Detecting Island Mass Effect through remote sensing

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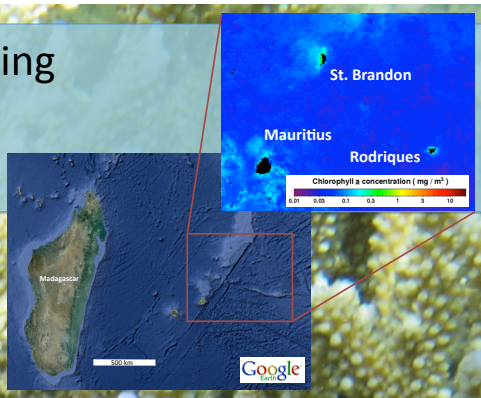

Study Sites

Figure 1: Mauritius (MRU), Rodrigues (ROD), and St. Brandon (SBR). Inset: False color composite Aqua MODIS image (4.64 km pixel) shows chl-*a* (mg/m^{-3}) from summer 2009-2010. IME is visible around all three islands.

Introduction

Island Mass Effect (IME) is enhanced primary production that occurs around oceanic islands in comparison to surrounding waters (Doty and Oguri, 1956).

IME can arise from:

(1) **strong tidal flows**, enhancing local vertical mixing, breaking down the pycnocline/nutricline.
(2) **geostrophic flow** generating a wake often extending for several island diameters downstream.
(3) **freshwater runoff** injecting limiting nutrients nearshore.

Why study IME near coral reefs? *IME phytoplankton blooms (Fig. 1) may cause an increase in nearshore zooplankton abundance.* This increase in abundance of food can help reefs weather stress. Here we suggest IME may be an overlooked aspect of oceanography affecting reef health during periods of stress.

Methods

We used Aqua MODIS sea surface temperature and chlorophyll-*a* data for 2009, 2010, and 2011 from http://oceancolor.gsfc.nasa.gov. Monthly average and seasonal composite images were composed for MRU, ROD, and SBR. Each image was 36 X 36 pixels = 27,902 km^2 (c. 1.5° latitude by 1.5° longitude).

Image processing programs SeaDAS 6.3 and NIH ImageJ 1.46h calibrated and analyzed images for mean and total chlorophyll-*a* and sea surface temperature.

Linear regression between mean monthly chlorophyll-*a* and sea surface temperature was computed using the least-squares algorithm, with significance tests.

Mechanisms for IME phytoplankton blooms were investigated by examining
- tidal regimes
- chlorophyll-*a* variation between leeward (west) to windward (east) coasts
- correlations between mean annual rainfall (MRU only) and chlorophyll-*a*.

Results

Phytoplankton blooms were detected at the three islands for the three years. Maximum local values of chlorophyll-*a* were 0.97 mg/m^3 (MRU), 2.77 mg/m^3 (ROD) and 0.71 mg/m^3 (SBR). The mean minimum and maximum chlorophyll-*a* values recorded for the entire bounding boxes were: 0.053 – 0.169 mg/m^3 (MRU); 0.053 – 0.129 mg/m^3 (ROD); 0.069 – 0.195 mg/m^3 (SBR).

The largest and highest intensity blooms occurred during the winter (June to August) (Fig. 2A&B).

Chlorophyll-*a* correlated negatively ($p < 0.05$) with temperature (Fig. 3).

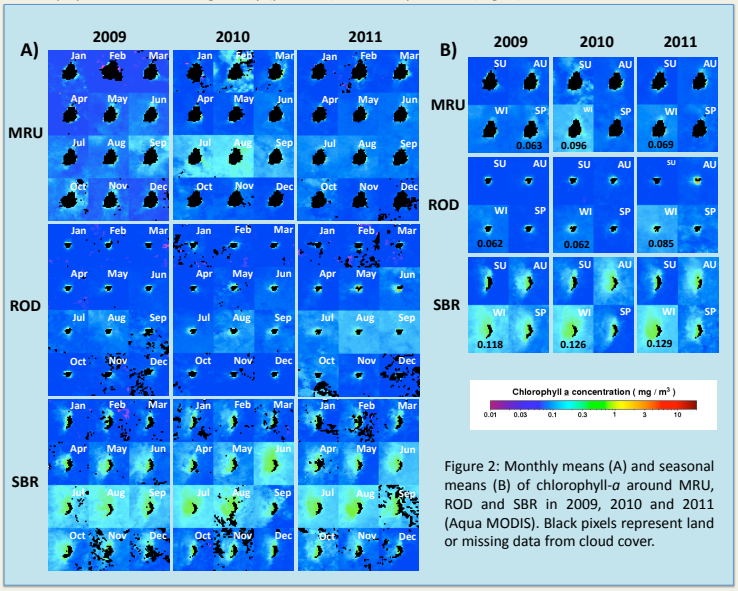

Figure 2: Monthly means (A) and seasonal means (B) of chlorophyll-*a* around MRU, ROD and SBR in 2009, 2010 and 2011 (Aqua MODIS). Black pixels represent land or missing data from cloud cover.

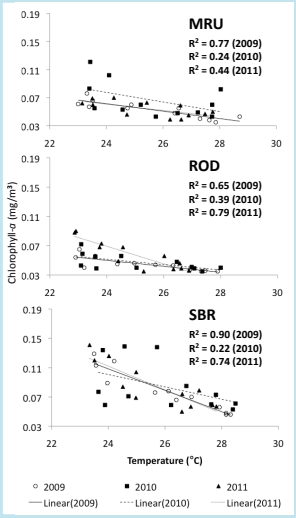

Figure 3: Correlation between chl-*a* and temperature (monthly mean) for three years for MRU, ROD and SBR.

Mean tidal range: 0.5 m (MRU), 1.2 m (ROD) and it is poorly known for SBR. This small range suggests that tidal mixing may not be significant.

SBR had the strongest blooms, always on the leeward side (Fig. 4). This indicates the possible mechanism of IME around SBR is strong currents generating eddies on the leeward side of the island, bringing cold nutrient rich waters to the surface.

There was no significant relationship between mean rainfall and chlorophyll-a concentration for MRU suggesting that rainfall does not play a role in the IME at the level of the bounding box.

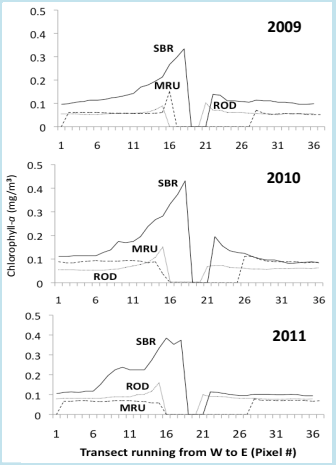

Figure 4: Mean values of chl-*a* per pixel in winter along a west-to-east transect for MRU, ROD and SBR. Pixels representing land have a zero chl-a. Transects were midway between the north and south tips of the islands.

Conclusions

Enhanced primary production was observed around the three islands, and highest in winter (June-August). SBR had the highest concentration, consistently on the leeward side (west), differing from MRU and ROD. There was significant negative correlation between temperature and chlorophyll-*a*.

Studies in the South Coral Sea (Rissik et al. 1999) and the Canary Islands (Hernández-Léon et al. 2001) report zooplankton blooms due to IME. Further studies are need to determine how much of the chlorophyll-*a* observed from space gets converted to zooplankton to benefit the reefs around MRU, ROD, and SBR.

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