

THE RECORD OF SEA TEMPERATURE DURING THE 2010 CORAL BLEACHING AT PHUKET, THAILAND – DIFFERENT DATASETS, DIFFERENT PERSPECTIVES – UNEXPLAINED ERRORS IN HADISST 1.1.

Richard P. Dunne

*West Briscoe, Baldersdale, Barnard Castle, Co Durham, DL12 9UP, UK
RichardPDunne@aol.com*

ABSTRACT: In 2010, coral bleaching at Phuket, Thailand was accompanied by monthly mean sea temperatures that were elevated above a proposed bleaching threshold of 30.11°C for four months from March to June. This extended warm period was accurately identified in both HadSST2 and IGOSS sea surface temperature datasets, but not the HadISST1.1 data which consistently under-recorded the true temperature by up to 1.38°C. HadISST1.1 also failed to differentiate between the 2010 hiatus and the same period in 1998, when less severe but widespread bleaching occurred. In both cases, had the HadISST1.1 data been relied upon to predict or explain the bleaching severity it would have produced an incorrect result. Although the error may only be a one-off event, nonetheless it highlights the caution that should be exercised when using remotely sensed, temperature datasets, even from seemingly reliable and trusted sources.

Keywords: Sea temperature, coral bleaching

INTRODUCTION

Global sea temperature datasets are widely used in the scientific community for examining long term trends and temperature fluctuations and how these relate to biological observations of the marine ecosystem. One such observation is that of coral bleaching which has long been correlated with abnormally high sea temperatures, both in terms of peak temperature and duration (Coles and Brown, 2003) and for which, one of the present datasets (HadISST 1) has been used previously (Sheppard and Rayner, 2002). Each dataset has a different mix of data source (e.g. measurements from ships or buoys, and/or satellite radiometer) and processing (e.g. simple quality control checks or more sophisticated interpolation techniques) and at different geographical scales (e.g. 1 degree latitude and longitude grid, or 5 degree grid) but the basic presumption exists that for a particular location, the pattern and magnitude of observed fluctuations should be similar if the data is to be taken as an accurate record.

In April 2010, one of the most severe and widespread records of coral bleaching occurred in Phuket, Thailand (see other papers in this issue)

and extended throughout the area to the Andaman Islands in the west (Krishnan *et al.*, 2011)). This was largely considered to be a function of elevated sea temperatures, prior to and at the time of bleaching. This paper compares the records of sea temperature for a 7 month period (Jan – July 2010) from three widely available datasets (HadISST 1.1, HadSST2 and IGOSS) together with *in situ* thermistor temperature data. Patterns in the temperature rise and magnitude in 2010 are contrasted to 1998 when the last widespread coral bleaching occurred.

MATERIAL AND METHODS

Monthly mean sea temperature was obtained from three datasets, two from the UK Meteorological Office Hadley Centre (HadISST1.1, and HadSST2) and one from the Integrated Global Ocean Services System Products Bulletin (IGOSS). The HadSST2 data was for a 5 degree grid square (95°–100°E, 5°–10°N), and for HadISST 1.1 and IGOSS a 1 degree grid square (98°–99°E, 7°–8°N) (Fig. 1).

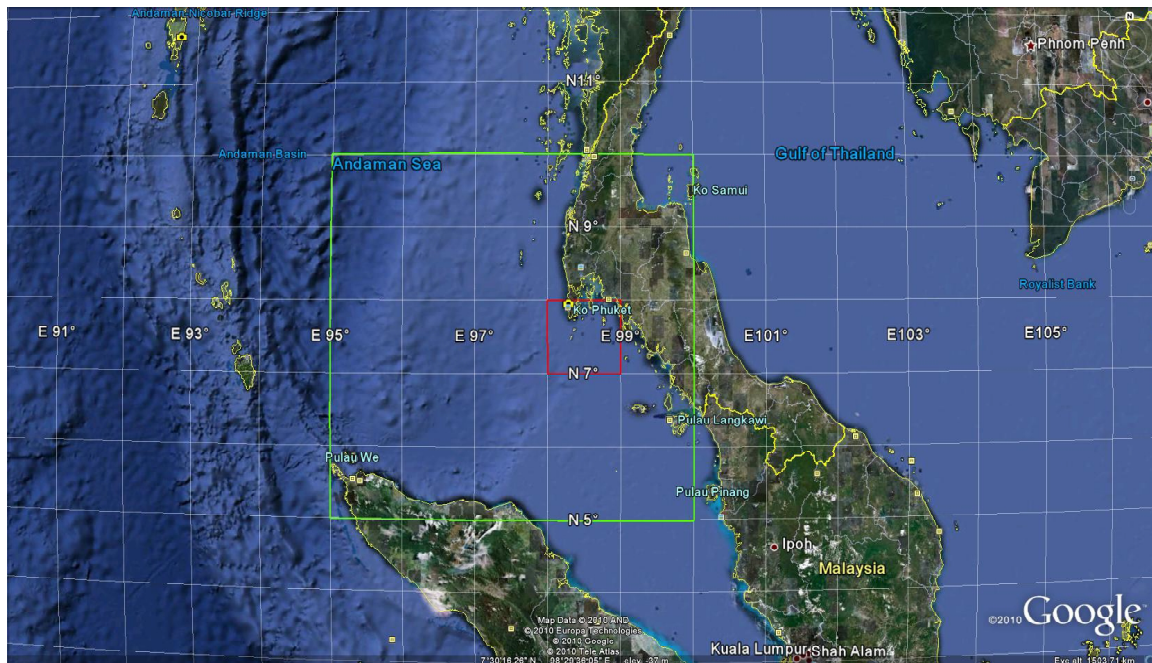


Figure 1. 5 degree (green) and 1 degree (red) grid squares for sea temperature datasets for Phuket, Thailand. Image courtesy of Google Earth ©.

HadISST1.1 (http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_hadisst or <http://www.hadobs.org/>)

The HadISST1.1 dataset contains reconstructed monthly mean sea surface temperature (SST) data from 1870 to present on a 1 degree latitude and longitude grid. Data are from the Met Office Marine Data Bank (MDB) which from 1982 onwards also includes satellite measurements (Advanced Very High Resolution Radiometer – AVHRR) received through the Global Telecommunications System (GTS). The MDB is part of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) (Woodruff, 2001). The data are reconstructed using a two stage reduced-space optimal interpolation (RSOI) procedure, followed by the superimposition of quality-improved gridded observations onto the reconstructions to restore local detail (Horton *et al.*, 2003).

HadSST2 (http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_11704341770613707)

or <http://www.metoffice.gov.uk/hadobs/hadsst2/>)

The HadSST2 dataset replaces the Met Office Historical Sea Surface Temperature dataset (MOHSST6) which has been used for earlier studies at Phuket (e.g., Brown *et al.* (1996)) from which a putative coral bleaching threshold of 30.11°C was established. It is a monthly mean global field of SST on a 5 degree latitude and longitude grid from 1850 to the present. The data are taken from ICOADS from 1850 to 1977 and then from the NCEP-GTS from 1998 to present, and consist of measurements from ships and buoys. The data are neither interpolated nor variance adjusted, but data are quality checked to reject spurious readings (Rayner *et al.*, 2006).

IGOSS nmc Reyn SmithOiv2 monthly sst: Sea Surface Temperature data (http://iridl.ldeo.columbia.edu/SOURCES/.IGOSS/.nmc/.Reyn_SmithOiv2/.monthly/.sst/)

The IGOS data consists of monthly 1 degree SST fields derived by linear interpolation of the weekly optimum interpolation version 2 fields

to daily fields, then averaging the daily values over a month (Reynolds *et al.*, 2002). Data is from in situ and satellite SST with the satellite data adjusted for biases using the method of Reynolds (1988) and Reynolds and Marsico (1993).

In situ thermistors

For the period 1997-98 data was obtained from a thermistor (Betatherm Corp 2Kohm, Delta T Devices DL2 logger 4 wire LFW1 input card) situated at the Cape Panwa Hotel jetty (98.411285°E, 7.807681°N). In 2010 a temperature logger (Sensus Ultra) was situated approximately 200 metres to the northwest of the jetty. Both sensors were sited at about 1 metre depth below chart datum and recorded at 30 minute intervals and were cross calibrated to the same calibrated precision mercury-in-glass thermometer (Zeal BS1900 SR6/34C 16-34°C by 0.05°C – NAMAS Calibrated 1996).

Statistical analysis

The temperature differences between the 3 datasets and the thermistor recording for 2010 were compared using the REGW-F multiple comparison procedure (Welsch, 1977) after checking for homoscedasticity and normality. Data for 1998 were homoscedastic but non-normal and a Kruskal-Wallis test and Dunn's multiple comparisons were used.

RESULTS AND DISCUSSION

In both 1998 and 2010, the monthly mean sea temperature recorded by thermistors peaked in May (Fig. 2). In 2010 the temperature was consistently higher than in the corresponding month from 1998 by up to 1.32°C in March and 1.22°C in May. In both years, the temperature exceeded the putative bleaching threshold of 30.11°C (Brown *et al.*, 1996). The higher sea temperature recorded in 2010 is consistent with the increased severity of the coral bleaching observed in 2010 compared to 1998 (Phongsuawan and Chansang this issue).

When the three SST datasets were examined for 1998, they were found to track the thermistor record within the range + 0.85°C to -

0.43°C from January to July, and + 0.06°C to - 0.43°C for the months of April and May (Figures 3 and 4).

In 2010 for the corresponding period, although the HadISST1.1, HadSST2 and IGOSS datasets show a similar pattern to the thermistor record of warming and cooling with peak temperatures in May (Fig. 5), the temperature differential for the HadISST1.1 data was consistently larger than for the HadSST2 and IGOSS data (Fig. 6) with the HadISST1.1. data recording a temperature up to 1.38°C lower than the thermistor record in April 2010.

Although all three datasets recorded lower SST than the thermistor for most months of 2010, the HadISST1.1 temperature was significantly lower than both the HadSST2 and IGOSS temperature across the period (Table 1) suggesting that the data were unreliable. By comparison, in 1998 there were no significant differences between the three datasets (Kruskal-Wallis $p = 0.42$).

The unreliability of the HadISST1.1 data during the 2010 bleaching months cannot be easily identified and has been dismissed as “an unfortunate blip in HadISST1.1 near Phuket” by the Hadley Centre (N.A. Rayner pers. comm.). However, further investigation of the HadISST1.1 data averaged over the 25 grid squares corresponding to the larger 5 x 5 degree grid of the HadSST2 data reveal that the same errors persist, and indeed, the average for the 5 x 5 degree grid gives temperature values that are in most months (apart from April) very slightly lower than those for the 1 x 1 degree grid square (Figure 7), although these differences are less than 0.1°C in most cases. Furthermore, the error cannot simply be explained as a difference between bulk SST from ships and buoys (HadSST2 data) and blended data sets which incorporate satellite measurements of the ‘skin’ SST, such as HadISST1.1 and IGOSS, given that the errors were only present in HadISST1.1, and were also not a characteristic of the 1998 period in any of the datasets. Whether or not the method of reconstruction used in computing the HadISST1.1 data could have given rise to the error is also not known. In an earlier use of the HadISST 1.1 data for coral bleaching, Sheppard and Rayner (2002) noted that the use of HadISST1.1 for “local

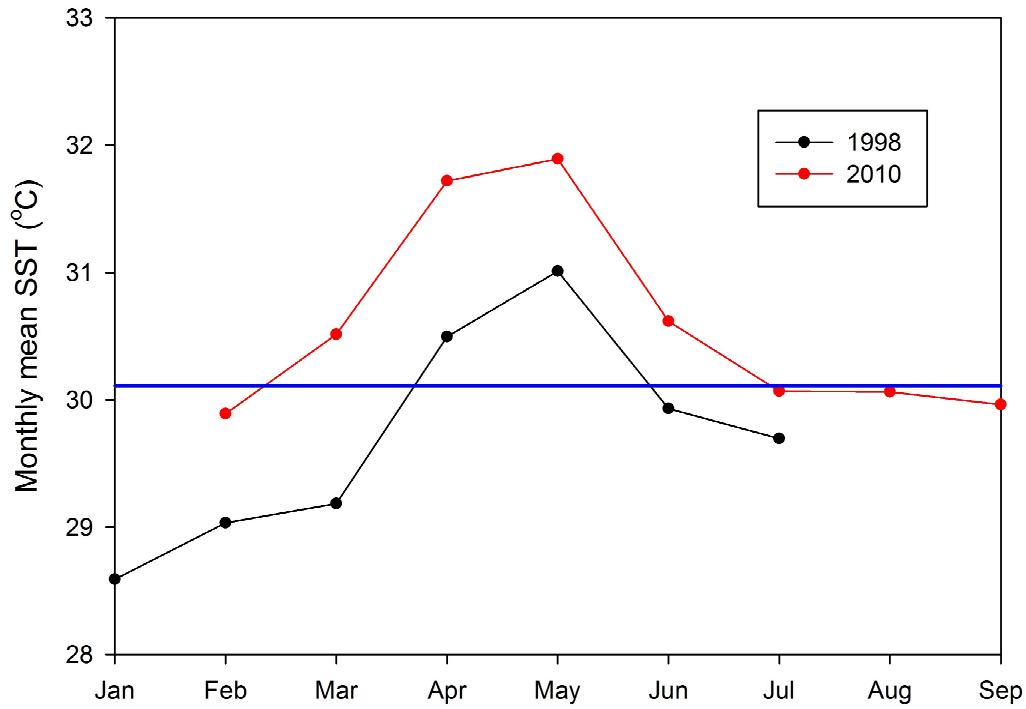


Figure 2. Monthly mean sea surface temperature from thermistors near the Cape Panwa jetty, Phuket, Thailand, for 1998 and 2010. Bleaching threshold of 30.11°C shown by blue line.

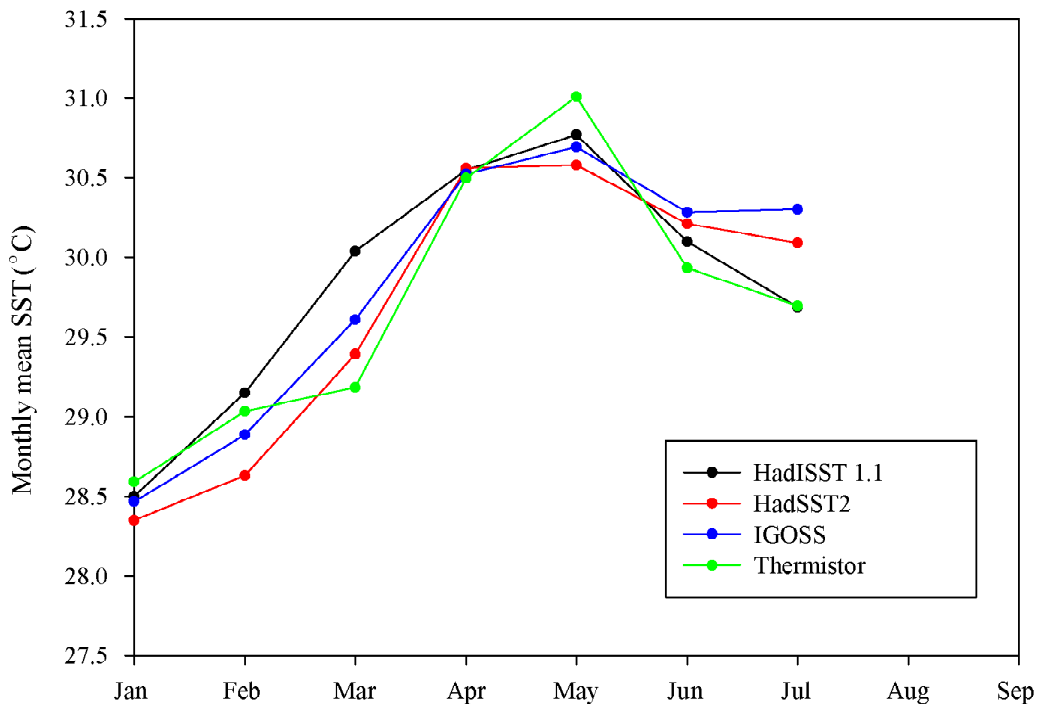


Figure 3. Monthly mean sea surface temperature in 1998 from the HadISST1.1, HadSST2 and IGOSS datasets and thermistor record.

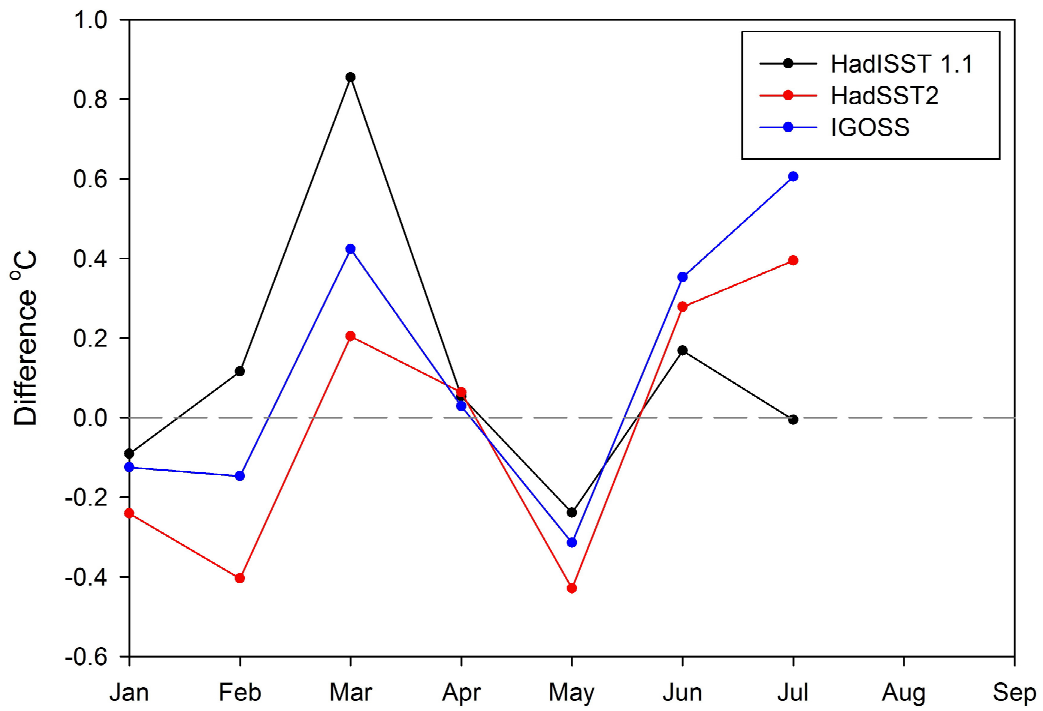


Figure 4. Difference between thermistor record and HadISST1.1, HadSST2 and IGOSS datasets - 1998.

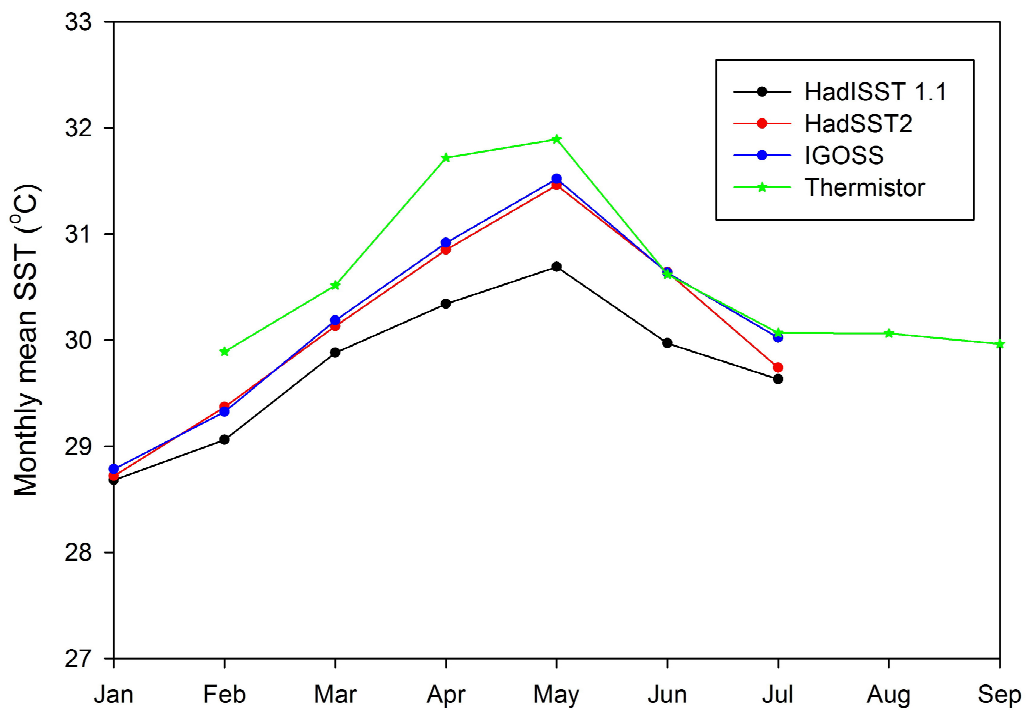


Figure 5. Monthly mean sea surface temperature in 2010 from the HadISST1.1, HadSST2 and IGOSS datasets and thermistor record.

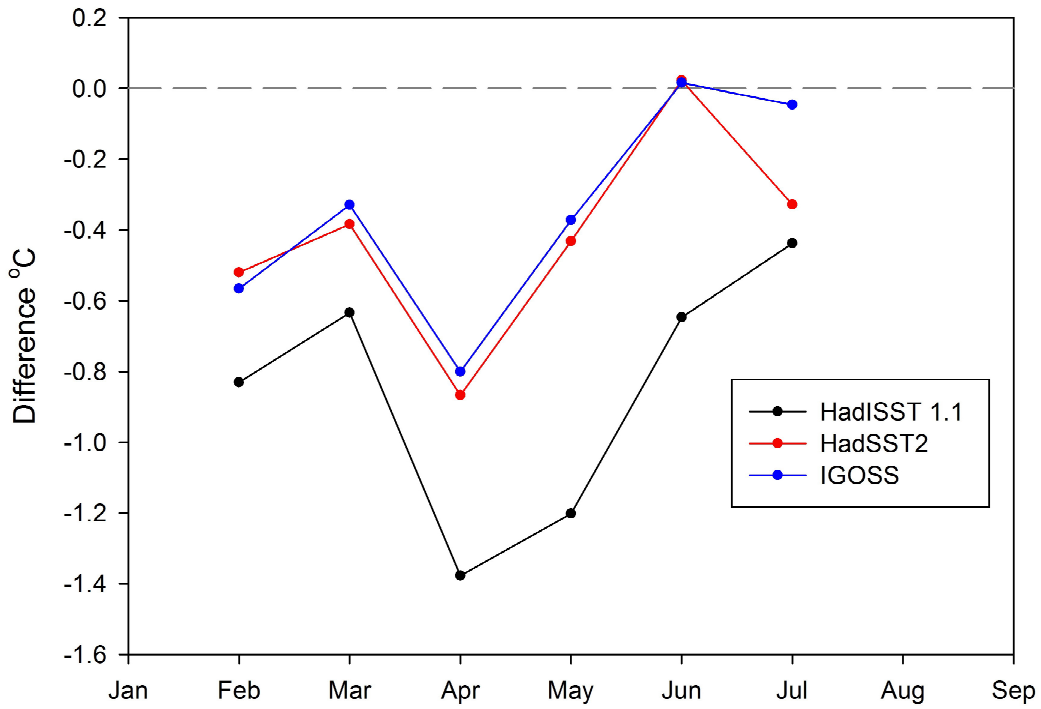


Figure 6. Difference between thermistor record and HadISST1.1 HadSST2 and IGOSS datasets - 2010.

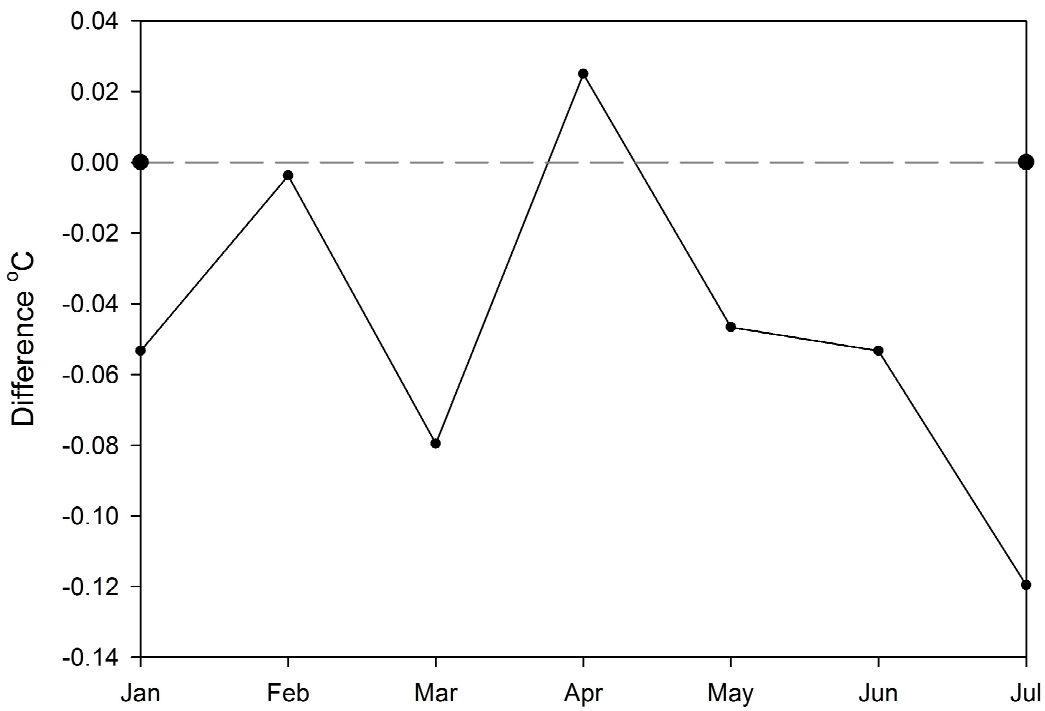


Figure 7. Difference between SST in 1 x 1 degree grid centred on Phuket and 5 x 5 degree grid for HadISST1.1 dataset in 2010.

Table 1. Summary statistics for difference between data sets and thermistor record Jan-Jul 2010. (Initial ANOVA F test significant, $p = 0.05$, F statistic 4.414, critical value = 3.682)

Data	Mean difference	Std error	REGW-F comparison	F statistic	Critical value of F at $\alpha = 0.05$
HadISST 1.1	0.855	0.148			
HadSST2	0.426	0.112	HadISST 1.1	5.55	4.54
IGOSS	0.355	0.123	HadISST 1.1	7.54	4.54
			HadSST2	0.15	4.54

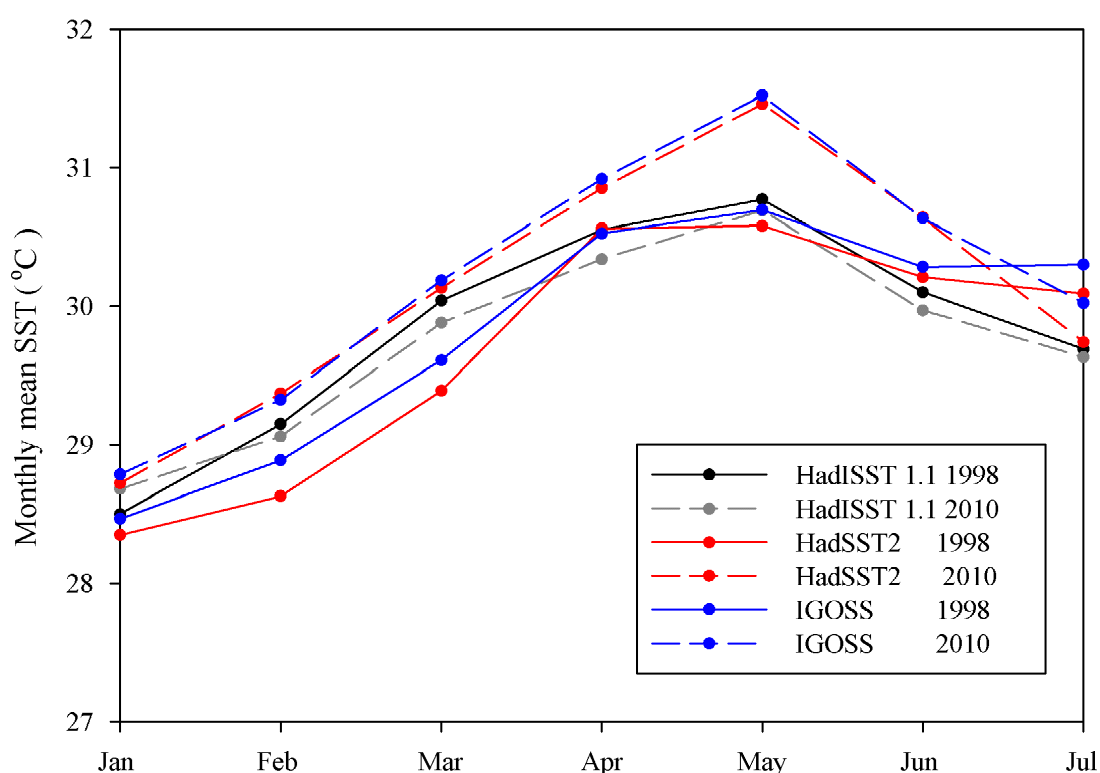


Figure 8. Combined plot of SST for 1998 and 2010 for the three datasets.

time series, stretches the dataset to its limits” but nonetheless endorsed its use across the full spectrum of temperature ranges encountered in the tropics. It would appear that in this instance its limitations have been revealed.

How critical is the error in the HadISST1.1 data?

If each dataset is compared for the two bleaching years, 1998 and 2010, a pattern emerges for the HadSST2 and IGOSS data, with 2010 being consistently warmer than 1998 over a prolonged period (Fig. 8). On this basis the temperature data are consistent with the far more severe coral

bleaching that was observed. By contrast, the HadISST1.1 data does not differentiate between the two years and would provide no evidence for the hypothesis that the difference in bleaching severity could be attributed to the temperature regime. Clearly this is erroneous given the conclusive evidence from both the *in situ* thermistor record and also the two other datasets and is a cause for concern, particularly since there is no obvious explanation. In particular, it highlights the need to rigorously cross-check sources of data even when these are from seemingly reliable and trusted sources, and emphasises the need for accurate *in situ* calibrated temperature recorders.

ACKNOWLEDGEMENTS

I thank Jani Tanzil for the thermistor records for 2010, and Professor Sandy Tudhope who provided the IGOSS data; also to Professors Barbara Brown and Alasdair Edwards for their helpful discussions.

REFERENCES

- Brown, B.E., R.P. Dunne and H. Chansang. 1996. Coral bleaching relative to elevated seawater temperature in the Andaman Sea (Indian Ocean) over the last 50 years. *Coral Reefs* **15**: 151-152.
- Coles, S.L. and B.E. Brown. 2003. Coral Bleaching - Capacity for Acclimatization and Adaptation. *Adv. Mar. Biol.* **46**: 183-223.
- Horton, E.B., C.K. Folland, L.V. Alexander, D.P. Rowell, E.C. Kent and A. Kaplan. 2003. Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. *J. Geophys. Res.* **108**: 4407 10.1029/2002JD002670.
- Krishnan, P., S. Dam Roy, G. Grinson , R.C. Srivastava, A. Anand, S. Murugesan, M. Kaliyamoorthy, N. Vikas and R. Soundararajan, 2011. Elevated sea surface temperature during May 2010 induces mass bleaching of corals in the Andaman. *Curr Sci* **100**: 111-117.
- Rayner, N.A., P. Brohan, D.E. Parker, C.K. Folland, J.J. Kennedy, M. Vanicek, T.J. Ansell and S.F.B. Tett. 2006. Improved Analyses of Changes and Uncertainties in Sea Surface Temperature Measured In Situ since the Mid-Nineteenth Century: The HadSST2 Dataset. *J. Clim.* **19**: 446-469.
- Reynolds, R.W. 1988. A real-time global sea surface temperature analysis. *J. Clim.* **1**: 75-86.
- Reynolds, R.W. and D.C. Marsico. 1993. An improved real-time global sea surface temperature analysis. *J. Clim.* **6**: 114-119.
- Reynolds, R.W., N.A. Rayner, T.M. Smith, D.C. Stokes and W. Wang. 2002. An improved In Situ and Satellite SST Analysis for Climate. *J. Clim.* **15**: 1609-1625.
- Sheppard, C.R.C. and N.A. Rayner. 2002. Utility of the Hadley Centre sea ice and sea surface temperature data set (HadISST1) in two widely contrasting coral reef areas. *Mar. Pollut. Bull.* **44**: 303-308.
- Welsch, R.E. 1977. Stepwise Multiple Comparison Procedures. *J. Am. Statist. Assoc.* **72**: 566-575.
- Woodruff, S.D. 2001. COADS Updates Including Newly Digitized Data and the Blend with the UK Meteorological Office Marine Data Bank. Japan Meteorological Agency and the Ship & Ocean Foundation, pp. 1-5.