Remote Sensing Measurements of Change in Coral Reefs in Kume, Japan after the 2011 Tsunami

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Abstract

This study measures the destruction of Okinawa's coral reefs caused by the tsunami that hit Japan in 2011. This project focuses on the island of Kume in the Okinawa Prefecture, and quantifies changes to the reefs around the island at the time of the event. This project had three goals: (1) identify regions of coral reef off Kume, (2) run a change detection of images before and after the tsunami, and (3) produce quantitative measurements of the change in reef structure caused by the tsunami. This project was able to identify that regions of the coral reef had changed, likely due to erosion of the sandbar affecting the water depth or survival of the marine organisms. Further detailed data would be necessary to draw conclusions about the nature of the effects of the tsunami.

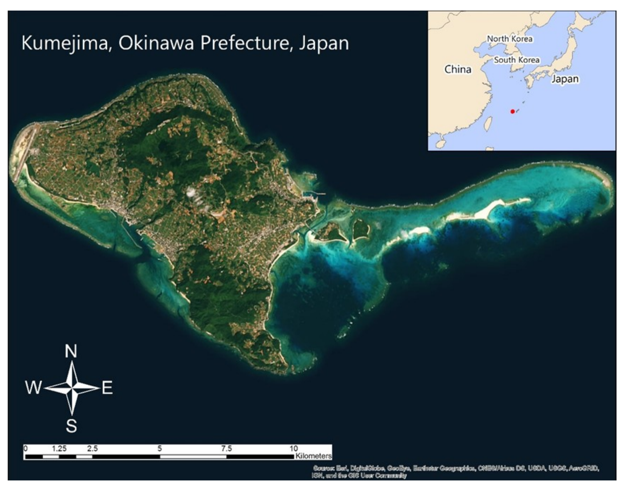

Figure 1: Map of the island of Kume

Image Choice and Preprocessing

- Landsat 5 TM
- Images chosen with <10% cloud cover
- Quick Atmospheric Correction (QUAC) and scaling
- Image co-registration (RMS Error = 1.97)

Figure 2: Wreckage from the 2011 tsunami in Japan.

Background

The Okinawa Prefecture is a chain of islands south of the mainland of Japan. The prefecture has a subtropical to tropical climate that makes it a popular tourism destination.

On March 11, 2011, Japan was hit by a magnitude-9.0 earthquake known as the Tōhoku Earthquake. The subsequent tsunami had devastating impacts on both human and animal populations. The tsunami reached 9 meters at its highest point and reached 0.6 meters at Okinawa. Studies of marine life have already found severe drops in biodiversity and species richness in Japan following the tsunami.

Classification

- Unsupervised K-means (20 classes, 5 iterations)
- Combine classes (land, deep water, reef areas)
- Ground-truthing using Google Earth
- Changes in the structure of the reef are apparent.
- Average spectral curves (Figures 3 and 4) match algae better than they match coral (Figure 5)
- The coral in the region tends to be associated with algae, so the algae's spectral profile may likely be usable as a proxy for coral.

	September 26, 2010	April 6, 2011
Reef Type 1	16 million m^2	13 million m^2
Reef Type 2	12 million m^2	10 million m^2
Reef Type 3	4 million m^2	6 million m^2

Table 1: Changes in reef cover areas. Reef Type 3 increased while Reef Types 1 and 2 decreased in area. These areas could represent different components of an ecosystem or different water depths.

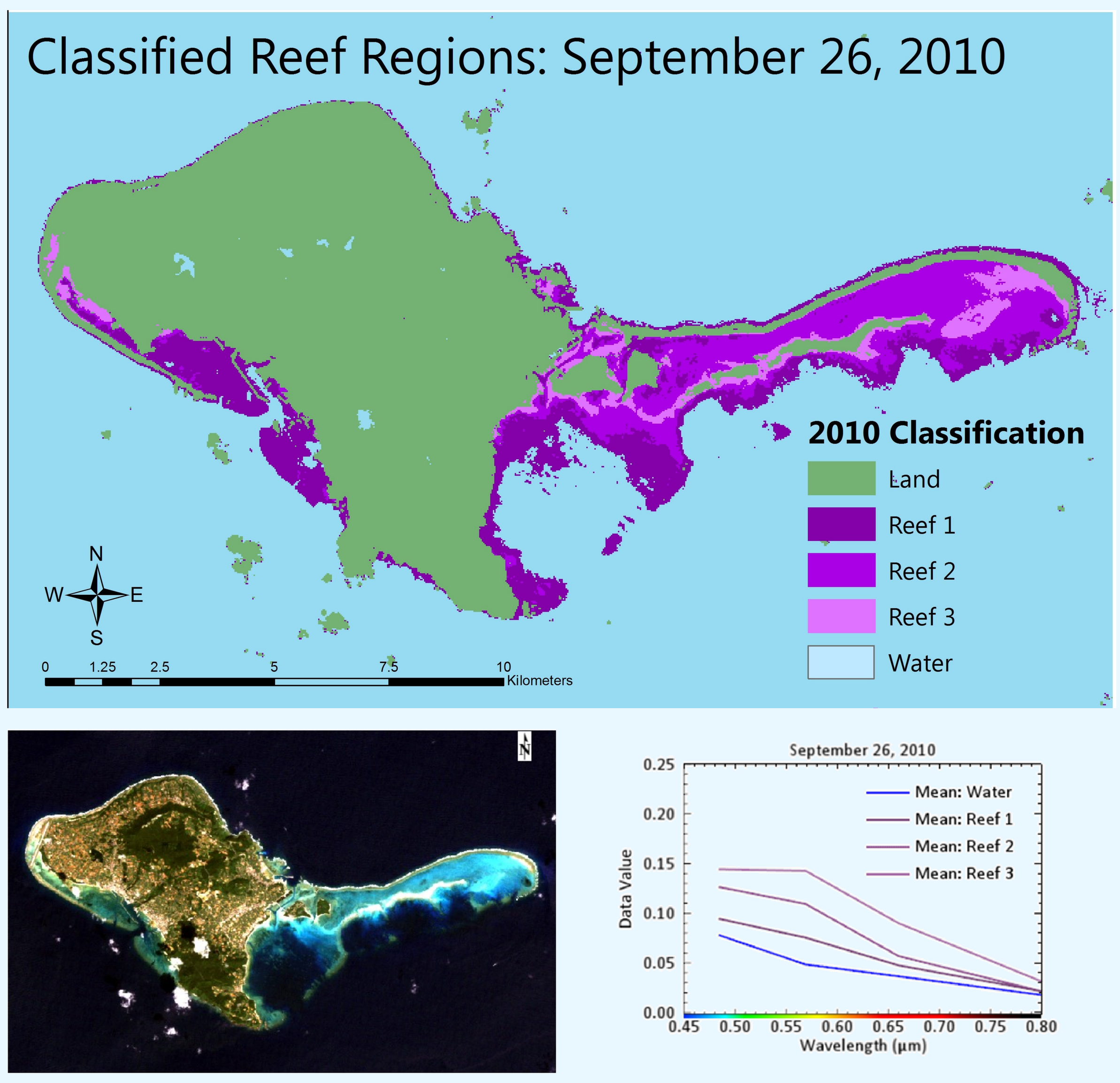

Figure 3: Classification of reef types from an image taken before the tsunami and the average spectral curve of each reef type.

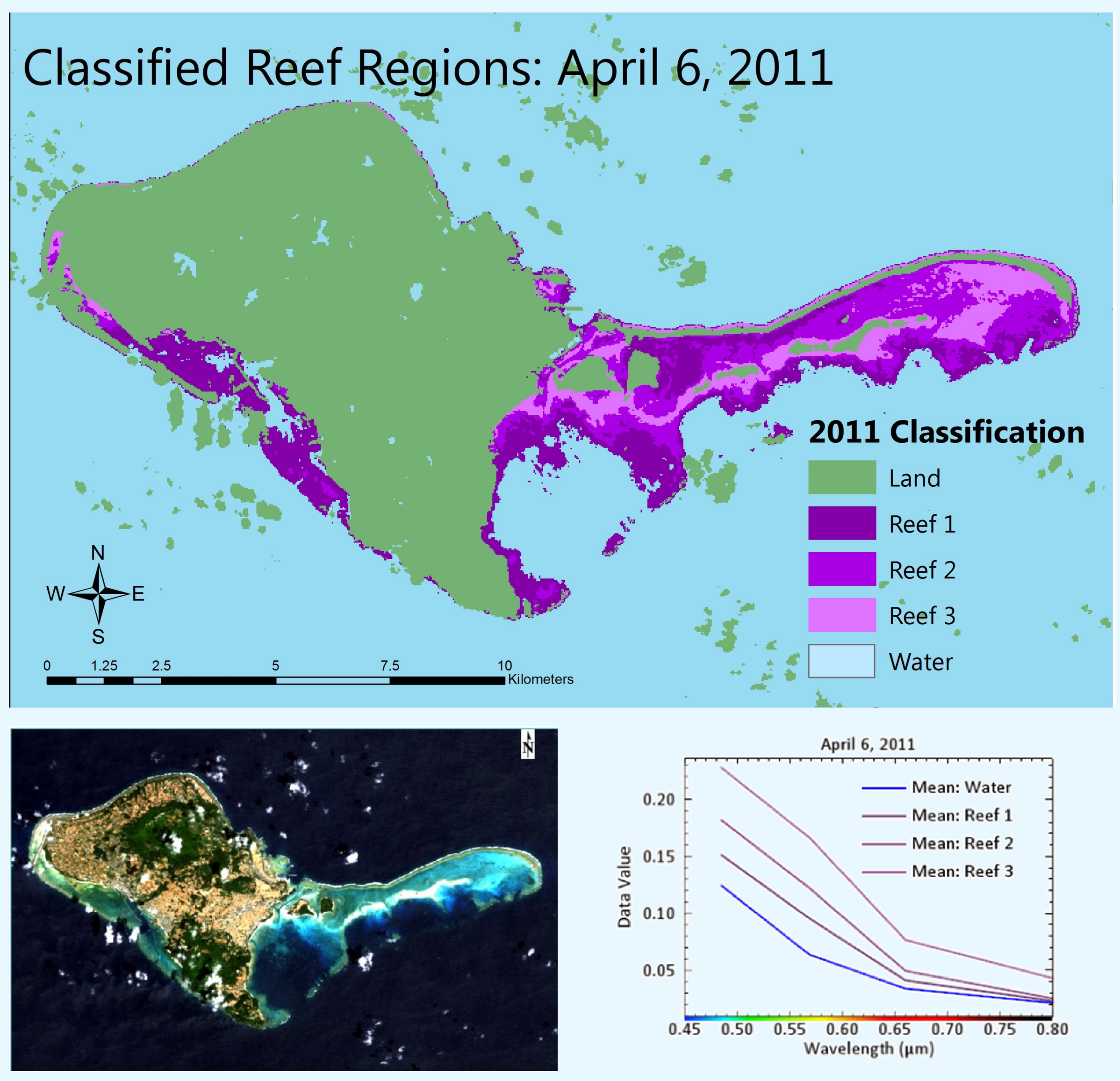

Figure 4: Classification of reef types from an image taken after the tsunami and the average spectral curve of each reef type.

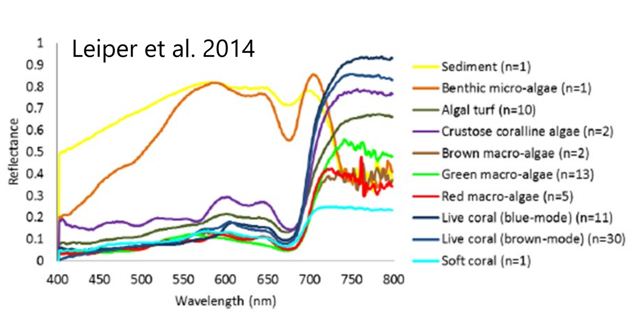

Figure 5: Spectral curves of marine surfaces. Coral has a strong IR spike not seen in the average spectral curves (Figures 3 and 4).

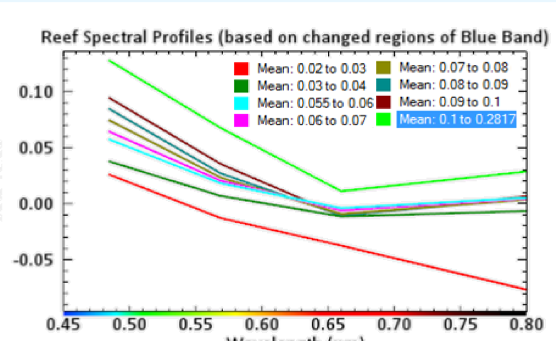

Figure 6: Spectral profile of regions of the reef sorted by change in reflectance. This may indicate change in coral cover.

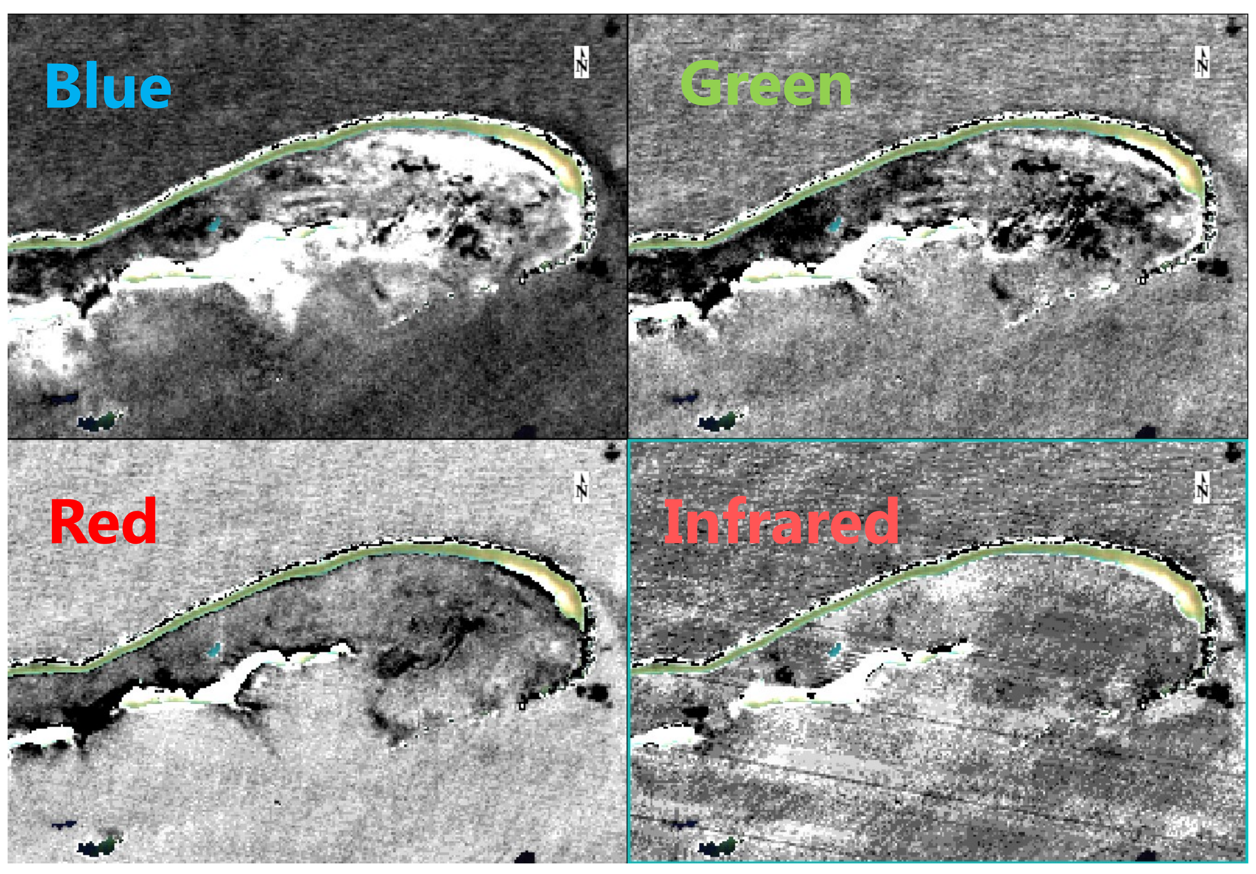

Figure 7: Change detection in the reef region in different bands. Positive change is light and negative change is dark. The blue and green bands show the greatest changes.

Change Detection

- Band math: (float(b1)-float(b2))
  - Change detection run on all bands
  - Peak with most pixels defined as "no change"
- Land mask to remove land features
- Largest changes in blue and green bands (Figure 7)
- Increase in reflectance in blue band all over, decrease in reflectance of both blue and green bands close to shore and sandbar (Figure 8)

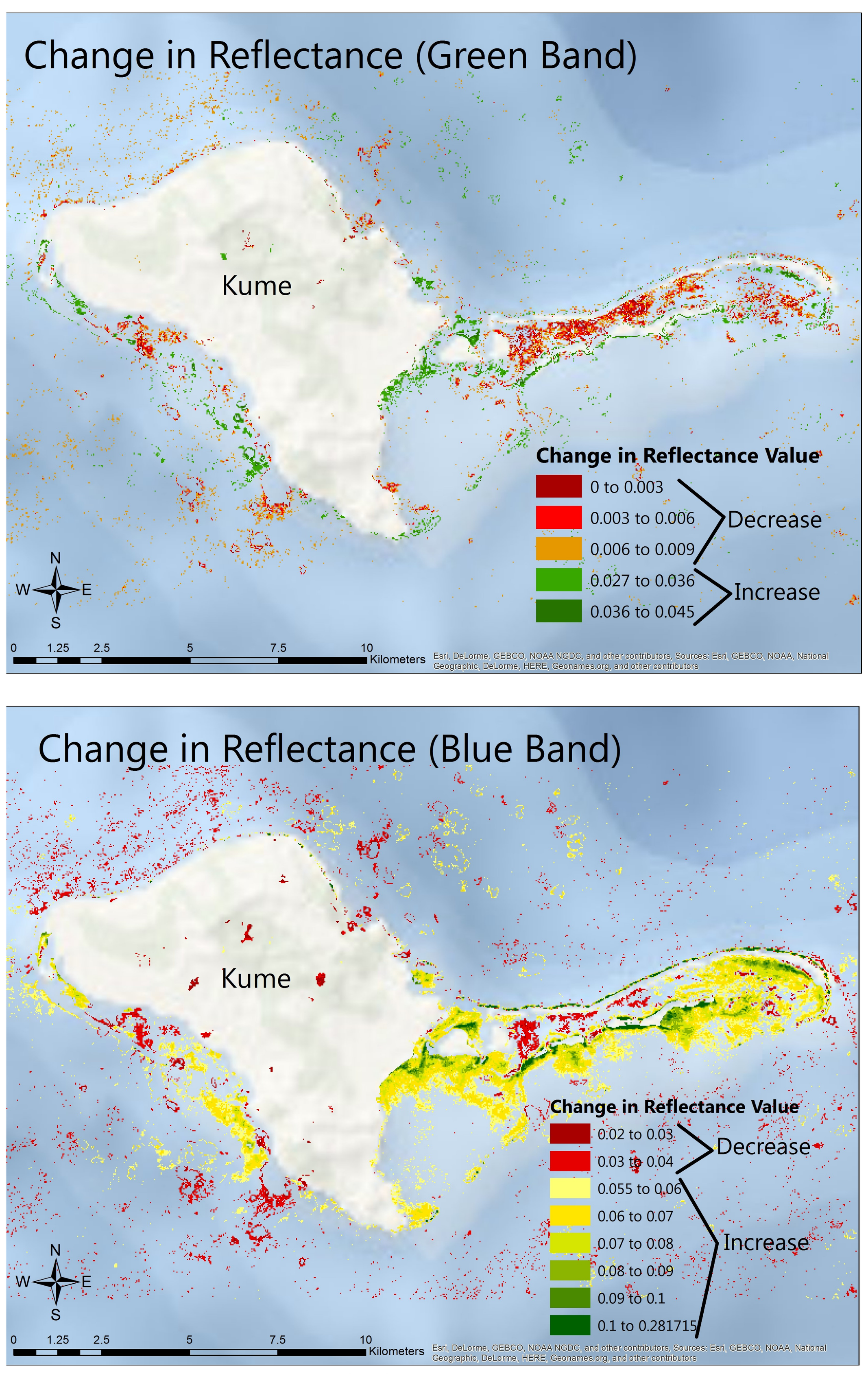

Figure 8: Change detection of reflectance values in green (top) and blue (bottom) bands, highlighting values that show change in the reef regions.

Conclusions

The tsunami changed the structure and composition of the reef type. Better ground-truthing (such as field data) is needed to identify coral reefs. This project would benefit from analyzing more images to get a baseline of changes in tides, algal cover, etc.

Erosion of the sandbar may have made the water shallower in the reef area and killed coral or other biomass close to shore. This is consistent with the changes seen in the shallow water regions.

Remote sensing has many useful applications in detecting and measuring changes in natural environments. It can highlight subtle variations in the landscape, map inaccessible areas, and make before-and-after comparisons even years after events. This project shows how remote sensing is a powerful tool to tackle conservation challenges.

Acknowledgements

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US Geological Survey & Tufts M Drive (data)

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