MONITORING CORAL BLEACHING BY SATELLITE THERMAL PRODUCTS

Case study of the
Southern East Sea, Vietnam

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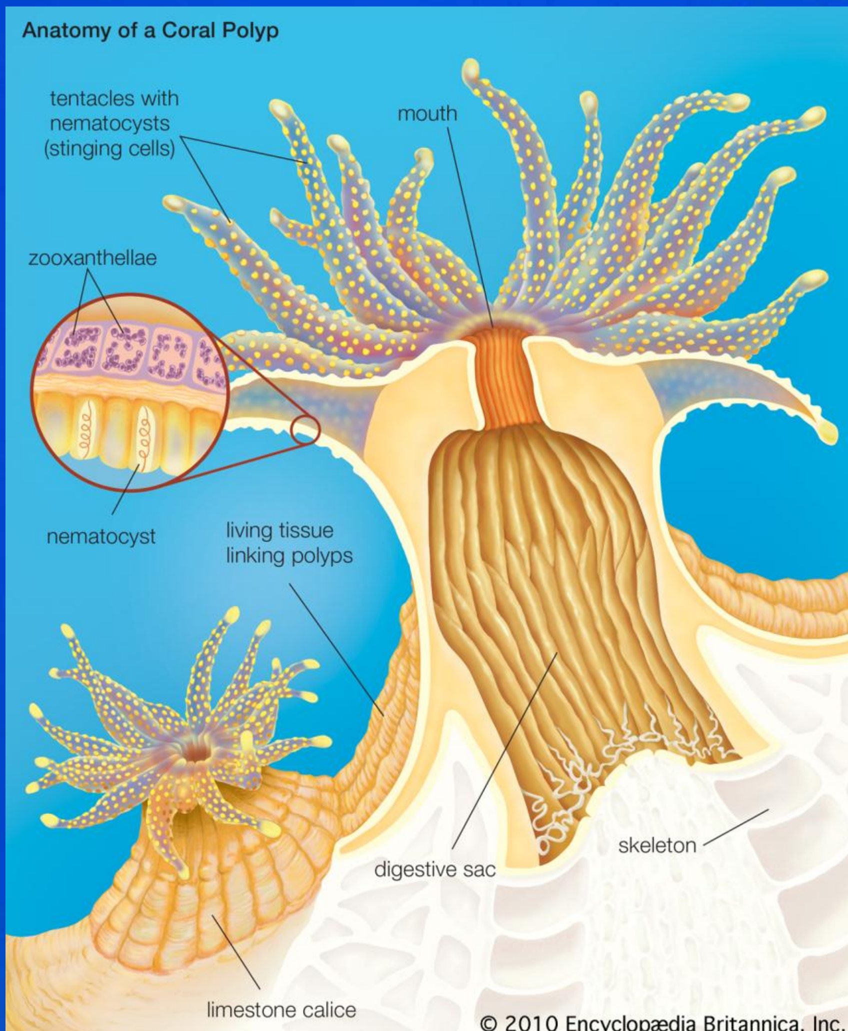
Coral Reefs


Anatomy of a Coral Polyp
tentacles with
nematocysts
(stinging cells)
mouth
zooxanthellae
nematocyst
living tissue
linking polyps
skeleton
digestive sac
limestone calice
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Threats to Reefs

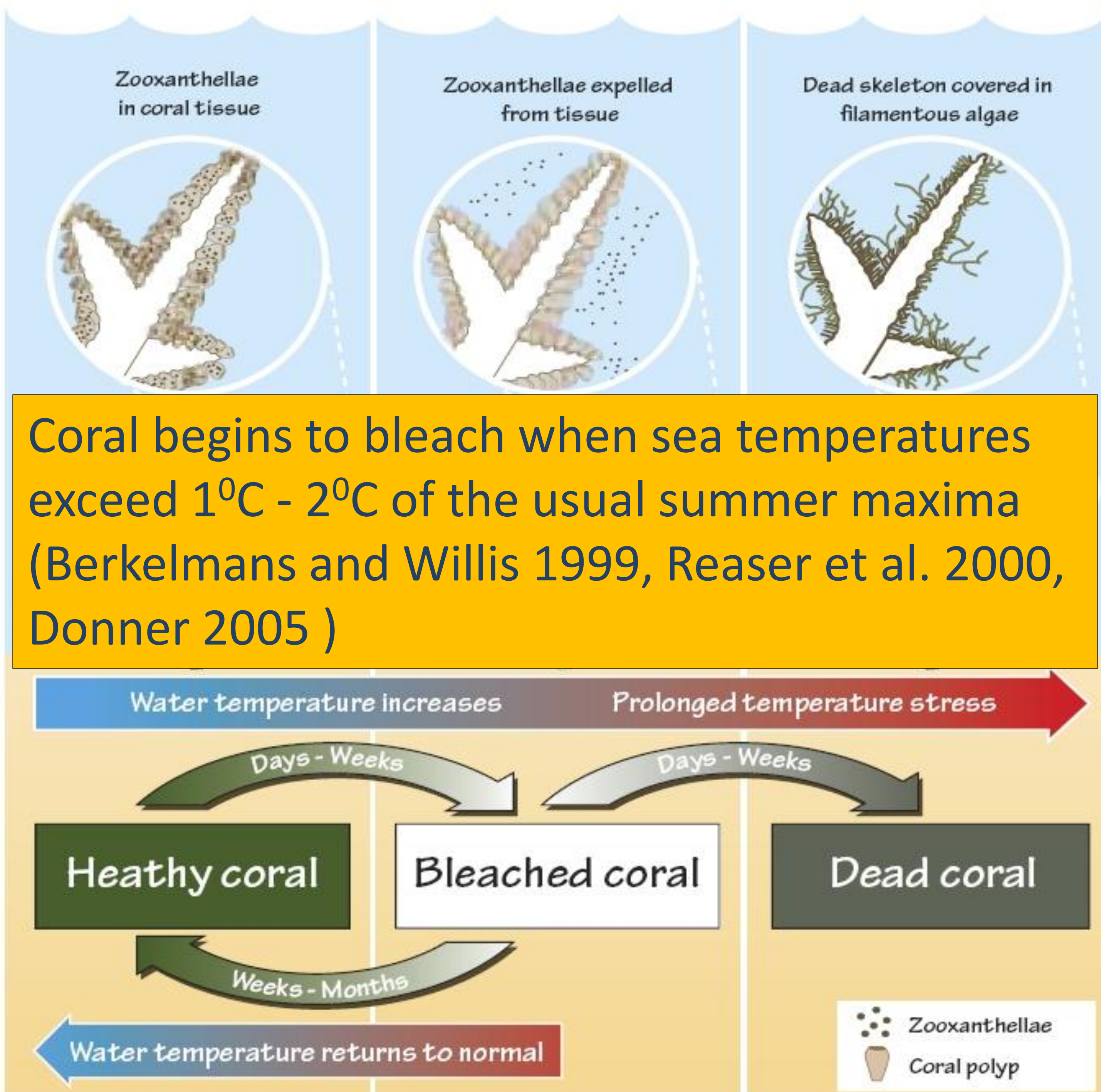
- **Human Threats**
- Coastal development
- Watershed-based pollution
- Marine-based pollution and damage
- Overfishing and destructive fishing
- **Natural Threats**
- Tropical typhoons, hurricanes and cyclones
- Plankton blooming and growth of alga organisms
- Disease and predators outbreaks
- **Increase of sea surface temperatures**

Coral begins to bleach when sea temperatures exceed 1^{0}C - 2^{0}C of the usual summer maxima (Berkelmans and Willis 1999, Reaser et al. 2000, Donner 2005)


Healthy coral

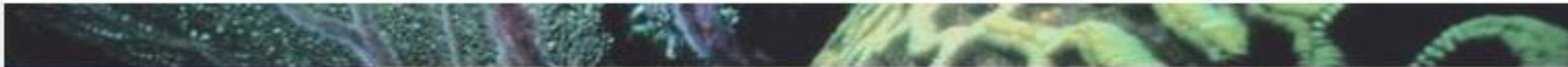

Bleached coral


Dead coral



NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

Coral Reef Watch



CRW Home

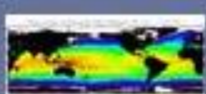
Product Overview

Near-Real-Time Data

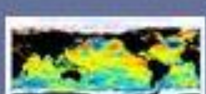
Bleaching Alert Area

Degree Heating Weeks

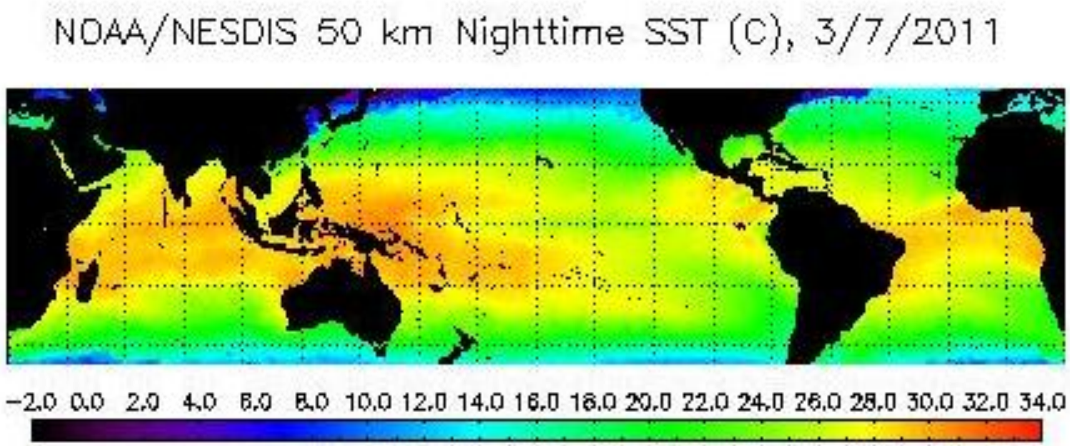
HotSpots



Sea Surface Temperature



Sea Surface Temperature



Click on the image to zoom in.

Current images: **Global** | **Eastern Hem.** | **Western Hem.** | **Pacific** | **Caribbean**

The SST product shows the nighttime ocean temperature, from the AVHRR sensor on NOAA's polar-orbiting satellites. The temperature scale goes from -2 to 34 degrees C. Spatial resolution is one-half degree.

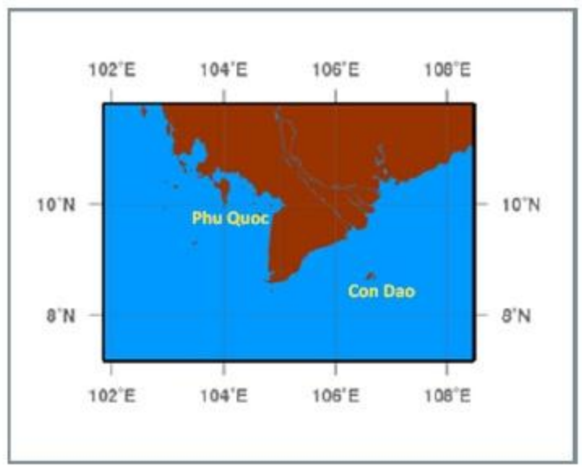
Product description in the tutorial.
Technical details on the methodology page.

Data Formats Available

Case Study: Southern East Sea, Vietnam

$7^{0}14'$ N - 11^{0} $97'$ N

$101^{0}61'$E - $108^{0}83'$ E



> 3200km shoreline

> 3000 inshore and offshore islands

400 hard coral species

Observed bleaching events:

- Con Dao: 1998, 2005
- Phu Quoc: 2010

Source: The Seattle Times and Ocean Color Website, combined by Ngan Le 2012

Datasets

AVHRR Pathfinder (PF) Version 5 SST Products (4 km)

Monthly Nighttime SST (1985-2009): 300 global images (12 months x 25 years)

8-Day Nighttime SST in 1998 and 2005: Each year include 45 global images

MODIS Aqua SST Products (4km)

8-Day Nighttime SST in 2005 and 2010: Each year include 46 global images

NOAA Coral Reef Watch Data Set (50 km)

Virtual Stations Time Series Data: Twice-weekly nighttime SST data at specific reefs, from 2001 to 2010

Bleaching monitoring products: HotSpot, DHW and Bleaching Alert maps in 1998, 2005, 2010

Observation Sites and Mainland Boundary

Data Processing

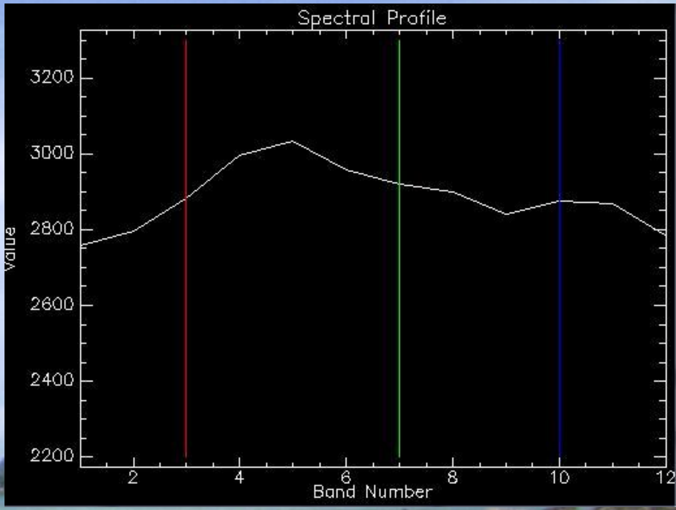
Calculate the usual sea temperature (Climatology SST)

Average of 25 years monthly SST for each month

Calculate the Maximum Monthly Mean (MMM) SST

Identify the warmest month in Climatology SST graph

Bleaching Threshold = MMM + 1^0C



Calculate HotSpot (HS) value

HotSpot = Weekly SST - MMM

HS = 0 : No Thermal Stress

0 < HS < 1: Temp. above maximum summer value

HS ≥ 1 : Thermal Stress

Calculate Degree Heating Week (DHW)

DHW: **accumulation of HS values > 1^0C in 12 weeks or more**

DHW = 0 : No Thermal Stress

DHW ≥ 4: Thermal Stress leading to significant bleaching

DHW ≥ 8: Thermal Stress leading to wide spread bleaching and significant mortality

Predicting Level of Bleaching

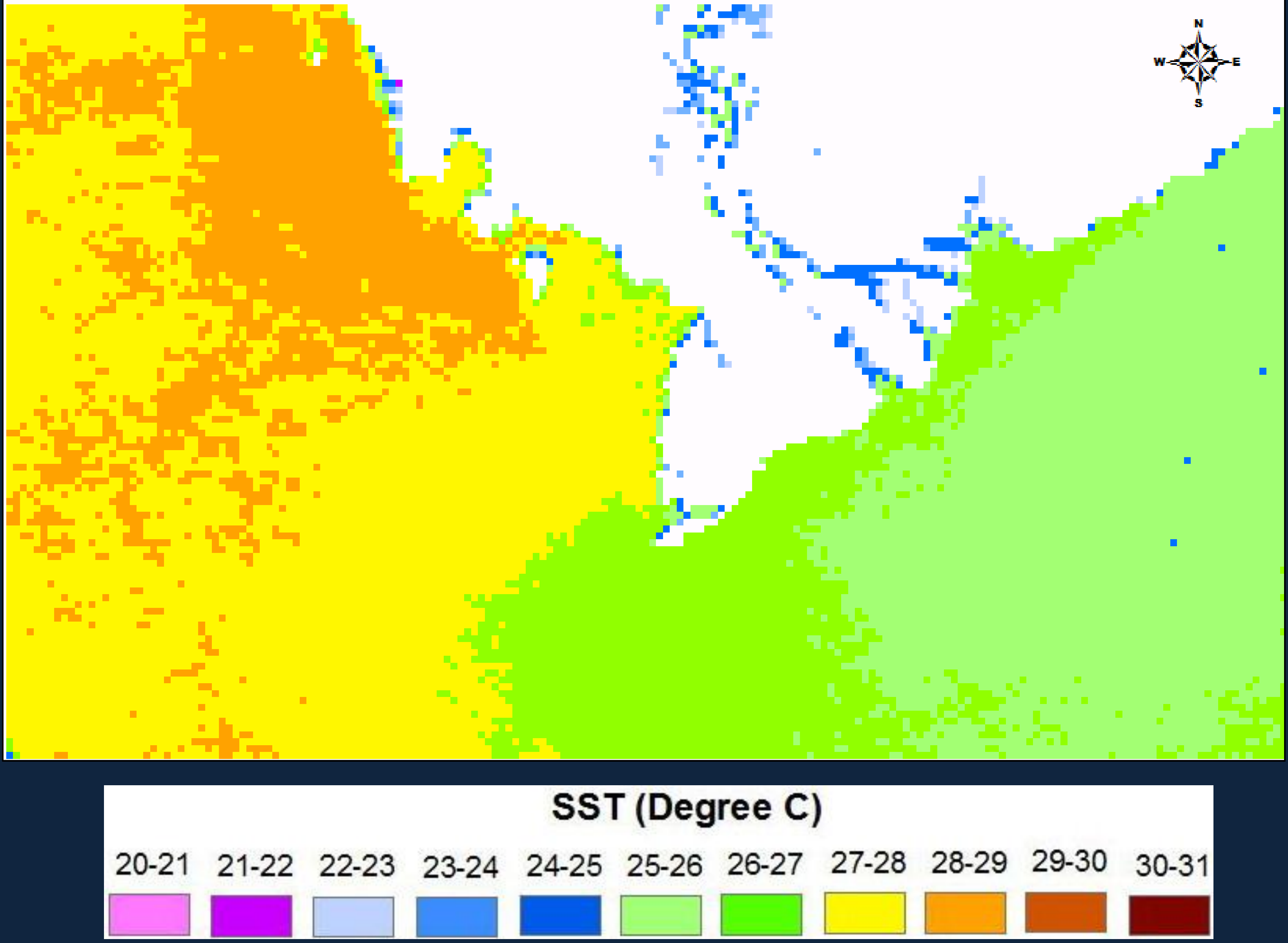
Stress Level	Definition	Description
No Stress	HotSpot ≤ 0	Corals are not currently experiencing any thermal stress
Bleaching Watch	$0 <$ HotSpot < 1	Temperatures are above normal summer maximum, but corals are not yet stressed
Bleaching Warning	$1 \leq$ HotSpot and $0 <$ DHW < 4	Corals are experiencing a low-level buildup of thermal stress
Bleaching Alert Level 1	$1 \leq$ HotSpot and $4 \leq$ DHW < 8	Corals are currently stressed, accumulating to a level where bleaching is expected
Bleaching Alert Level 2	$1 \leq$ HotSpot and DHW ≥ 8	Corals are currently stressed, accumulating to a level where widespread bleaching and some coral mortality is expected

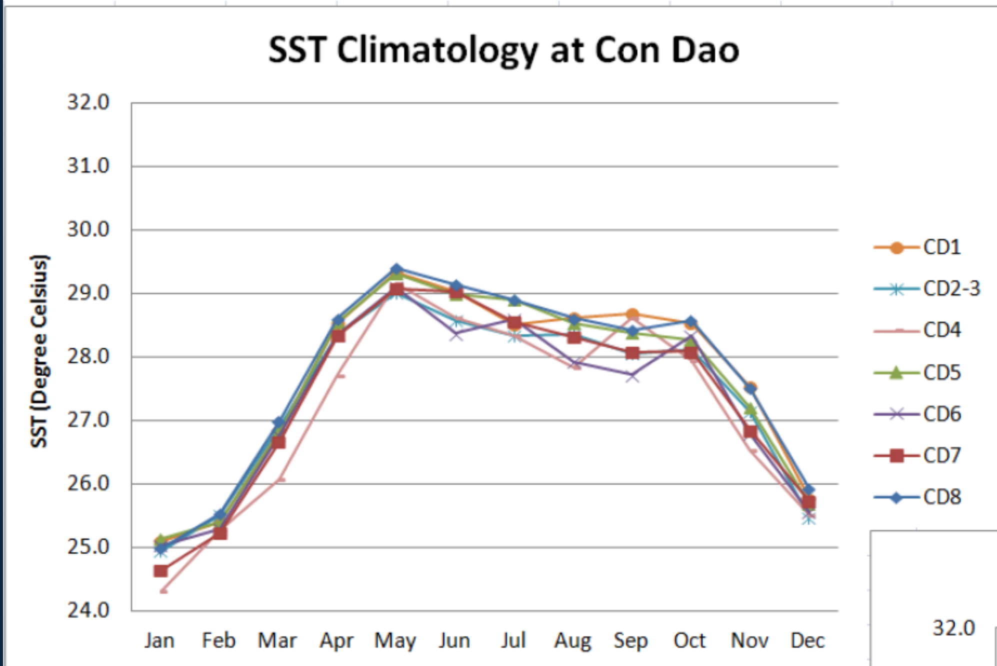
Source: CRW 2011

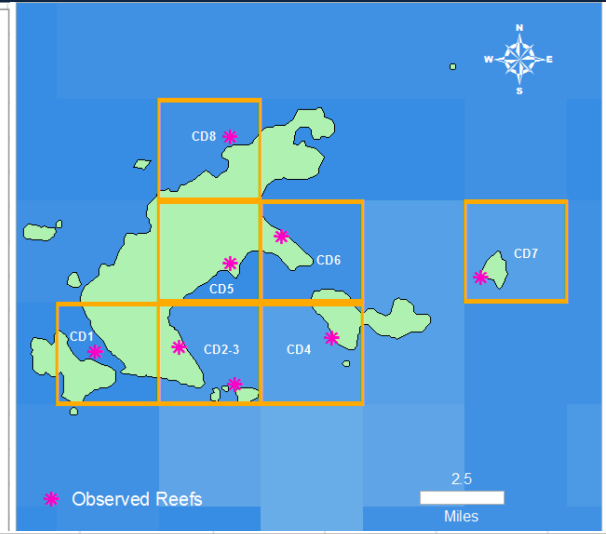
Results and Discussions

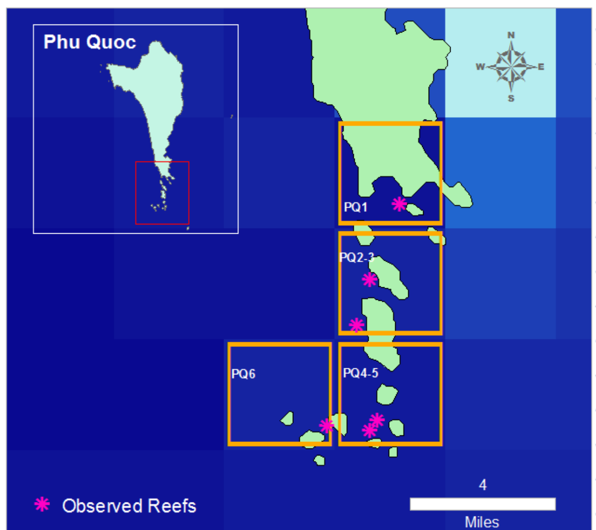
1. Comparison of SST in Southwestern and Southeastern areas
2. Thermal Stress in Bleaching Years 1998, 2005, 2010
3. Comparison of the 50 km and 4 km Bleaching Prediction Products

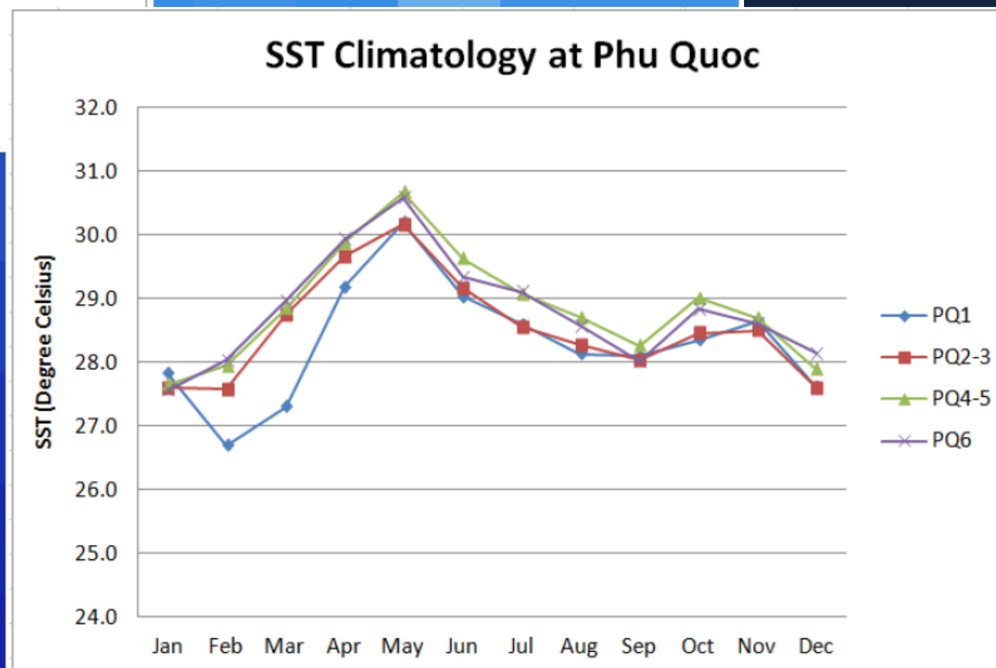
Sea Surface Temperature Climatology
December







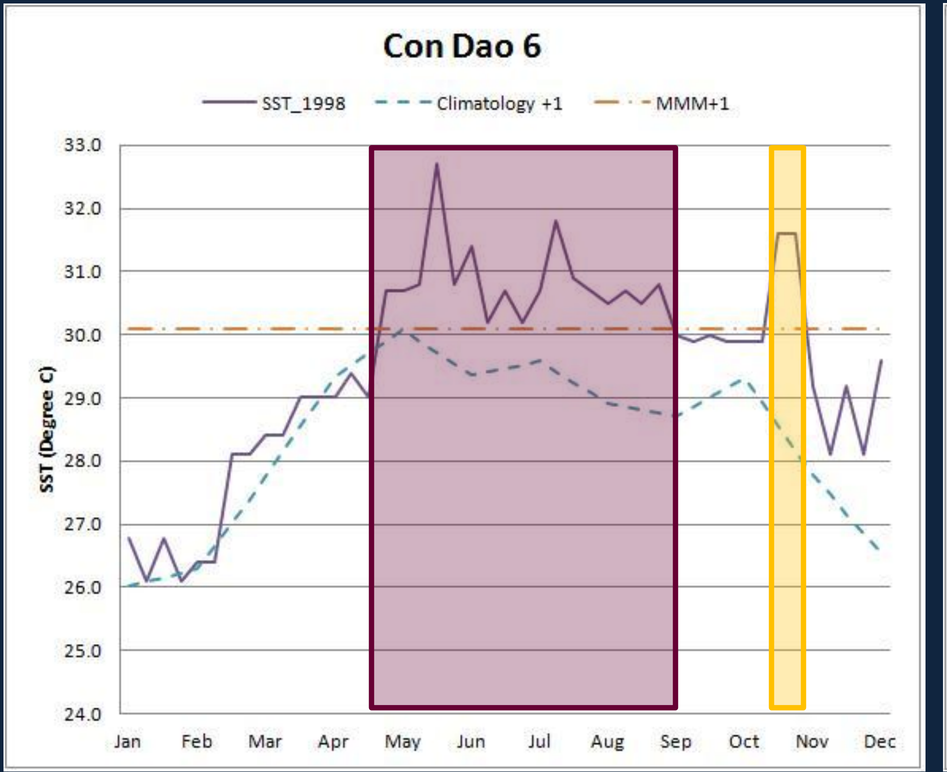


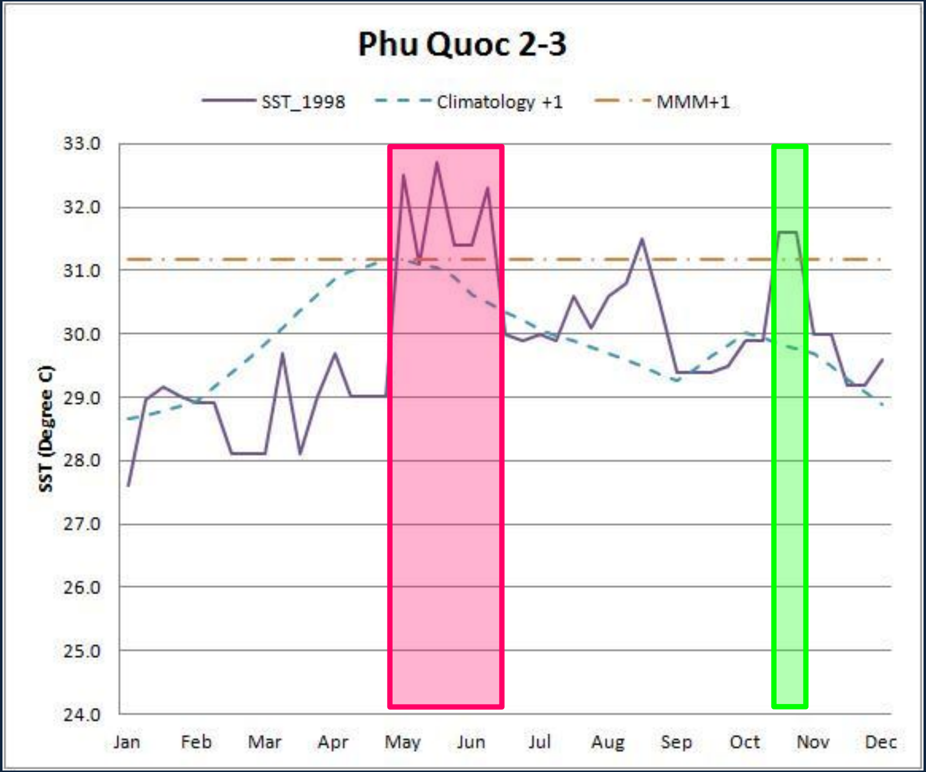


Average of Maximum Monthly Mean SST at Con Dao : 29.19^{0}C

Phu Quoc: 30.4^{0}C

Thermal Stress in 1998

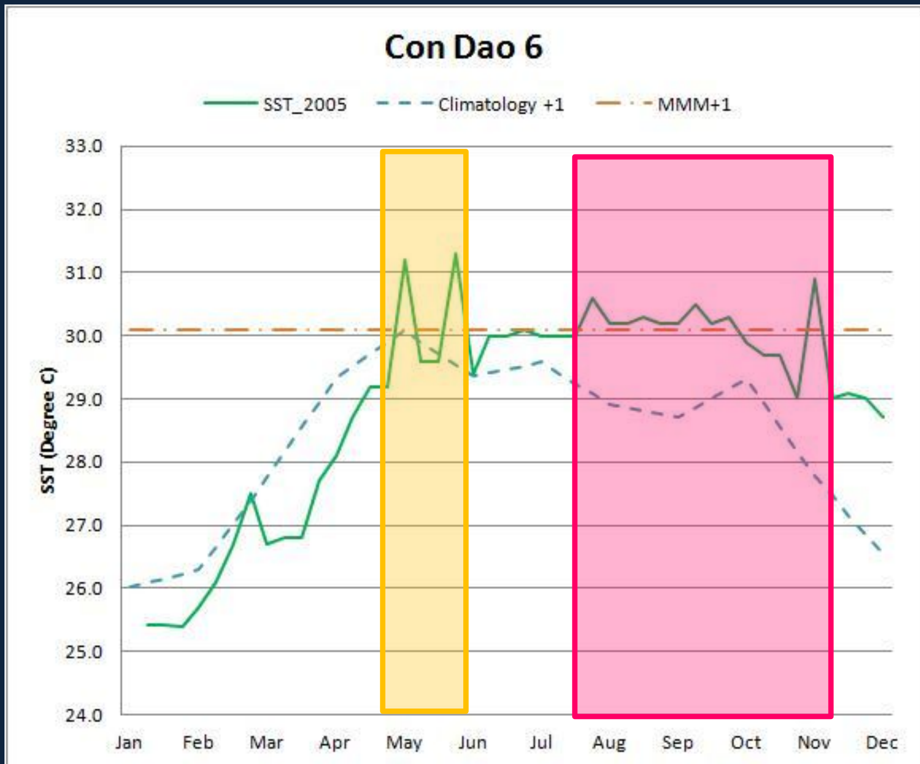


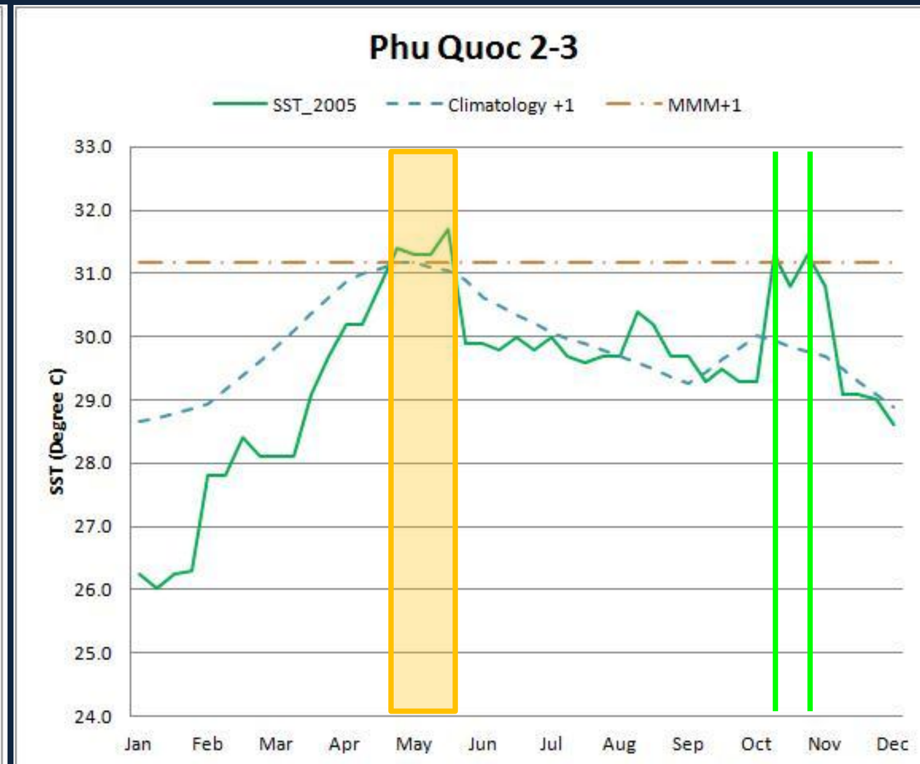


Site	Duration of Thermal Stress	DHW
CD6	Mid April to the End of August (18weeks)	35.78
	Last 2 weeks of October (2 weeks)	5.02
PQ2-3	April to Mid-July (12 weeks)	9.53
	Last 2 weeks of October (2 weeks)	2.82

- DHW > 12
- 8 < DHW < 12
- 4 < DHW < 8
- 1 < DHW < 4

Thermal Stress in 2005

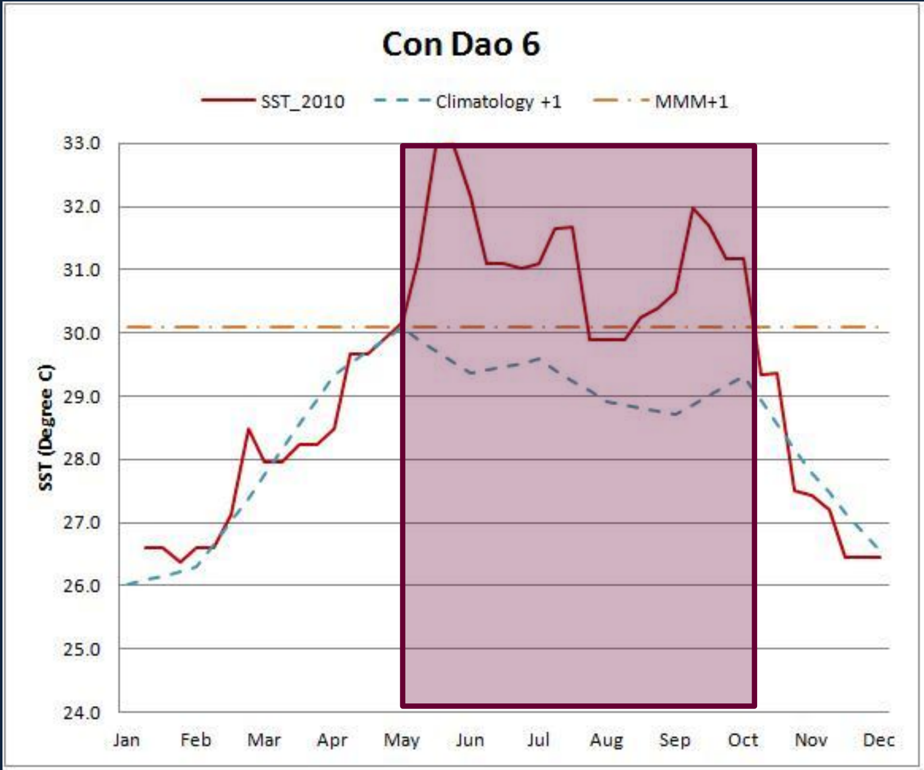


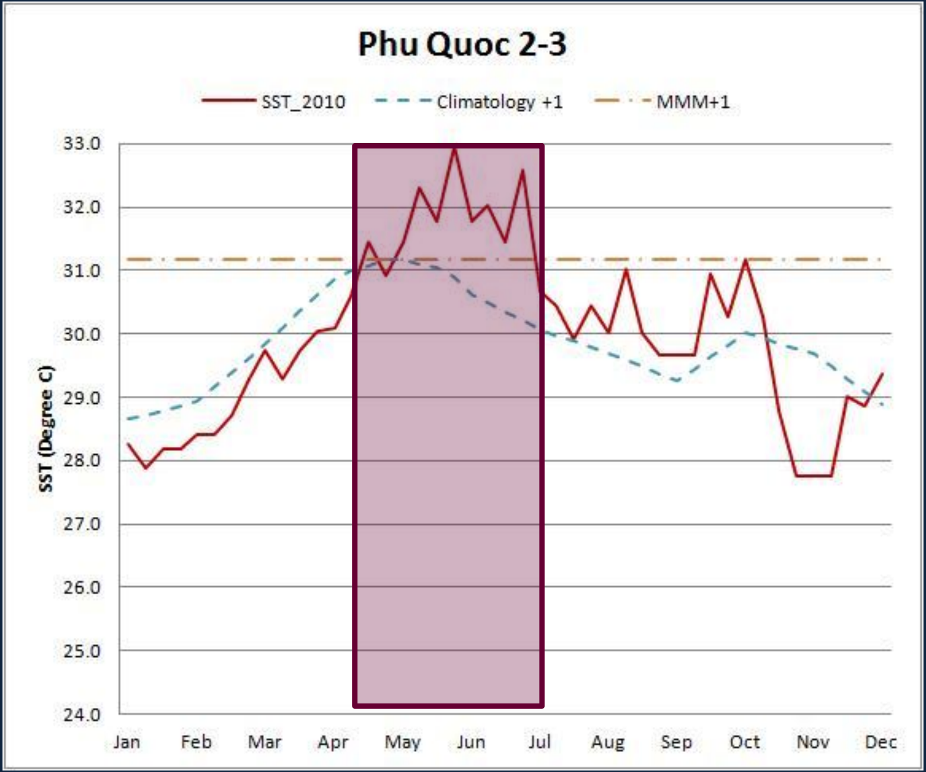


Site	Duration of Thermal Stress	DHW
CD6	May to July (12 weeks)	4.8
	August to October (12 weeks)	8.2
PQ2-3	May (4 weeks)	4.97
	October (2 weeks)	2.22

DHW > 12
8 < DHW < 12
4 < DHW < 8
1 < DHW < 4

Thermal Stress in 2010

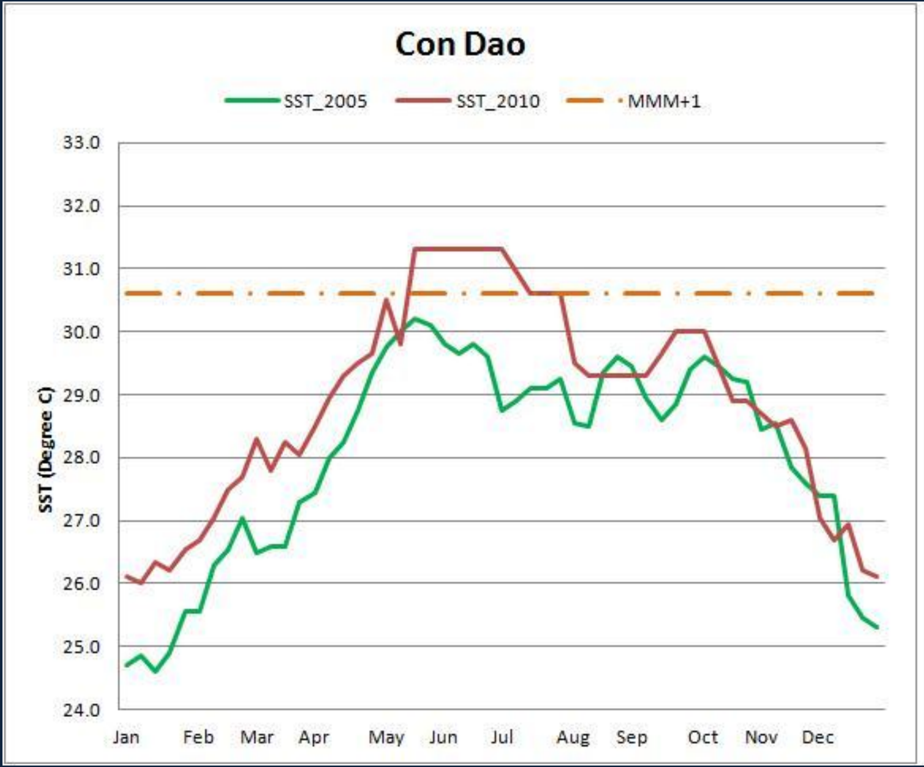


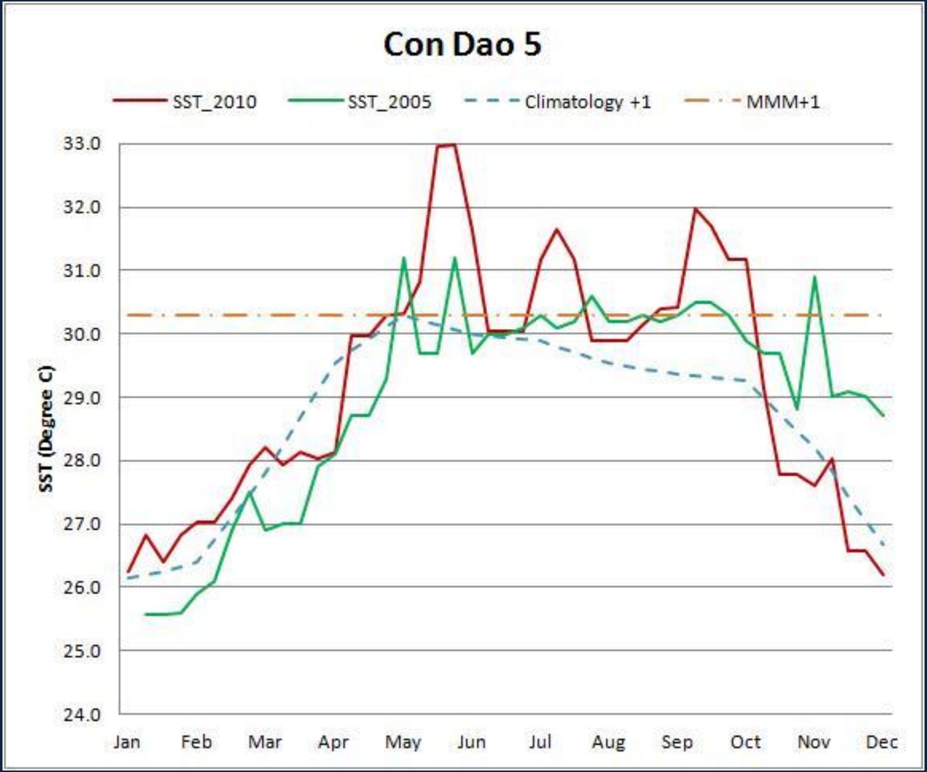


Site	Duration of Thermal Stress	DHW
CD6	Apr to Jul (12 weeks)	22.35
	Apr to Oct (24 weeks)	34.39
PQ2-3	Feb to Jul (19 weeks)	16.31
	Apr to Jul (12 weeks)	16.31

- DHW > 12
- 8 < DHW < 12
- 4 < DHW < 8
- 1 < DHW < 4

Comparison of the 50 km and 4 km Bleaching Prediction Products

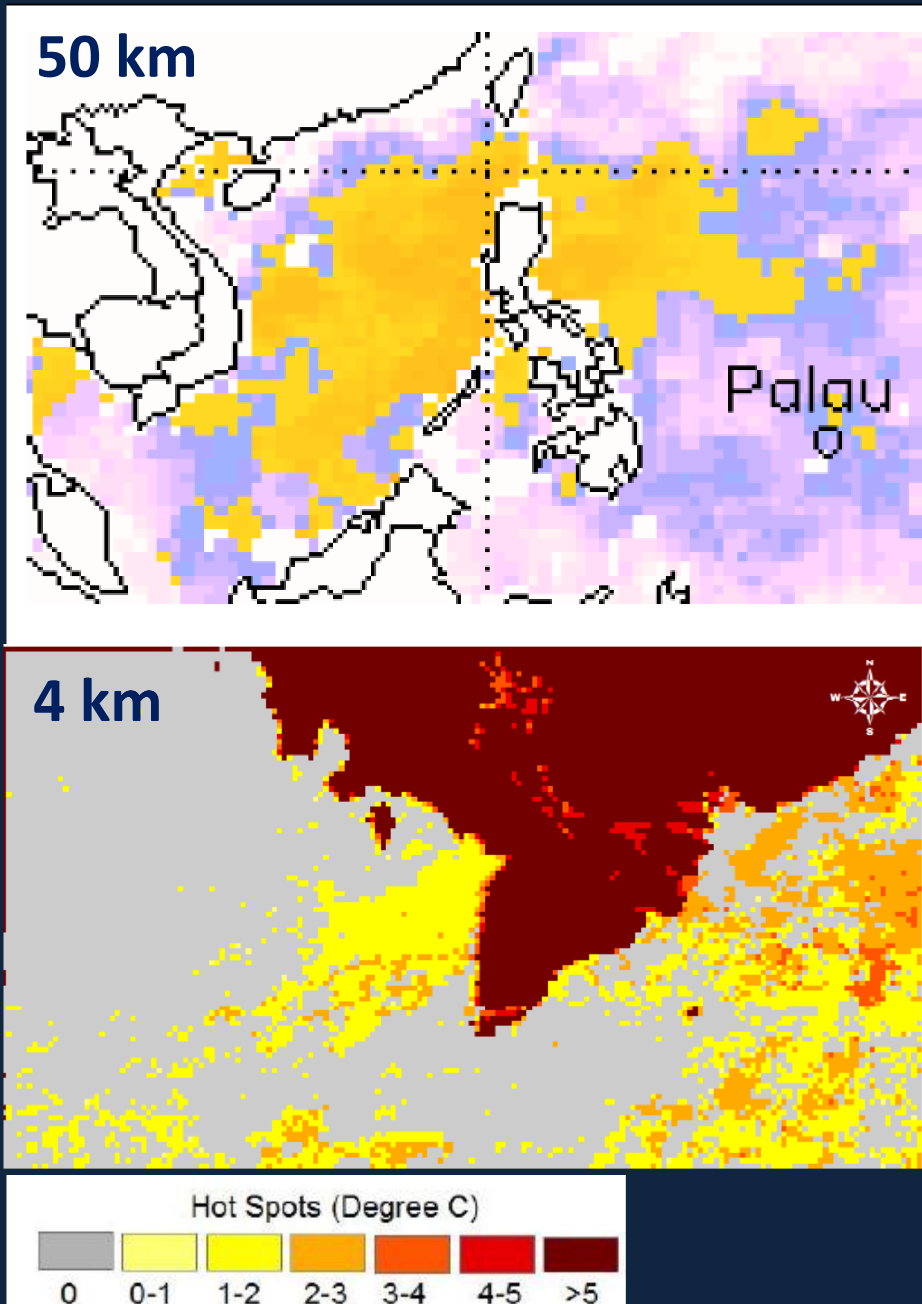




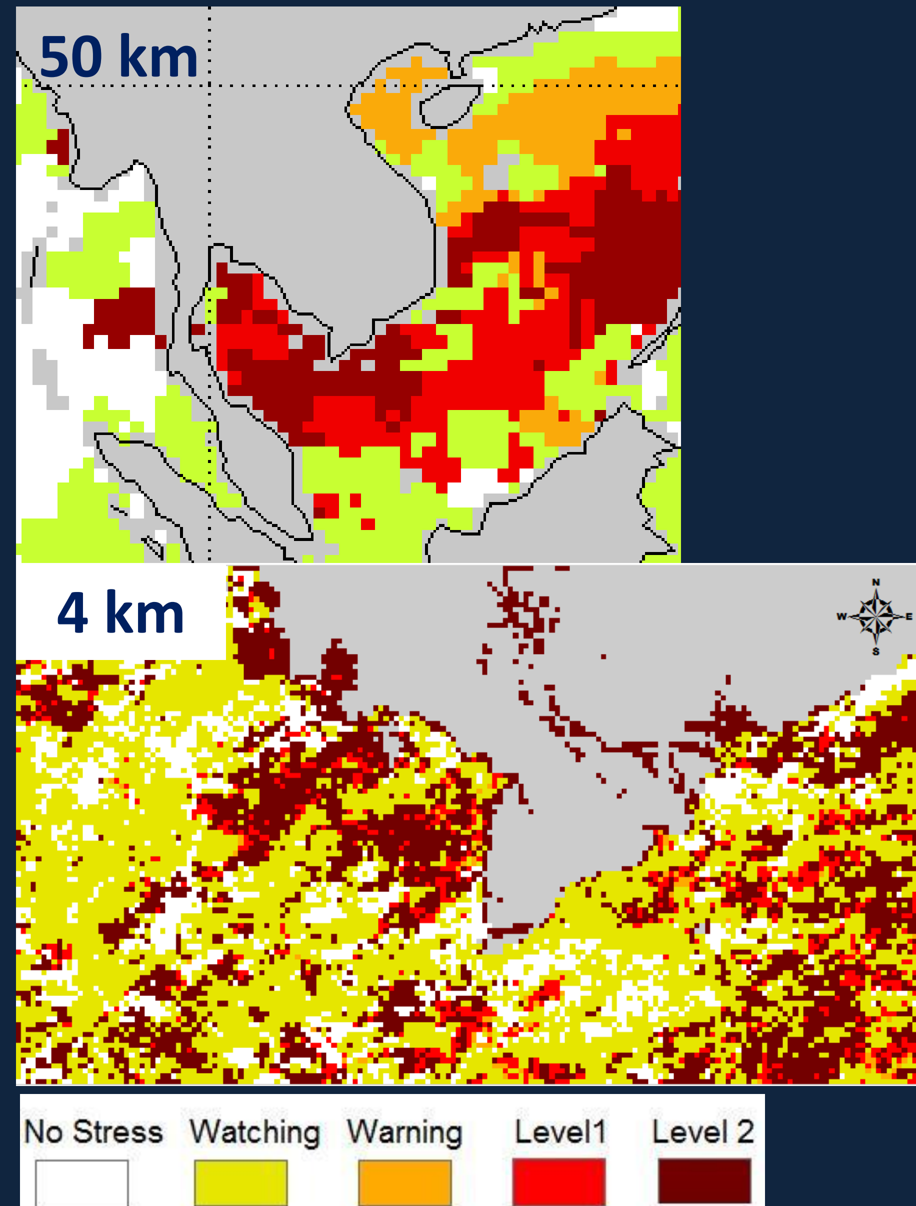
50 km

4 km

HotSpot, July 12th 2010



Bleaching Alert, July 4th 2010



Conclusions

Major Findings

(1) SST climatology data revealed that SST in the southwest sea is approximately 1^{0}C higher than SST in the southeast sea;

(2) Coral reefs at the study area suffered a severe thermal stress in 2010 with longer duration and higher DHW value than in 1998 and 2005;

(3) The application of 4 km spatial resolution data prevented underestimating thermal anomaly than with the 50 km resolution data.

Conclusions

Limitations

(1) The satellite-derived SST data were **not validated with ground–measured sea temperature**;

(2) This research **could not give a sufficient explanation** why thermal difference between the southwestern and southeastern areas;

(3) Only **SST in discrete years coinciding with bleaching events** was analyzed in this study whereas thermal stress may also occur in non-bleaching years;

(4) Using **a constant bleaching threshold**, 1^0C above MMM while thermal thresholds may vary geographically, reflecting adaptation by corals and their symbiotic algae to the microenvironment;

(5) The **thermal resilience of individual coral species** as well as their zooxanthellae was not included in this study.

Conclusions

Future Envisions

(1) **Validating SST data** with historical sea temperature measured at the meteorological stations at Phu Quoc and Con Dao;

(2) **Expanding the study area** to include other areas in the Gulf of Thailand and East Sea;

(3) Conducting **SST analyses in non-bleaching years**, at least from 1994 when coral data are available;

(4) Conducting studies about the relationship of percent bleaching and all environmental elements at Phu Quoc and Con Dao to **identify the key stressors**;

(5) **Collecting adequate coral reef observation data**, including reef cover, percent bleaching, number of coral species and their symbiotic algae to conduct broader research about the thermal resilient ability.

Thank you for your attentions!

ACKNOWLEDGEMENTS:
Many thanks to Dr. Cuizhen Wang, Associate Professor at the Department of Geography, University of Missouri-Columbia, for her supervising and supporting during my two years conducting this research.