Hydrographic Use of Satellite Imagery in South Pacific

The French Hydrographic Office (SHOM) uses remotely sensed visible imagery for the cartography of atolls and reefs. It is considered as an efficient and relatively inexpensive method to collect information where data is sparse.

Remotely sensed visible imagery is used in Pacific French Overseas territories for the cartography of atolls, reefs et cetera. All shallow-water areas may be involved, in particular when the cost of usual hydrography would be out of proportion with maritime traffic. Remotely sensed imagery is mixed with all field information available (bathymetry, buoys, seamarks) and a â€˜spatiocarteâ€™ (spatio-chart) is produced, which provides information on:

- Land: coastline, port installationsâ€¦
- Maritime areas: assessment of bathymetry obtained from the radiometric content of the image, large and medium coral pinnacles are detected et cetera

This spatiochart also provides assistance in the search of waterways before an in situ survey, for example in lagoons scattered with coral structures.

Images
The remote-sensing images used by SHOM (French Hydrographic Office) are mainly SPOT imagery provided by SPOT IMAGE (www.spotimage.fr). If there is no image of the relevant area in the catalogue or if the quality is not adequate, for example when there are clouds, a programme planning is ordered. SPOT imagery uses the visible spectrum and the colour of water gives information about the depth. The horizontal resolution before SPOT 5 was 10m x 10 m or 20m x 20 m. The image can be purchased with differing levels of treatment: from 1A (homogenisation of the Charge-Coupled-Device1 measurements sticks) to 2B (with position rectification). SHOM chooses 1A to apply its own precise positioning and bathymetric models.

Field Measurements
The precise positioning of the image is obtained by site observations. Using zooms of the image, a team is in charge of determining the real position of pixels. If a pixel is identifiable without doubt (crossroads for example) a differential GPS position is sufficient. Otherwise, the operator follows a remarkable feature, for example, coastline, limit of vegetation, to continuously record his DGPS position: the comparison of the recorded path with the zoom at the same scale allows fixing this.
The geometric rectification carried out by SHOM software makes possible generation, with a single base point, of a corrected image with a precision of the size of the pixel. However, usually SHOM uses the position of 5 pixels for an image in order to have redundancy and accuracy control.
The bathymetry model is derived from the colour of the water. To initialise the model a minimal survey must be conducted: at least one line from the shoreline toward the sea. If the conditions, nature of the sea-bottom, turbidity and so on, are not homogeneous over the entire image complementary surveys must be carried out.

Processing
The software used by SHOM comprise packages dedicated, respectively, to geometric and radiometric processing.
The steps involved in this processing are:

- De-striping
- Geometric rectification
- Pre-processing
- Building of masks
- Calculating the model of bathymetry
- Building a thematic map called â€˜la spatiocarte marineâ€™ (the marine image-map)

De-striping
Due to the sensor (CCD sticks), there are stripes on some images, a difficulty in water areas due to the low radiometric dynamics. This noise must be removed before calculating the bathymetric model.

Geometric Correction
While being taken by the satellite the image is distorted as a result of certain factors such as yaw, pitch, roll, altitude and orbit parameters. The purpose of georeferencing is to transform the image coordinate system into a specific map projection. Orbit parameters provided by Spot Image and the geodetic field measurements are used to model and rectify distortions. The precision of positioning is about 10 metres.

Pre-processing

To check the quality of the image and characteristics of detected objects the following processes are run:

- Enhancing visible green (G), visible red (R) and the Near-InfraRed2 (NIR) images
- Calculating the index of transparency nf = G2/R (quite good in the description of shallow waters)
- Calculating the local standard deviation in the nf band (to stress changes in slope and bottom-type)
- Converting colours from Red Green Blue model to Hue Saturation Value model (hue image is quite good for separation of land and water)
- Converting from rectangular coordinates (G, R) to polar coordinates (p,q) (to de-correlate the visible green and red bands)
- Calculating the Normalized Difference Vegetation Index NDVI (NIR-R) / (NIR+R) (to outline vegetation)
- Calculating the index of texture p = (G/R)*50
- Computing statistical principal components analysis (PCA) from (G, R, p) bands (to describe more accurately some objects difficult to detect in the original bands)
- Computing statistical PCA from (q, p, p) bands (to perform the same analysis as the preceding one, but from the de-correlated bands q, p, therefore extracting more accurate information)

Building Masks

Extracting Land-area

At a scale of 1/50,000, nautical charts do not need details over land area. Hence, a uniform mask is built from the image. Depending on image quality and atoll geomorphology, SHOM uses either the NIR band of the NDVI band or a band resulting from PCA analyses for extraction of a land-mask. This mask is then compared with the Hue band.

Extracting clouds and their shadows

Due to the spectral bands of SPOT (in the visible spectrum) clouds may mask useful information. The shadows of such clouds minimise the true radiometric value of the pixels, thus affecting the accuracy of the bathymetric model.
At SHOM, clouds and their shadows are merged as a unique cloudy mask.

Calculating the Model of Bathymetry

The signal received by the satellite is a composite of reflection from the water surface, water volume and the sea floor, leaving aside atmospheric interference. To get a reading on depth, at least some sunlight must be reaching the bottom and then being reflected back through the water towards the satellite. Water absorbs light, such absorption increasing with the wavelength until the light is almost totally absorbed in the NIR. So to extract depth contours several wavelengths are useful, with visible Blue going deepest, visible Green less deep, visible Red less deep and NIR not deep at all. SHOM uses the visible Green and Red bands of SPOT.
Bathymetry is calculated in shallow waters, over the atoll's lagoon and off the cloudy mask. The model used at SHOM is classically based on the Lyzenga model:

$$Z = A * LN(R1 - R1inf) + B * LN(R2 - R2inf) + C$$

where

ZThe calculated depth of the pixel
R1The radiometry of the pixel in the visible Green band
R2The radiometry of the pixel in the visible Red band
R1infThe radiometry, in the visible Green band, over a deep-water zone (where the radiometry is free from bottom effects)
R2infThe radiometry, in the visible Red band, over a deep-water zone
A, B, CThe modelÃ•s coefficients. Thirty or more sounding measurements allow accurate calculation of these coefficients and thus calibration of the model

The quality of the model depends on several factors:

- The water column has to be clear. If there is a lot of sediment, intense pigmentation of the water or plankton, most of the return will be from scattering within the water column itself, not from the bottom
- The water conditions have to be homogeneous over the atoll's lagoon. If there are two distinct water types in the lagoon, for instance, due to a windy area versus a calm one, two distinct bathymetric models have to be calculated. Thus two distinct sets of soundings are needed for calibration purposes
- The bottom surface has to be homogeneous and reflective. A sandy bottom reflects more light than does a coral reef or a bottom covered with algae. The changes in bottom type diminish the quality of the model

Over a homogeneous atoll, such as Ouvea in New Caledonia, the relative error is lower than 10% for depth between [5-20] metres but increases for depth between [0-5] metres. This increase is due to the slope, to correlation of the visible Green band with the Red one (after 5m visible Red light is totally absorbed) and to a more heterogeneous feature bottom.

La Spatiocarte Marine

The land-mask, inter-tidal-mask, cloud mask and bathymetric model are merged as a thematic map. Bathymetry is mapped as coloured depth ranges of 5m, between (0-20) m. The scale of the spatiochart is about 1/50,000.
Three negative films are generated by a laser-plotter:

- Land and inter-tidal areas
- Inter-tidal area and ranges of bathymetry [0-5], [5-10], [10-15], [15-20]
- Cloud and their shadows

These films and the thematic map are provided to the cartographic department for production of the navigational chart.

Conclusion

The processing of satellite images in areas of clear water provides an efficient and relatively inexpensive method of checking on an isolated item of information, optimising the work of survey missions, completing a partial survey or updating an old document. It is the method currently utilised by SHOM.

When included in a nautical chart, information derived from satellite imagery is clearly presented in a different way than is â€˜S44 hydrographic dataâ€™ due to differences in accuracy and reliability and in order not to confuse the mariner. But it is helpful information in huge areas where the data is scarce and expensive to collect: in Rangiroa atoll a pass to a tourist island was detected on a spatiochart and then checked by the SHOM survey team, allowing access to large cruise liner. This is just one example among numerous daily others.

Notes

1. 1Semiconductor devices arrayed so that the electrical charge at the output of one provides the input stimulus to the next
2. Infrared radiation extending approximately from 0.7 to 1.3 micrometers and being part of the radiative infrared

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https://www.hydro-international.com/content/article/hydrographic-use-of-satellite-imagery-in-south-pacific