the bathymetric model

Using a statistical analysis, it is possible to reference the algorithm values to the chart's datum.



Top part of the image shows the scatter plot of the algorithms results as a function of the chart sounding (Mean Sea Level, MSL). The bottom part of the image provides a possible explanation for the algorithm results and their relation to the optical depth of extinction at 17 m below MSL.

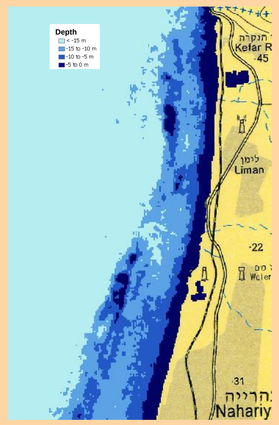
Algorithm

The core of the procedure is the Stumph et al. (2003) algorithm (more details are provided in Pe'eri et al. 2013):

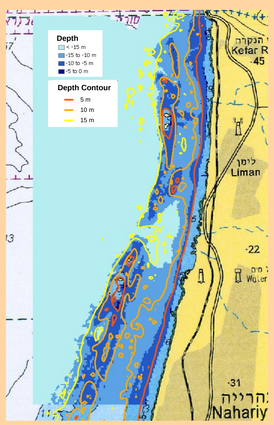
$$Z = m_0 \cdot \frac{\ln(L_{obs}(\lambda_i))}{\ln(L_{obs}(\lambda_j))} - m_1$$

$L_{obs}(\lambda i)$, $L_{obs(}\lambda j)$- band values
mo- gain
m1- offset

4. Results



Final satellite-derived bathymetry model



Contours of the derived model overlaid on the multibeam bathymetry

Effectively, the bathymetry was mapped up to 17 m below MSL. Although the significant depth contour matched the reference bathymetry, with an overall average difference of 0.3 m. The standard deviation was relatively high (1σ = 2.4 m).

5. Future directions

The shallow-water bathymetry will be used to estimate the water attenuation occurring in aerial and satellite imagery.

The satellite-derived bathymetry procedure is a useful reconnaissance tool deriving bathymetry and water clarity in the coastal region.

An additional benefit of the procedure is the possibility to generate a time-series that shows changes in bathymetry using multiple Landsat images. This is particularly useful for monitoring seafloor changes in the coastal environment.

References

Stumpf, R. P., K. Holderied, and M. Sinclair. 2003. Determination of water depth with high-resolution satellite imagery over variable bottom types, Limnol. Oceanogr. 48:547–556.

Pe'eri, S., C. Parrish, C. Azuike, L. Alexander, and A. Armstrong. 2013. Determination Satellite Remote Sensing as a Reconnaissance Tool for Assessing Nautical Chart Adequacy and Completeness, Mar. Geodesy, *submitted*.

Acknowledgements

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