IN SITU SUBSURFACE AND REMOTELY SENSED SEA SURFACE TEMPERATURES: AN INITIAL COMPARISON

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In-situ Subsurface and Remotely Sensed Sea Surface Temperatures: an Initial Comparison

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In response to the mass coral reef bleaching event of 1987, the Caribbean Marine Research Center (CMRC) initiated a long-term program to continuously monitor sea water temperatures at selected reef sites near established facilities in the Bahamas, Florida Keys, and around the Caribbean. The greatest number of thermographs is located between depths of about 3 m and 33 m near the CMRC's marine laboratory on Lee Stocking Island (LSI), Exuma Cays, the Bahamas, where meteorological data are taken and the condition of coral reefs is being tracked. Intervals of calm wind with little rain and high insolation, followed by elevated seawater temperatures in July and September, were closely associated with mass bleaching during 1990 (Dennis, G.D. and R.I. Wicklund, 1993, in R.N. Ginsburg, Ed., "Case Histories for the Colloquium and Forum on Global Aspects of Coral Reefs: Health, Hazards and History," Univ. Miami). A smaller-scale bleaching event occurred after a similar warming trend in late July, 1993 (Dennis, G.D. *et al.*, AMLC Meeting, June 1994, Abstract).

The high habitat-scale complexity that characterizes mass bleaching at LSI (Lang, J.C. *et al.*, 1988, 6th Int. Coral Rf. Symp. 3: 269-274) appears to be at least partially attributable to its location on the eastern margin of Great Bahama Bank. Seawater over the Bank responds rapidly to local meteorological conditions and is usually hypersaline, while the timing, extent and duration of tidal currents are variable among shallow reef sites. For example, we have found that ambient flow is strong after high tides at the ~3 - 6 m deep Rainbow Gardens channel patch reef, yet ~ 2 km to the southeast, brisk currents follow low tides on the ~1 - 4 m deep Norman's Pond Cay fringing reef. Hence, reef organisms at the former site are relatively more exposed to warm, saline underflows moving off the Bank during low tides in the summer and early autumn. Very high levels of bleaching were characteristic of the reef benthos at Rainbow Gardens during the 1987, 1990 and 1993 events, whereas comparatively little discoloration occurred at the Norman's Pond Cay site.

A long-term goal is to characterize the relationships between measured subsurface temperatures and satellite-derived estimates of sea surface temperature (SST) for reefal areas in the CMRC thermograph network. Our initial--and still very preliminary--attempt is a comparison of data spanning the late July, 1993 warming trend that preceded last year's minor bleaching event. Three LSI-area thermographic locations were selected to be representative of a seaward fringing reef (South Perry, 16 m), a seaward tidal channel (Adderley Dropoff, 33 m), and Great Bahama Bank (East Barracuda Rocks, 1.5 m), respectively. Imagery from all passes received from NOAA-11 and NOAA-12 satellites during this period by the Center for Space Research at the University of Texas (UT) was uploaded from 8 mm tapes and, for each, a 1024 x 1024 image centering on the Bahamas was registered to a map file of this region. After visual inspection for clouds in channel 2, 32 passes at each site were judged to be satisfactory for processing. All 5 AVHRR channels were then extracted from the "acceptable" images in a linear array consisting of 9 pixels (pixel size is ~1 km^2) that had been specified by latitude and longitude coordinates at each site. (The arrays were centered on, and parallel to, South Perry Reef but offset from the coastline by 1.5 km, as above for Adderley Channel but 10 km offshore

over the deep waters of Exuma Sound, and centered on East Barracuda Rocks, respectively.) Data from channels 4 and 5, and the calculated satellite zenith angle, were then used to estimate a SST for every pixel, using the NOAA/NESDIS-derived, split channel Cross Product Sea Surface Temperature (CPSST) algorithm that has previously been used to track thermal features during humid months in the Gulf of Mexico (May, D.A. *et al.*, 1993, J. Atmos. Oceanic Technol. 10: 64-75). Mean, median and maximum SSTs at each site were estimated after discarding obvious outliers. Corresponding subsurface temperature data for the same time intervals were obtained by averaging the two closest thermographic records. (Data are logged at 30 minute intervals; accuracy of the calibrated thermographs is expected to exceed $\pm$ 0.2^{o} C.)

Progress to date: at each site, the 32 selected, subsurface temperature records reasonably approximate the full subsurface data set obtained from July 14 -30, 1993. There is little difference among the mean, median and maximum SST estimates for each site. SST trends at the two seaward sites are similar, suggestive of little direct interference from land or the Bank at 1.5 km *versus* 10 km offshore, respectively. The residuals (mean, median or maximum satellite SST - subsurface T) are usually positive, but highly variable between passes at any given site. Attempts to treat the residuals as dependent variables and to fit some sort of correction for the mean SSTs based on tidal height, relative humidity, insolation and rainfall were "appallingly bad" at the South Perry Reef (multiple $R^2 = 0.07$, $p = 0.55$) and nearly as poor for Adderley Channel (multiple $R^2 = 0.11$, $p = 0.35$). The total regression is significant at East Barracuda Rocks, however, due almost entirely to the contribution of the tide, even though the multiple R^2 is still pretty low ($R^2 = 0.28$, $p = 0.02$).

In the near future: we hope to improve our sampling criteria to better eliminate SSTs that might be distorted by sub-pixel clouds by (a) examining the hourly-scale insolation data for this time interval and (b) pre-processing the images with adaptations of existing, km-scale, cloud screening algorithms. It may prove desirable to further reduce the effects of atmospheric interference by accessing images of the Bahamas collected at a receiver that is located closer to nadir than the UT receiver. D.A. May (pers. comm.) has recommended substituting a newer, non-linear SST for the CPSST algorithm. Near-surface *in-situ* temperature data are also needed to correct for any minor, water-column related temperature stratification as may occur at these sites (P.A. Pitts and N.P. Smith, 1993, CMRC Tech. Rept. Ser. 93-3).

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