Kelp & Bathymetry Modelling in the Falkland Islands

Technical report




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Executive summary

This report details the technical aspects of modelling kelp and bathymetry in the Falkland Islands, carried out as part of the Darwin Plus project DPLUS065: Mapping Falklands and South Georgia coastal margins for Spatial Planning. Two years of Sentinel-2 imagery was downloaded and processed to create a single composite layer for kelp modelling, achieved through the use of a vegetation index using red-edge and red wavelengths. A composite bathymetry dataset was modelled using individually selected Sentinel-2 images, which were empirically processed to single beam echo sounder depth data. The extinction depth of the imagery, and the output model, was restricted to five metres. A preliminary investigation into other forms of pre-processing, before application of the bathymetry algorithms, suggests ways of mitigating for certain seafloor and/or water column conditions.

1. Kelp modelling

1.1. Data

The data used for this aspect of the modelling process consisted solely of Sentinel-2 imagery. Every image capture during 2017 and 2018 was downloaded, processed with cloud masking, resampled to 10 m pixel sizes in EPSG 4326 projection, and mosaicked in accordance to the image capture date. To create a single, usable dataset that also mitigated the effects of sun glint and cloud, an image composite of the entire region was created using the minimum values from each dataset.

1.2. Modelling

Kelp was modelled using a vegetation index based on red-edge and red, allowing for vegetated features floating on-top or within the water column to be identified. Terrestrial land was masked using a shapefile supplied by SAERI, buffered by -50m. The kelp layer was normalised to values 0.1 – 1. Values less than 0.4 were not considered to be kelp, and were masked out of the dataset. The final layer was re-classed into integer values from 1 to 9 (1 representing low certainty of kelp present) (Figure 1.1). Values of NoData indicate terrestrial features, areas outside a 10 km terrestrial buffer zone, or areas of persistent cloud cover.

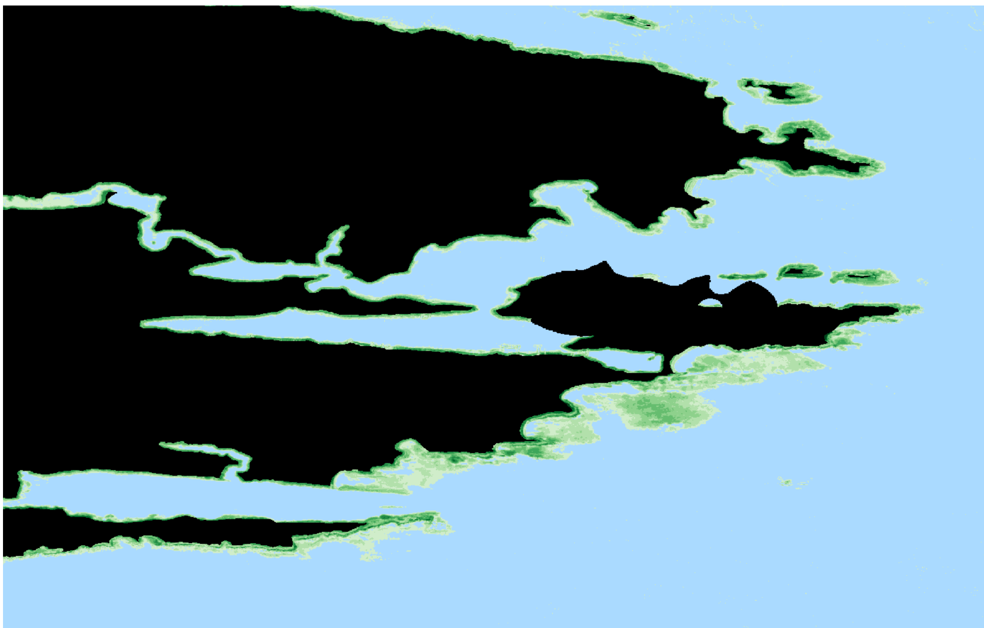

Figure 1.1: Subset of kelp modelling output

A binary mask layer of the 0.4 kelp cut-off value was also delivered as an output, re-classed as 0 (NoData) and 1 (Kelp).

2. Bathymetry modelling

2.1. Data

The data used for the bathymetry modelling used the same Sentinel-2 source data as for the kelp. Six of the best captures were selected for analysis, based on cloud cover extent, observed sea state conditions, visible water column quality (e.g., suspended sediment). Survey depth data was provided by SAERI, derived from single beam echo sounder points collected around the Falkland Islands in September 2018 and November 2018.

2.2. Modelling

The bathymetric modelling workflow follows widely used and well-established practices. A sun-glint correction algorithm was applied to each of the selected Sentinel-2 images, following the procedure set by Hedley et al. (2005). A low pass 3 x 3 filter was applied to reduce any noise. The depth survey data was reduced to those points that observed 0 m and 5 m depth sounding. These were visually assessed to exclude those that occurred under patches of kelp, and/or outside the image extinction depths i.e. the depth that the satellite image was able to extract meaningful values from.

Bathymetry modelling was based on the approach by Stumpf et al. (2003), whereby an empirical relationship of depth survey data is sought between a ratio of log-transformed blue and green bands. A composite dataset from the minimum values of all the outputs was created to mitigate for the effects of artificially high values that may have occurred due to temporal sedimentation.

The output was converted from float values to integers, with any depth values greater than 5 m converted to NoData (Figure 2.1).

Figure 2.1: Subset of SDB modelling output

2.3. Limitations of satellite-derived bathymetry in the Falkland Islands

The original method for creating the bathymetric layers involved using the minimum value composite Sentinel-2 dataset, created during the kelp modelling. This composite was modelled to bathymetry following the methodology of Lyzenga (1985), though had a low validation accuracy, and a high RMSE; suggesting that a pixel could be accurate to +/- 10 m. The Stumpf et al. (2003) method was also modelled, but similarly had low accuracy and high RMSE. Following this, six of the best input datasets based on observed cloud cover, sea state, and water quality, were selected for bathymetric processing, to form the basis of a composite bathymetric dataset.

Both the Lyzenga (1985) and Stumpf (2003) algorithms rely on the blue and green wavelengths and their intensity divergence with depth. It is therefore a necessity that a reflectance value can be extracted from both bands. Further inspection of the Sentinel-2 imagery found no significant reflectance in the coastal marine environment, except for those areas immediately adjacent to the shore, with a sandy substrate, and at depths no more than 6 m. Figure 2.2 demonstrates the blue band after sun glint removal overlaid by the depth survey points (light blue for shallow points, dark blue for deep points). A reflectance signal is only observed in the very shallow, sand/mud substrate. The remaining marine environment has a flat reflectance.

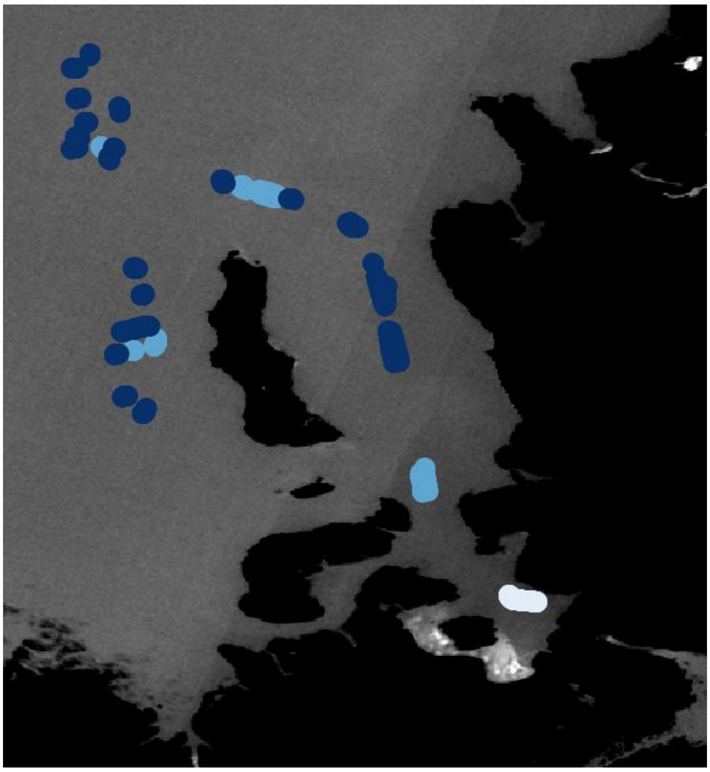

Figure 2.2: Subset of Sentinel-2 blue band over shallow and deep (20 m) water

Issues such as waves, sun glint, sky glint, temporal sedimentation from land/marine-based processes, and suspended matter in the water column (both organic and in-organic), are known to reduce the quality of, and prevent, SDB. It is unclear at the time of writing, the coastal dynamics which may inhibit the process of satellite-derived bathymetry in the Falkland Islands, to a depth greater than 5 m. Further research is required to understand the water conditions/quality of the Falklands coastal environment, to inform an appropriate correction and/or satellite-derived bathymetry algorithm.

2.4. Further research

A preliminary study into the Sentinel-2 imagery and other forms of pre-processing (Figure 2.3), demonstrates that a distinction can be made between substrate features that have a depth (cyan), possibly organic features with depth (green hues) and swirls of sediment or algae (red hues). This confirms that reflectance is either from the water body or suspended matter, but that it is also possible to distinguish between them, and therefore possible to address such issues in any further SDB analysis.

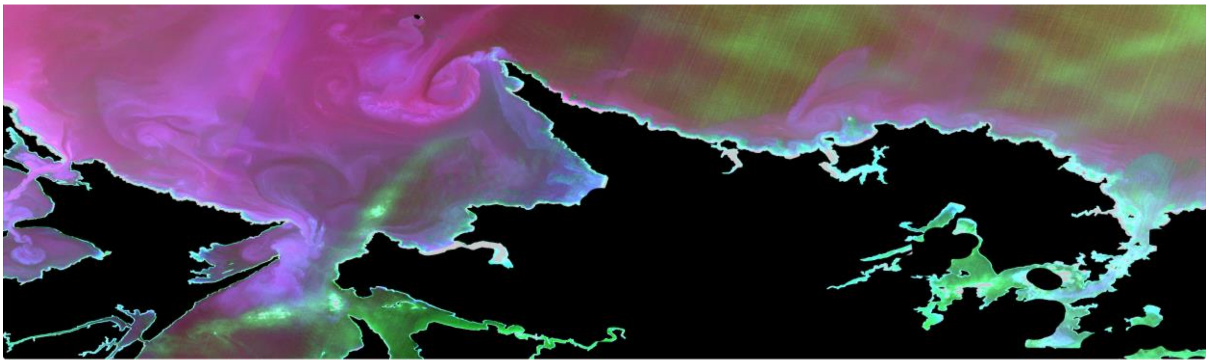

Figure 2.3: Subset of Sentinel-2 imagery and preliminary work into shallow marine water column/sea floor conditions

3. References

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Hedley, J.D.; Harborne, A.R.; Mumby, P.J. Technical note: Simple and robust removal of sun glint for mapping shallow-water benthos. *Int. J. Remote Sens*. 2005, 26, 2107–2112