

# The use of Coral Physiology to combine Satellite SST and Insolation to track Daily Coral Health

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# Light/temp product development team

## Funding:

**NOAA**

- *Coral Reef Conservation Program (CRCP)*
- *Center for Satellite Applications and Research (STAR)*

**2x Australian Research Council Linkage Grants**

**Future of Reefs in a Changing Environment (FORCE)**

**World Bank Coral Reef Targeted Research (CRTR)**

## Team includes:

**NOAA CRW/STAR**

**Universidad Autonoma Nacional de Mexico**

**University of Exeter – UK**

**University of Queensland – Australia**

**Australian Institute of Marine Science**



# Overview

- **Basic coral physiology**
- **LSD algorithm development**
- **Testing the algorithm**
- **Algorithm and product development**
  - ARC Linkage Grant



# Goal of Project

## Current satellite-based bleaching algorithms

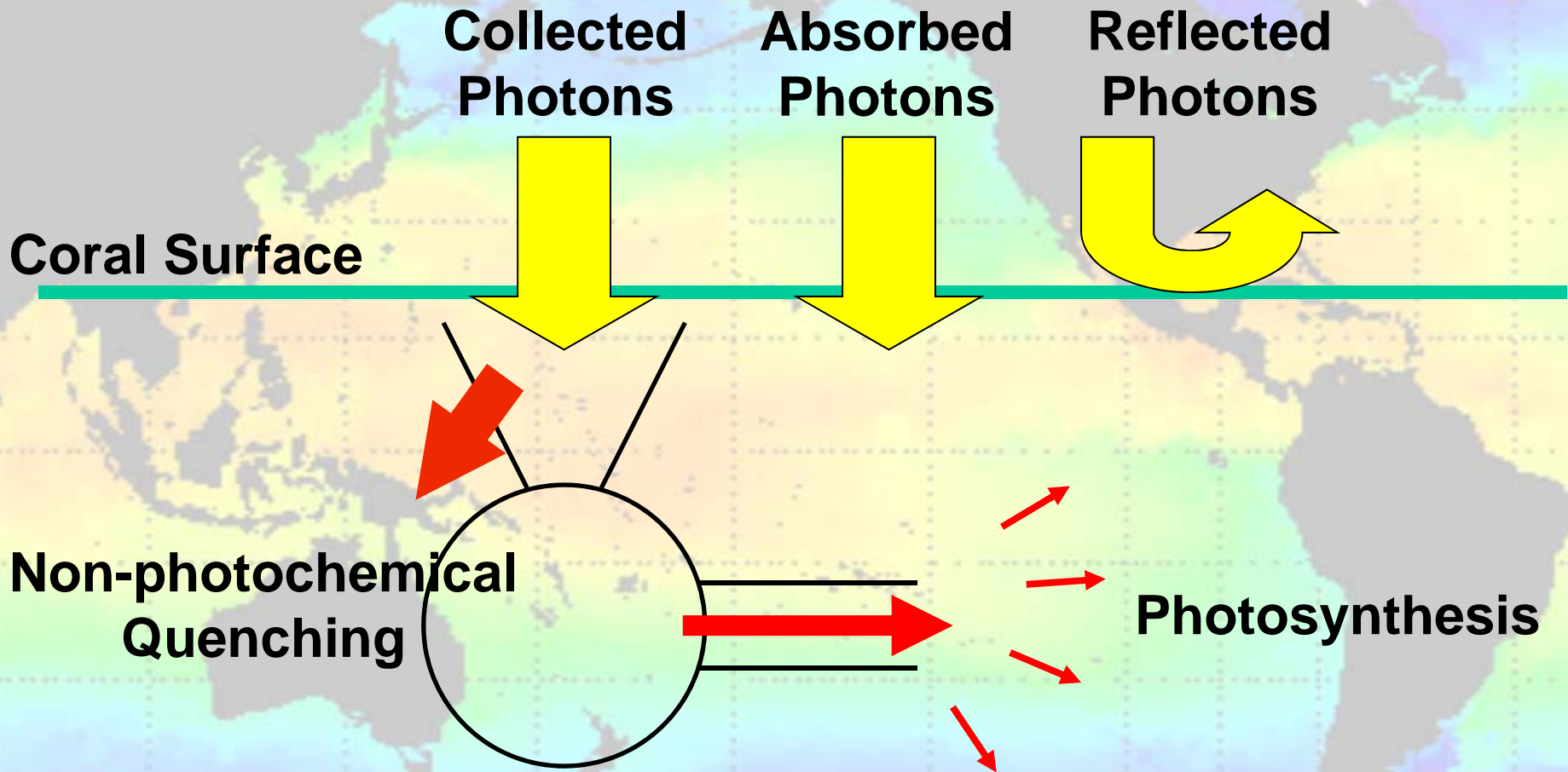
- Based on SST only
- Not physiology based
  - ONSET – yes
  - RECOVERY – no
  - SEVERITY – yes
  - MORTALITY – somewhat
- Only tracks coral health during a bleaching event

## Goal of new satellite-based bleaching algorithm

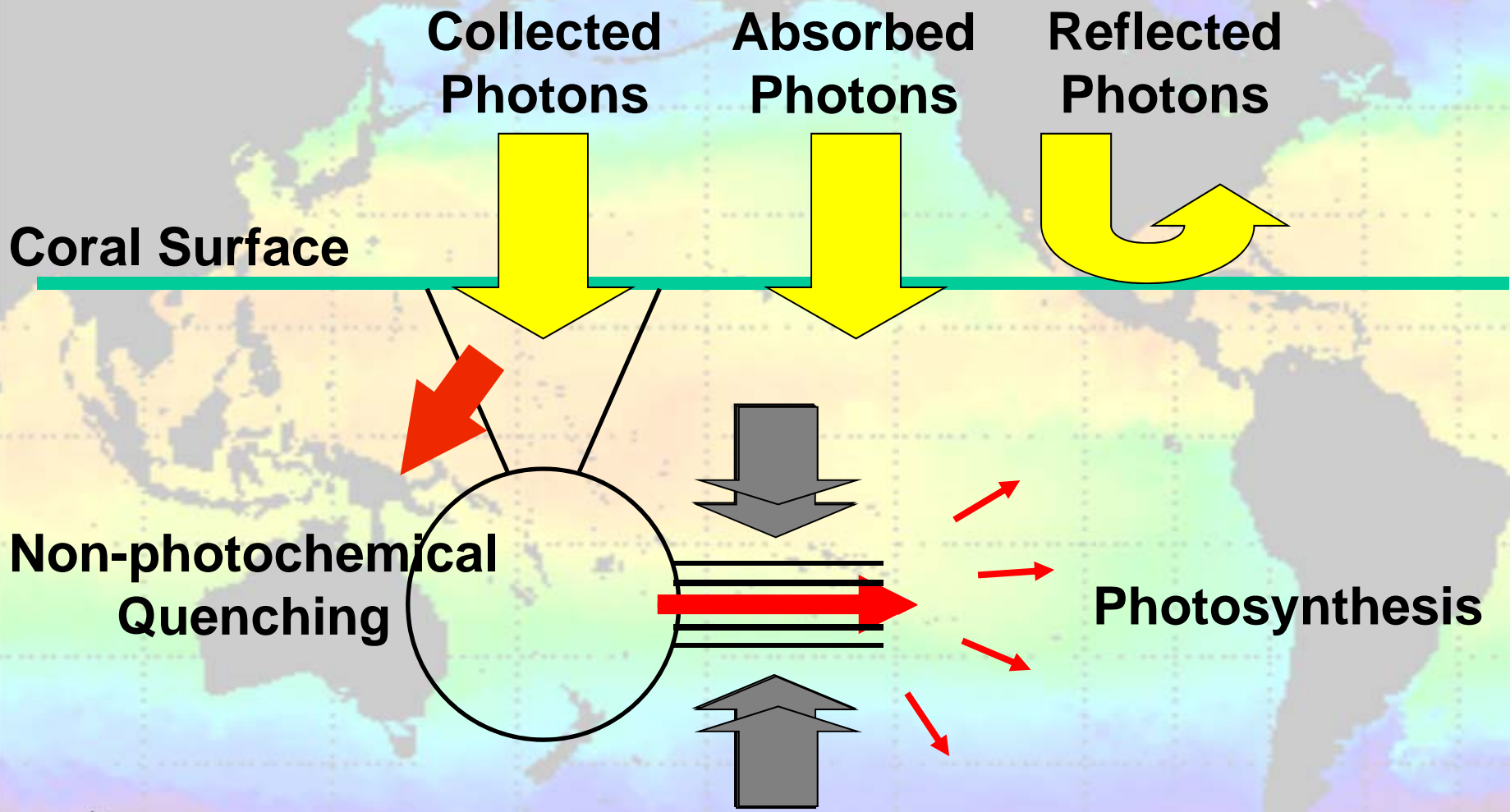
- Based on light and SST
- Physiology based
  - ONSET – yes, improved accuracy
  - RECOVERY – yes
  - SEVERITY – yes, improved accuracy
  - MORTALITY – yes
- Tracks coral health continuously on a daily basis



# Simplified Photosynthetic System



# Effect of extreme temperatures



# The Algorithm

## Definitions:

$EEE$  = Excessive Excitation Energy

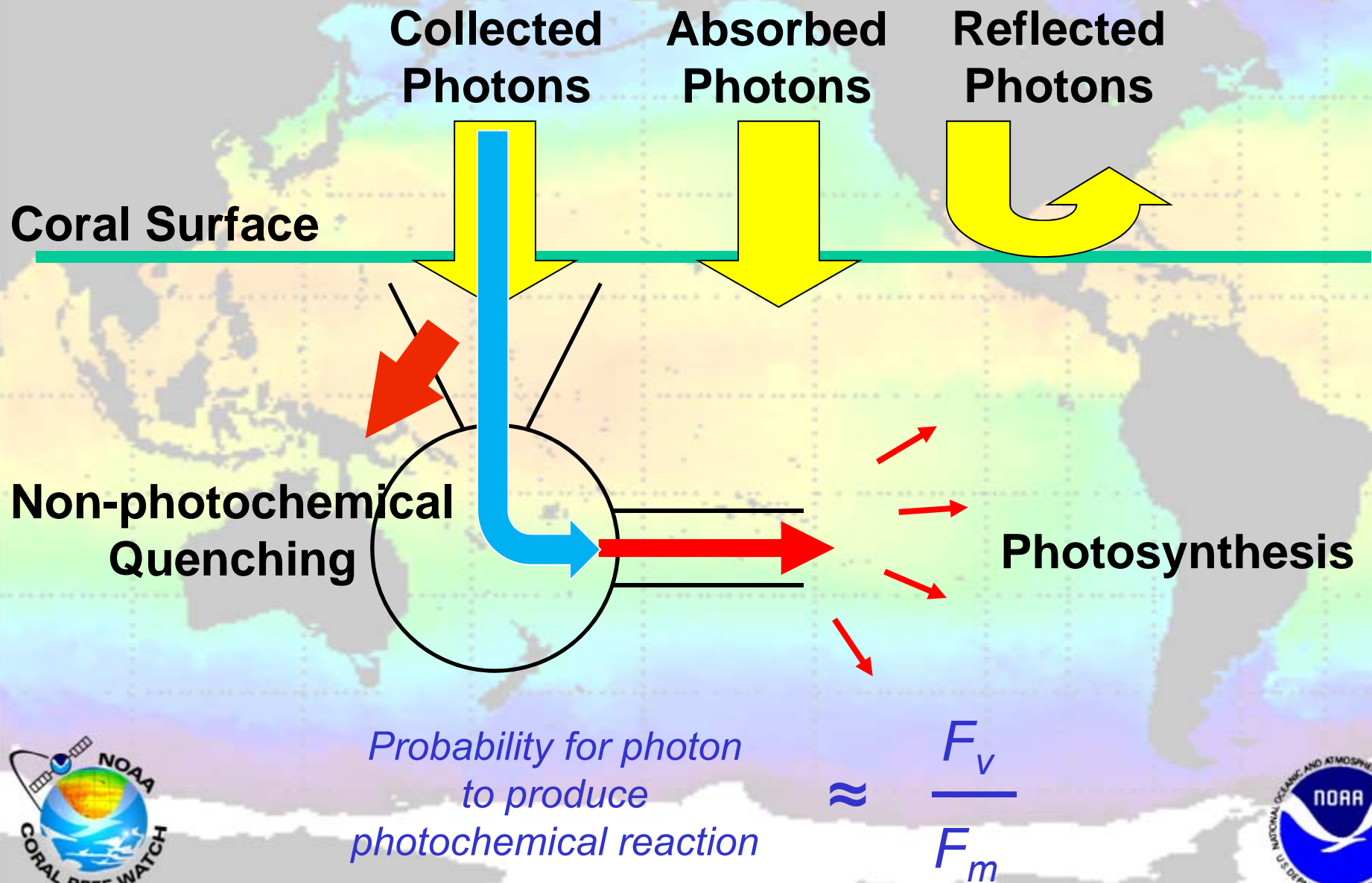
=  $PAR_{\text{today}} - PAR_{\text{yesterday}}$ , *accounting for acclimation*

$\frac{F_v}{F_m}$  = a measure of photosystem efficiency  
(fluorescence change / max fluorescence)

$\Delta \text{rel} \frac{F_v}{F_m}$  = change in relative photosystem efficiency



# Simplified Photosynthetic System





# The Algorithm

## Experiments

$$\Delta_{\text{rel}} \frac{F_v}{F_m} = f(EEE)$$

$$\Delta_{\text{rel}} \frac{F_v}{F_m} = f(\text{temp})$$

## Algorithm

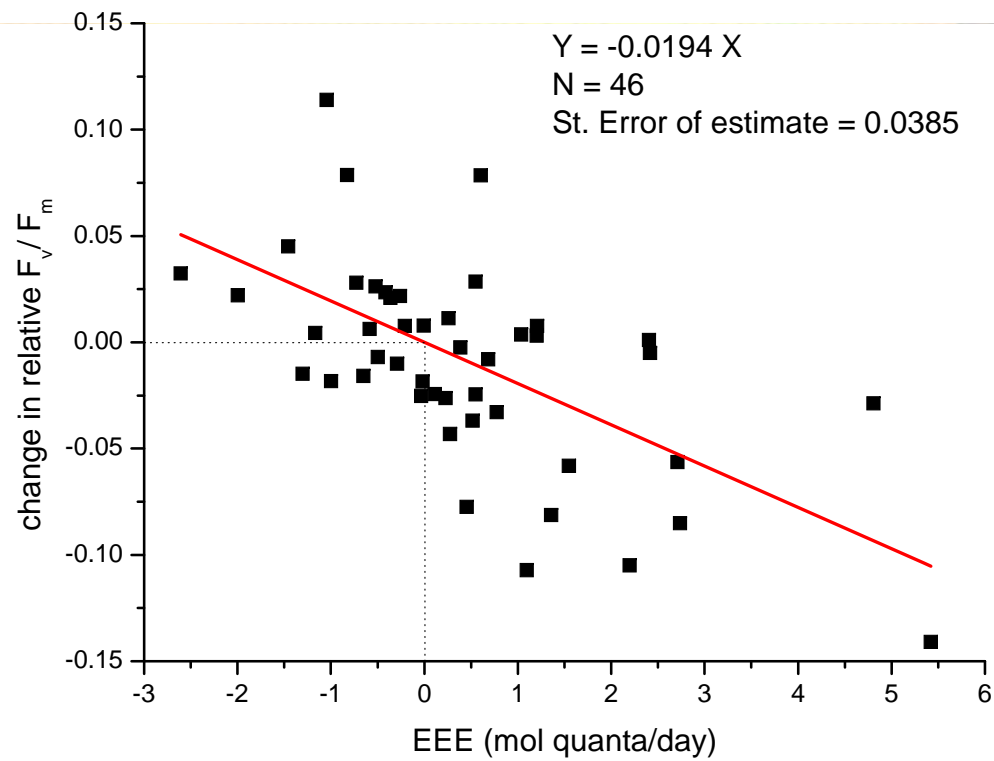
$$\Delta_{\text{rel}} \frac{F_v}{F_m} = f(EEE, \text{temp})$$

$$\sum \left( \Delta_{\text{rel}} \frac{F_v}{F_m} \right) = \text{LSD index}$$



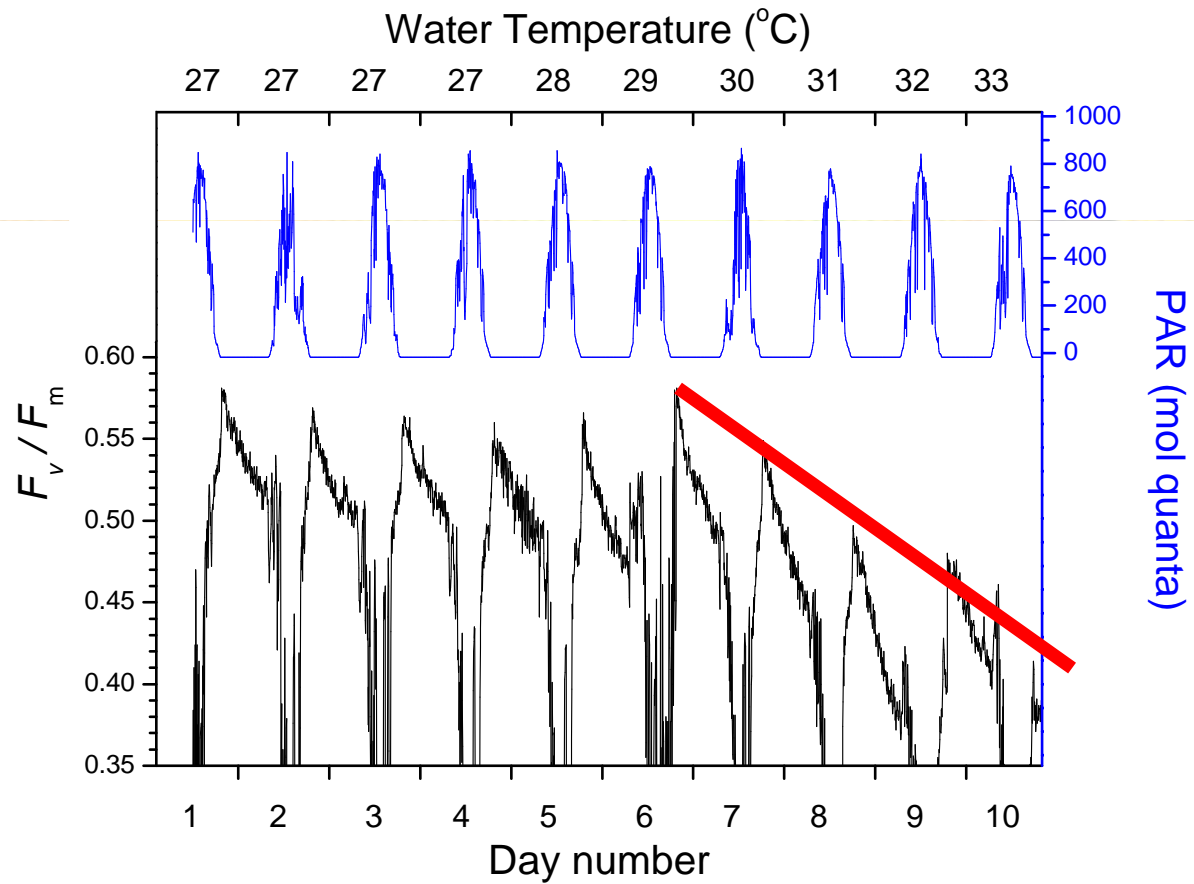
# The Algorithm

$$\Delta_{\text{rel}} \frac{F_v}{F_m} = f(EEE)$$



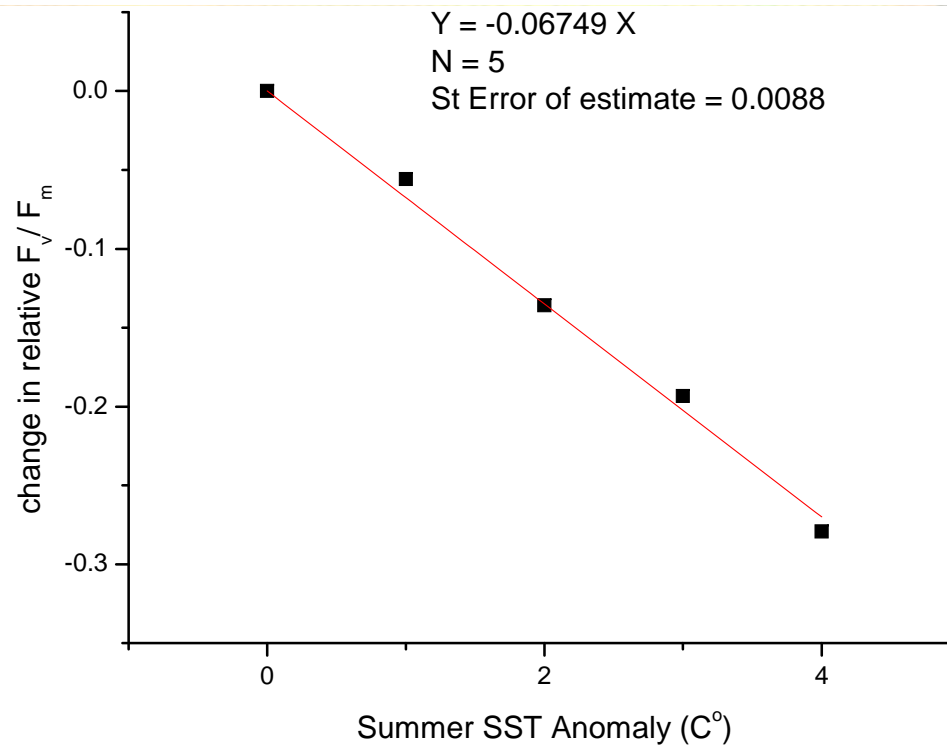
# The Algorithm

## Temperature Experiment



# The Algorithm

$$\Delta \text{rel} \frac{F_v}{F_m} = f(\text{temp})$$

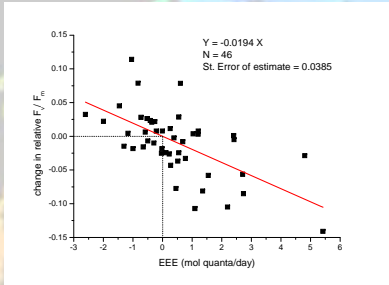


# The Algorithm

Experiments

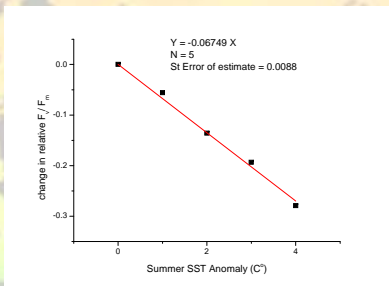
Algorithm

$\Delta_{rel}$



$(EEE)$

$\Delta_{rel}$



$(temp)$

$$\Delta_{rel} \frac{F_v}{F_m} = f(EEE, temp)$$

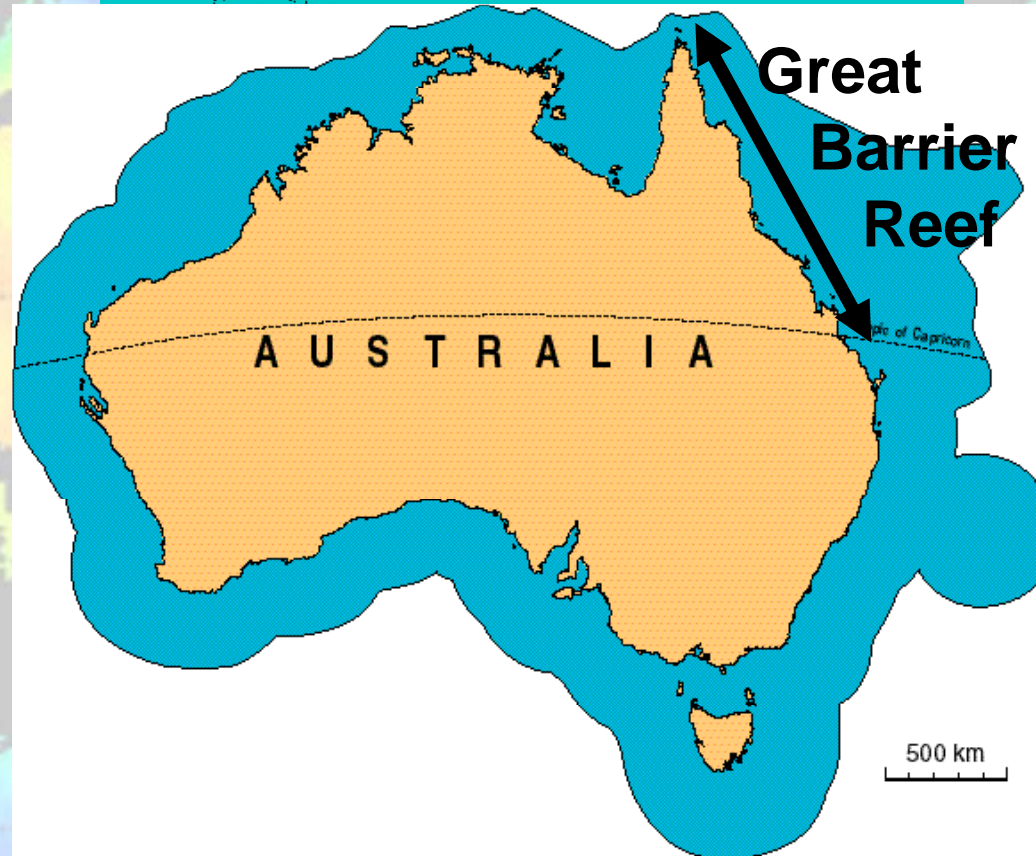
$$\sum \left( \Delta_{rel} \frac{F_v}{F_m} \right) = LSD \text{ index}$$



# Testing the Algorithm



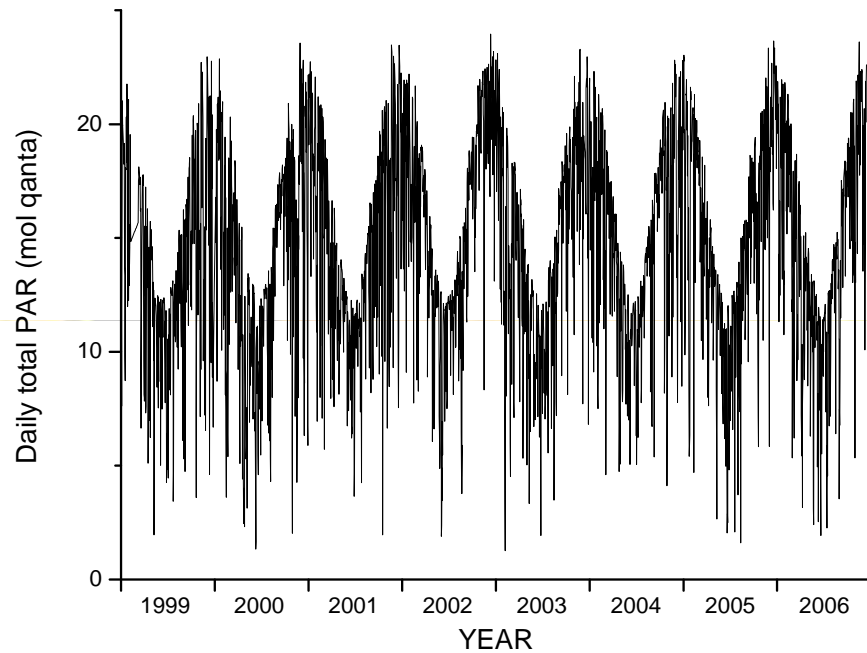
# The Great Barrier Reef



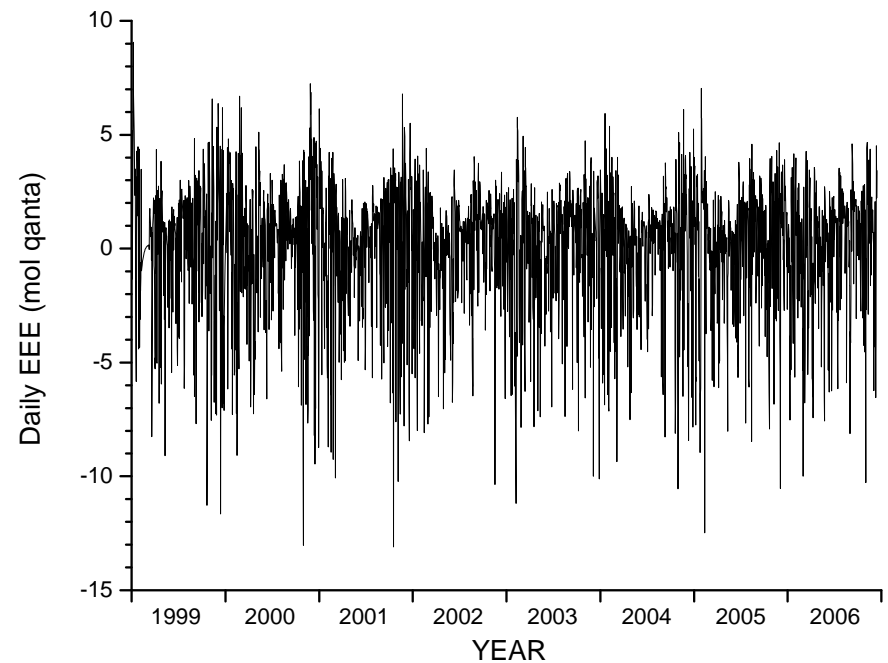
Rockhampton • Keppel Islands



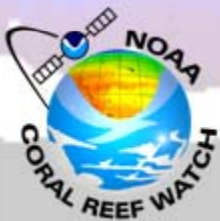
# Testing the Algorithm



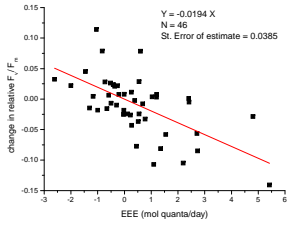
***PAR*** → ***EEE***



Data from Rockhampton  
Bureau of Meteorology  
Solar Radiation Station



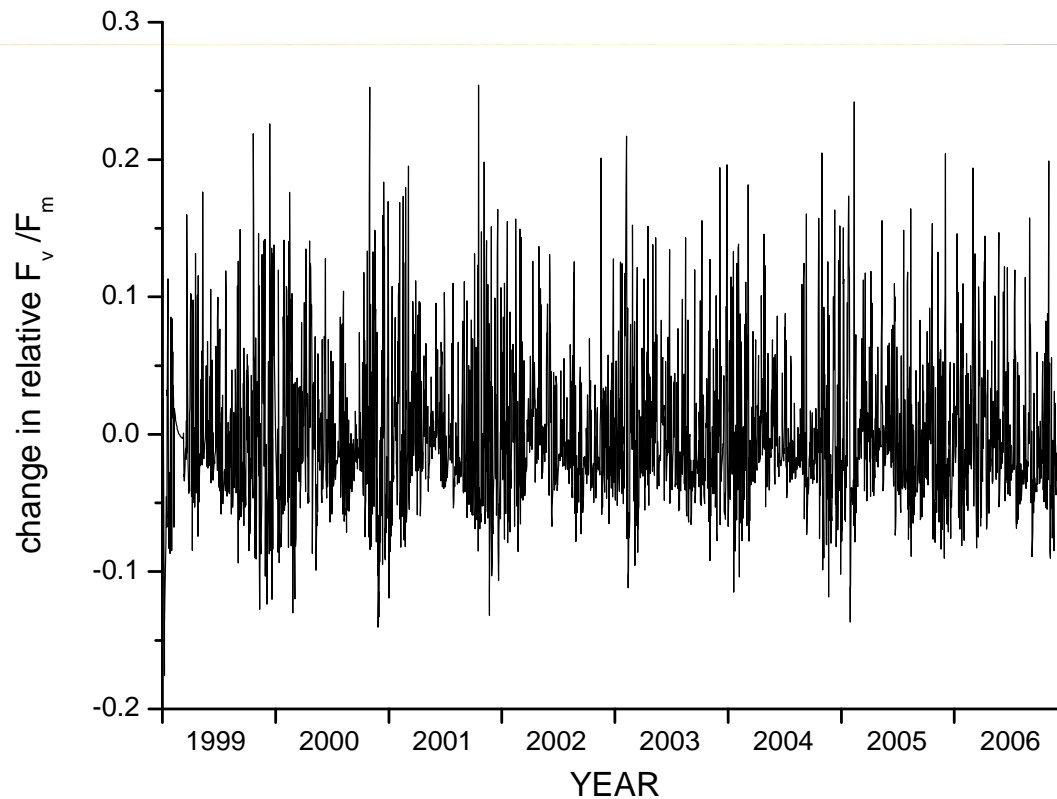


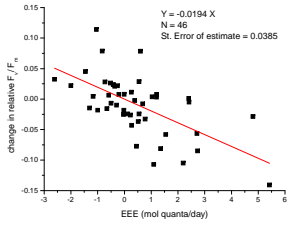


# Testing the Algorithm

$$\Delta \text{rel} \frac{F_v}{F_m} = f(EEE)$$

## Seasonal fluctuation in PSII efficiency

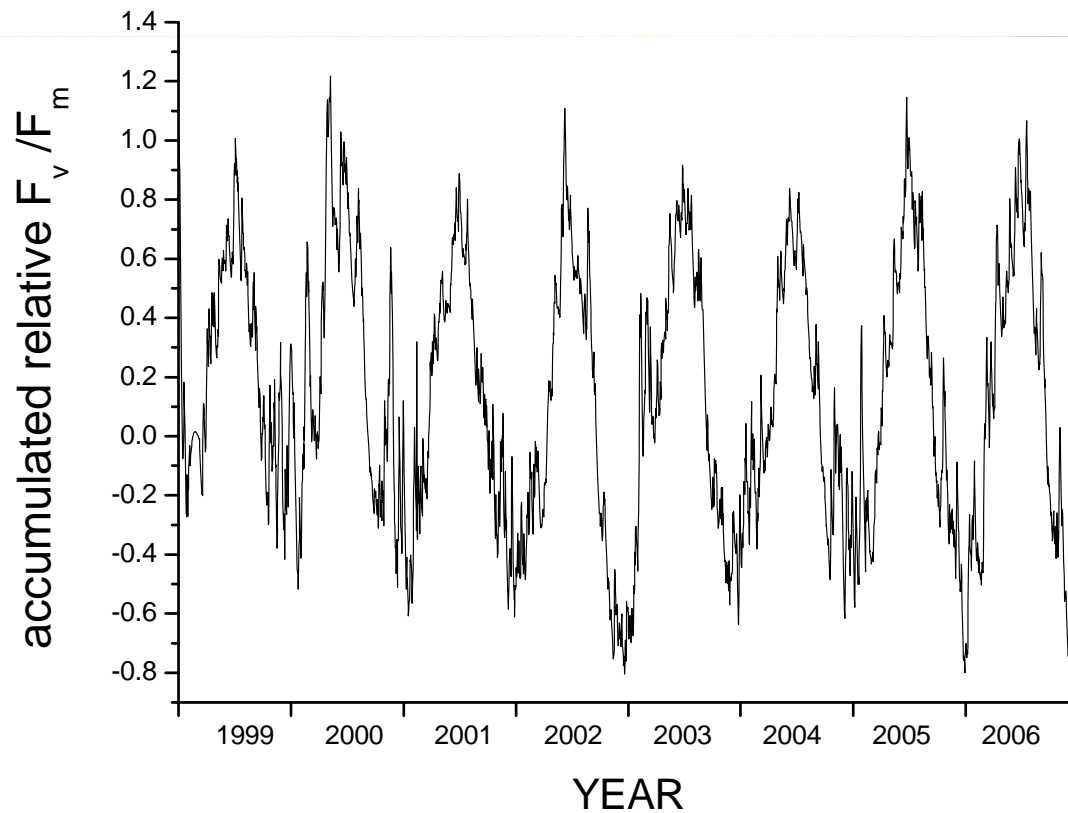


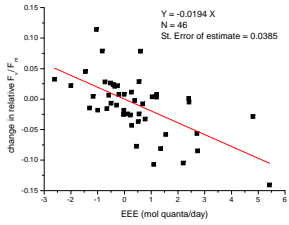


# Testing the Algorithm

$$\Delta \text{rel} \frac{F_v}{F_m} = f(EEE)$$

Seasonal fluctuation in PSII efficiency



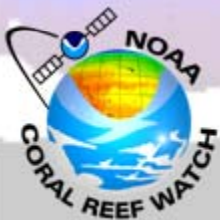
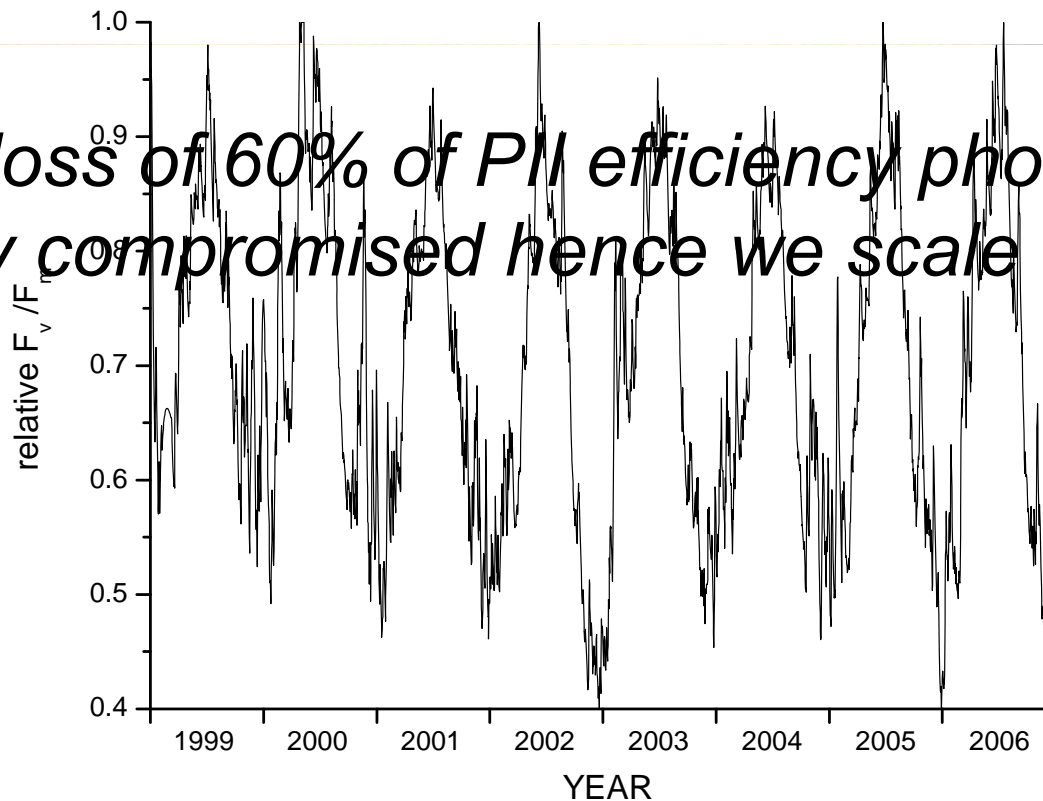


# Testing the Algorithm

$$\Delta \text{rel} \frac{F_v}{F_m} = f(EEE)$$

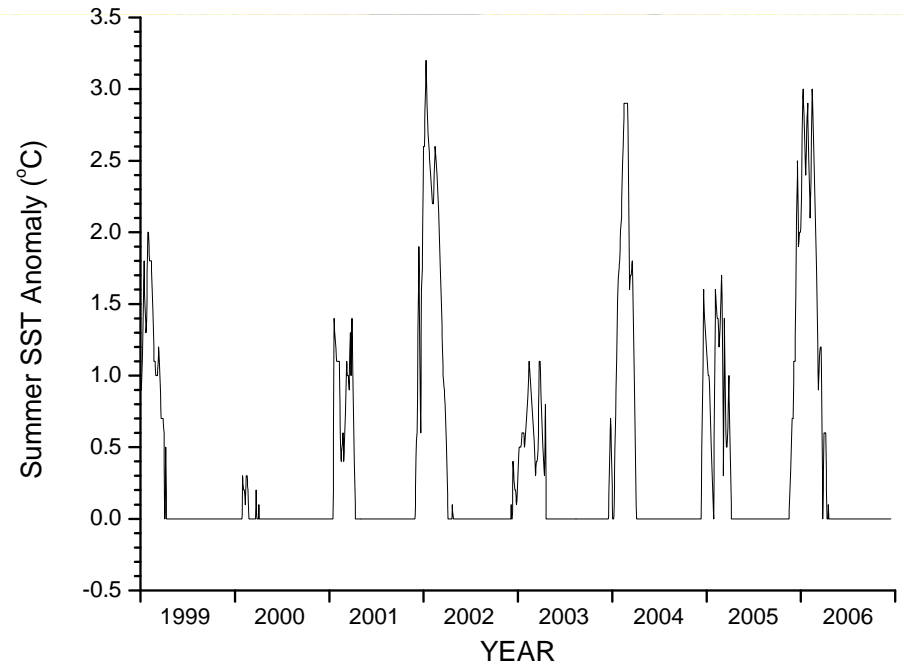
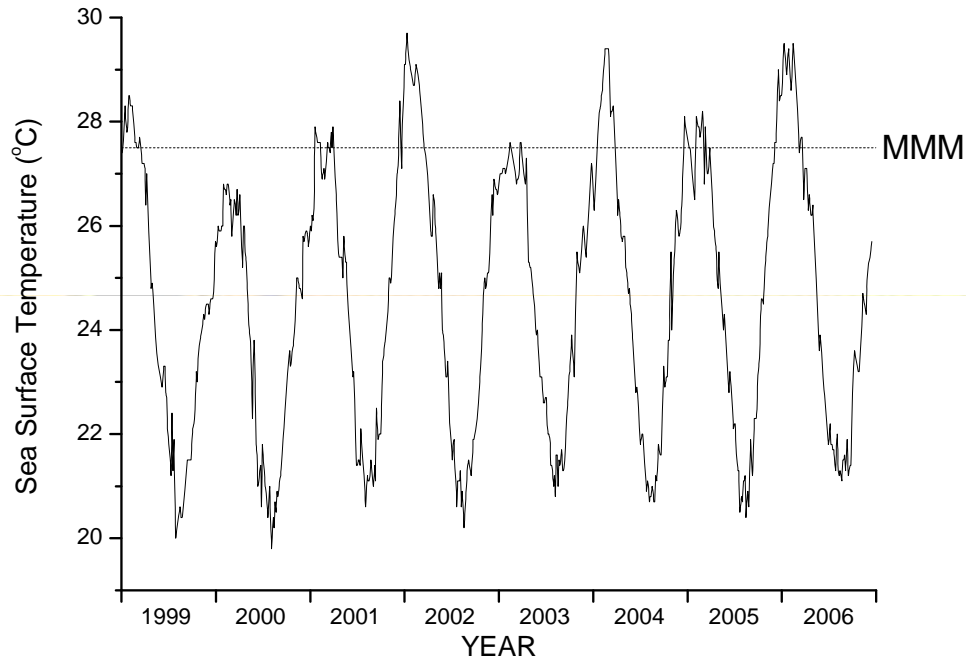
## Seasonal fluctuation in PSII efficiency

*After a loss of 60% of PII efficiency photosynthesis is highly compromised hence we scale to 0.4-1.0*

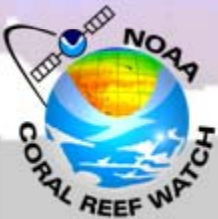


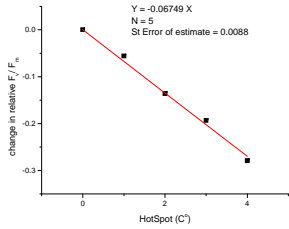
# Testing the Algorithm

**Summer  
SST** → **SST  
Anomaly**



**Data from CRW  
E50 SST product**

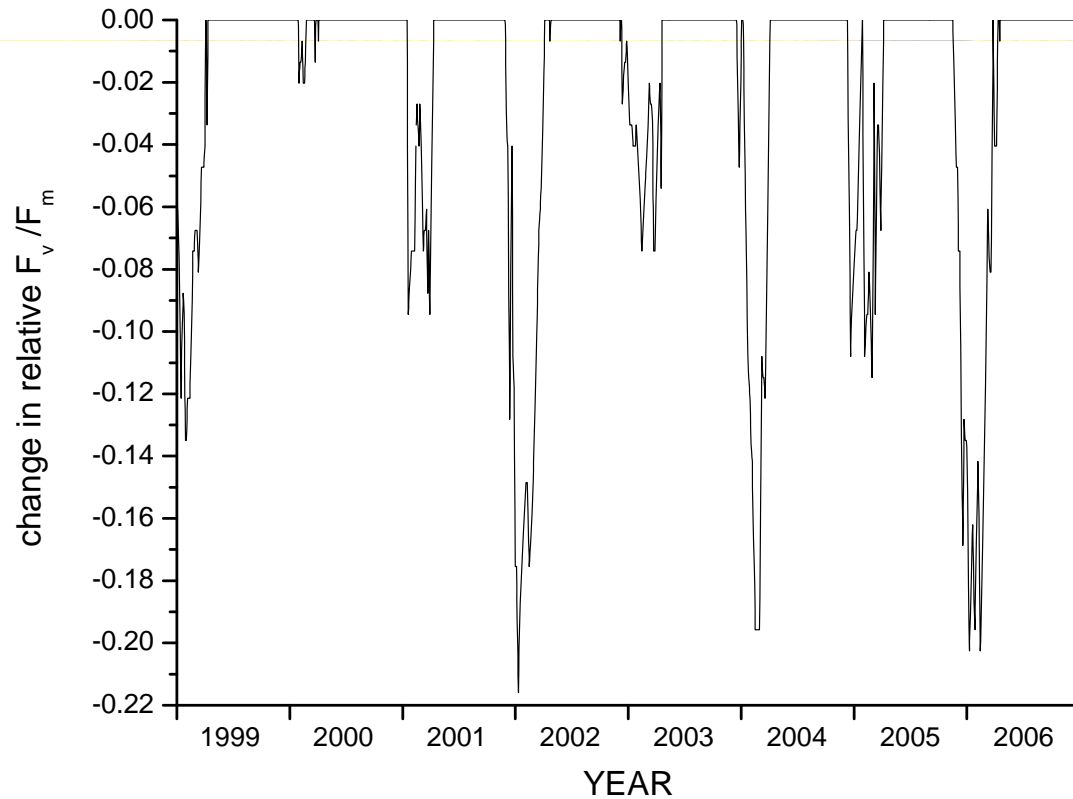




# Testing the Algorithm

$$\Delta \text{rel} \frac{F_v}{F_m} = f(\text{temp})$$

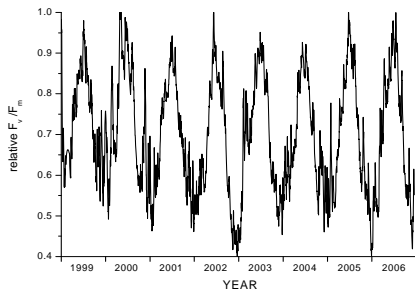
Change in Photosystem efficiency due to thermal stress



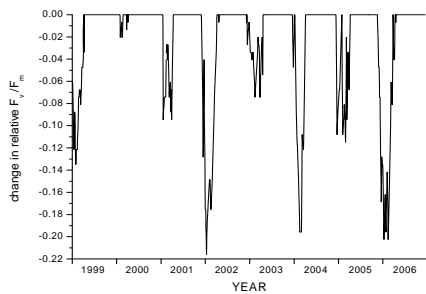
# Testing the Algorithm

$$\Delta \text{rel} \frac{F_v}{F_m} = f(EEE, \text{temp})$$

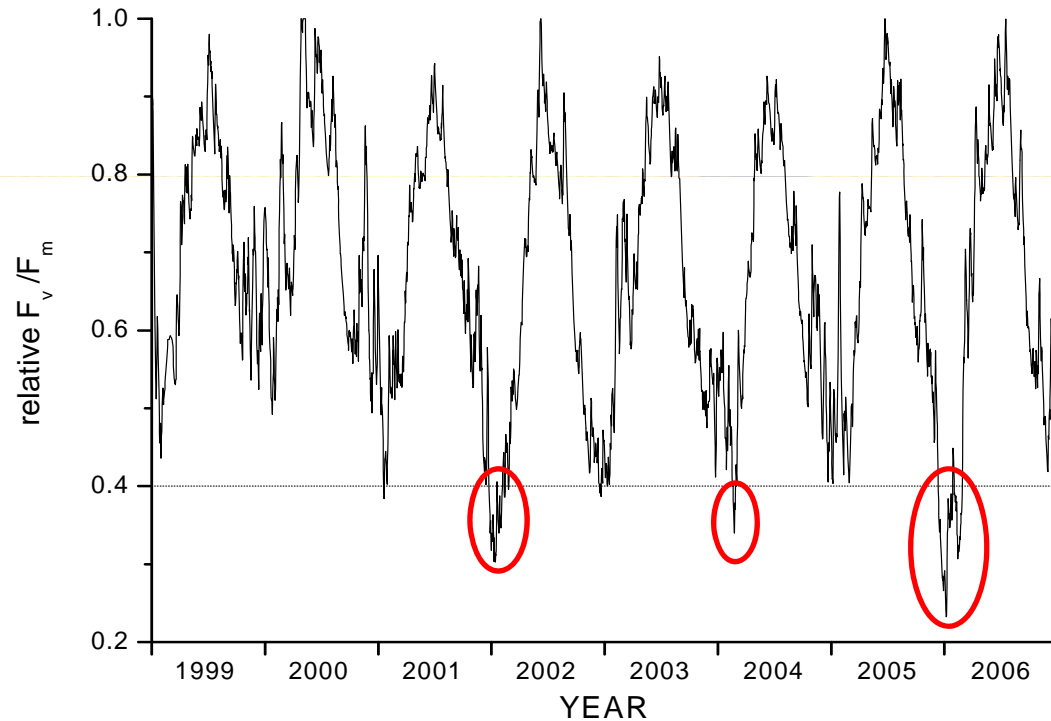
## PAR Stress



## Temperature Stress



## Net Photosystem efficiency

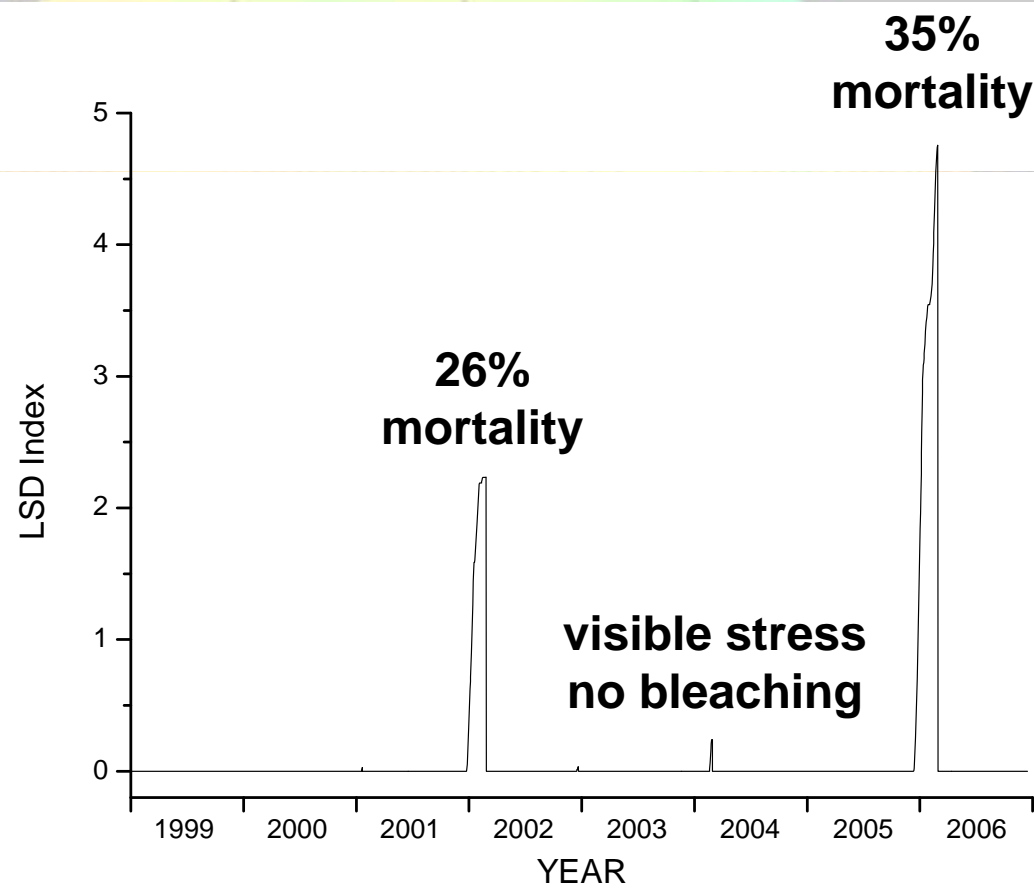


**LSD = accumulations under 0.4**



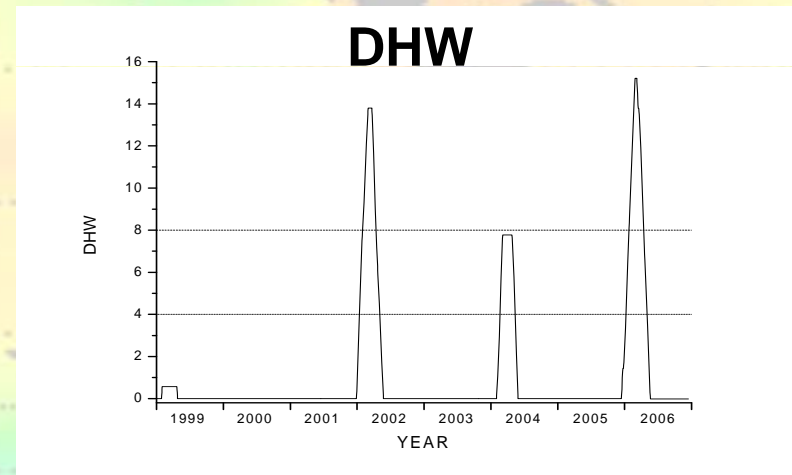
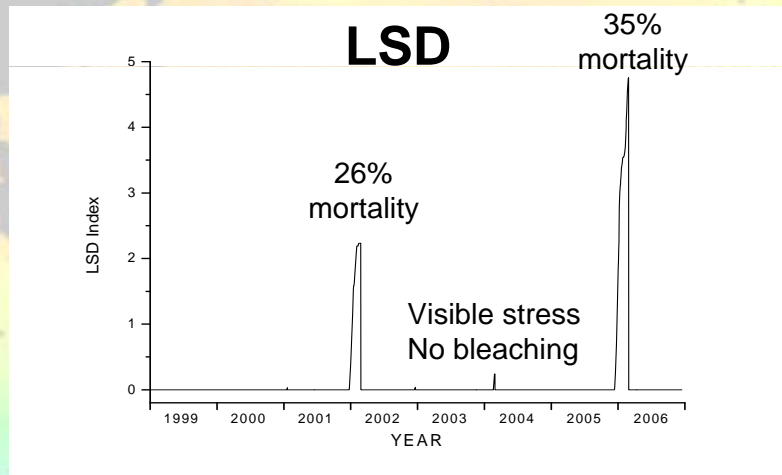
# Testing the Algorithm

$$\sum \left[ \Delta_{\text{rel}} \frac{F_v}{F_m} \right] = \text{LSD index}$$



# Testing the Algorithm

## Bleaching events at the Keppel Islands

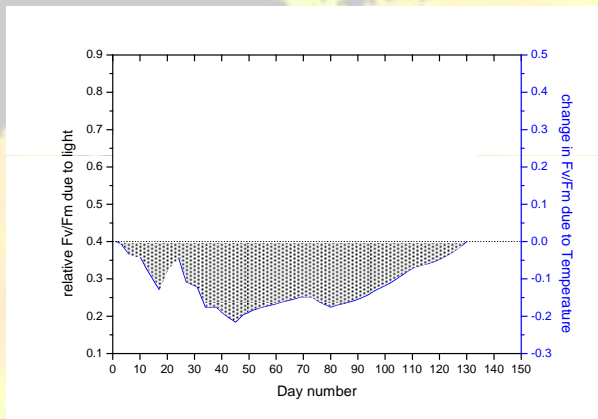




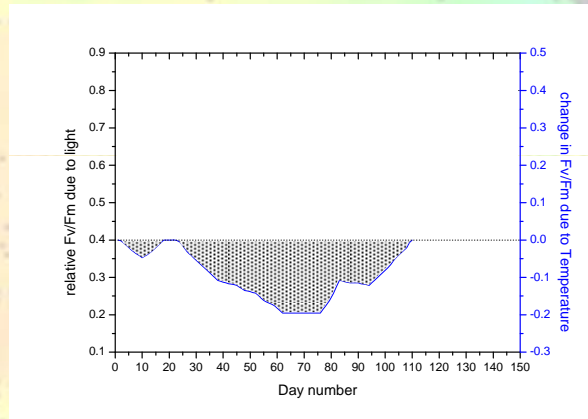
# Testing the Algorithm

## Bleaching events at the Keppel Islands

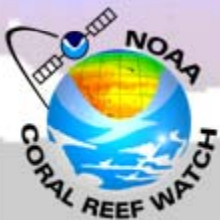
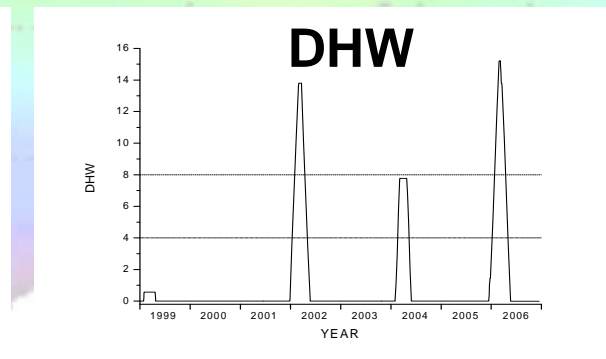
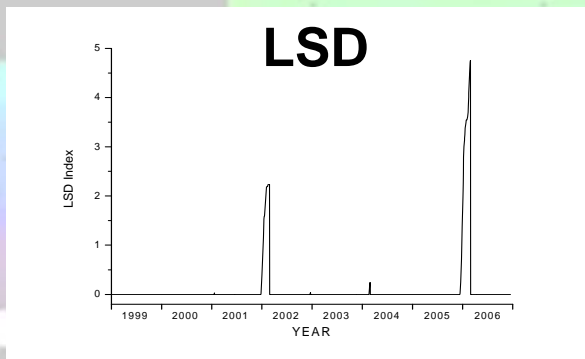
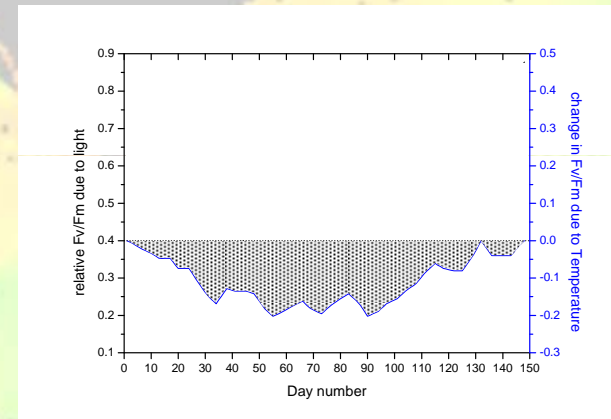
2002



2004



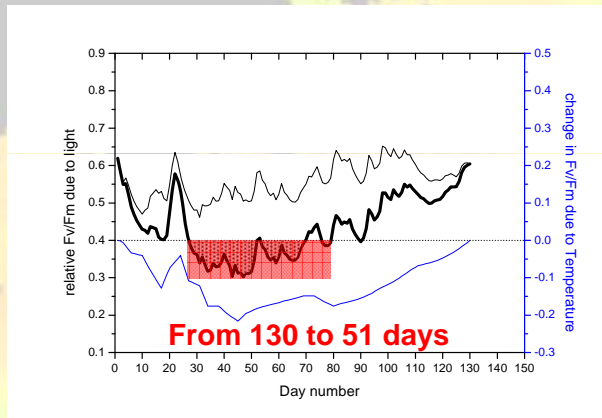
2006



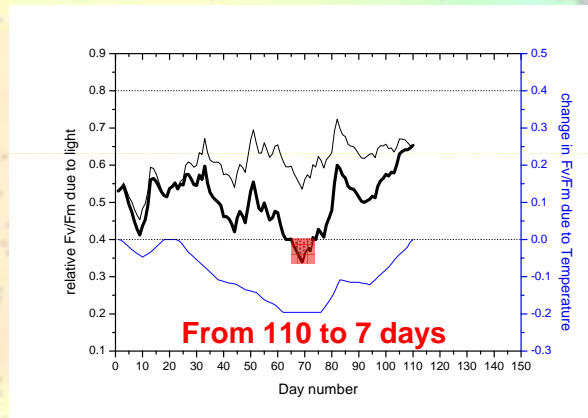
# Testing the Algorithm

## Bleaching events at the Keppel Islands

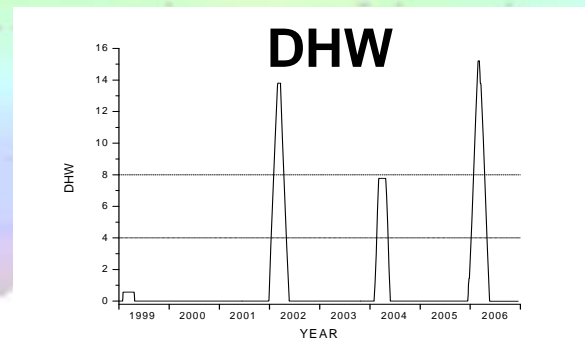
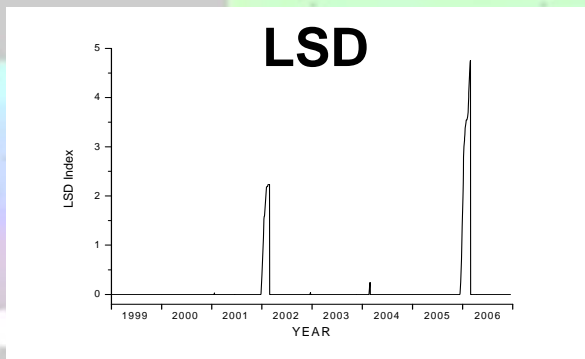
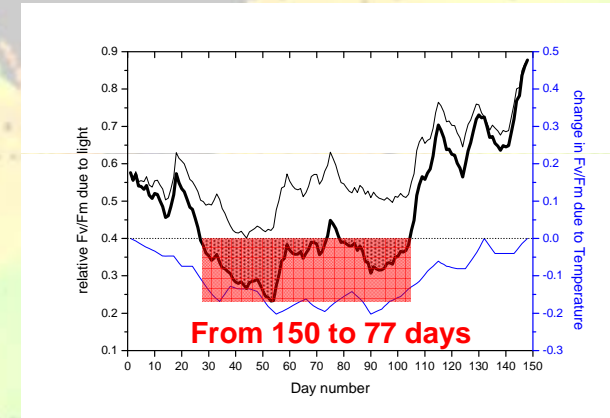
2002



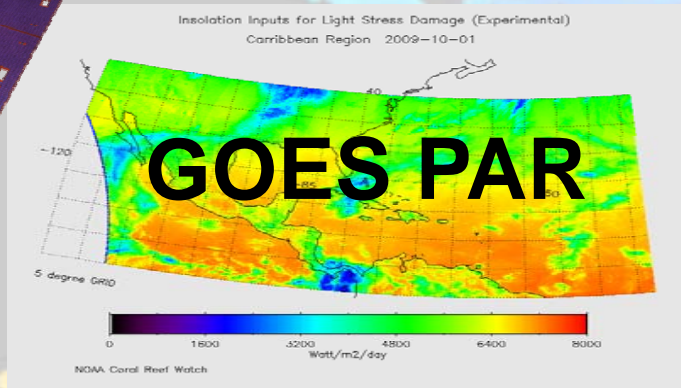
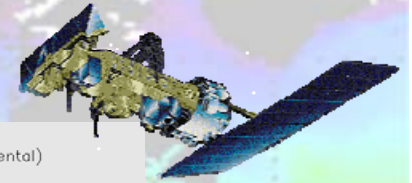
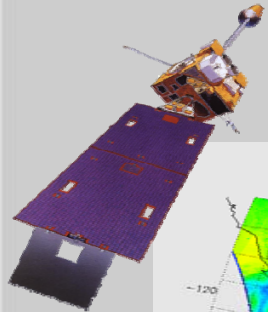
2004



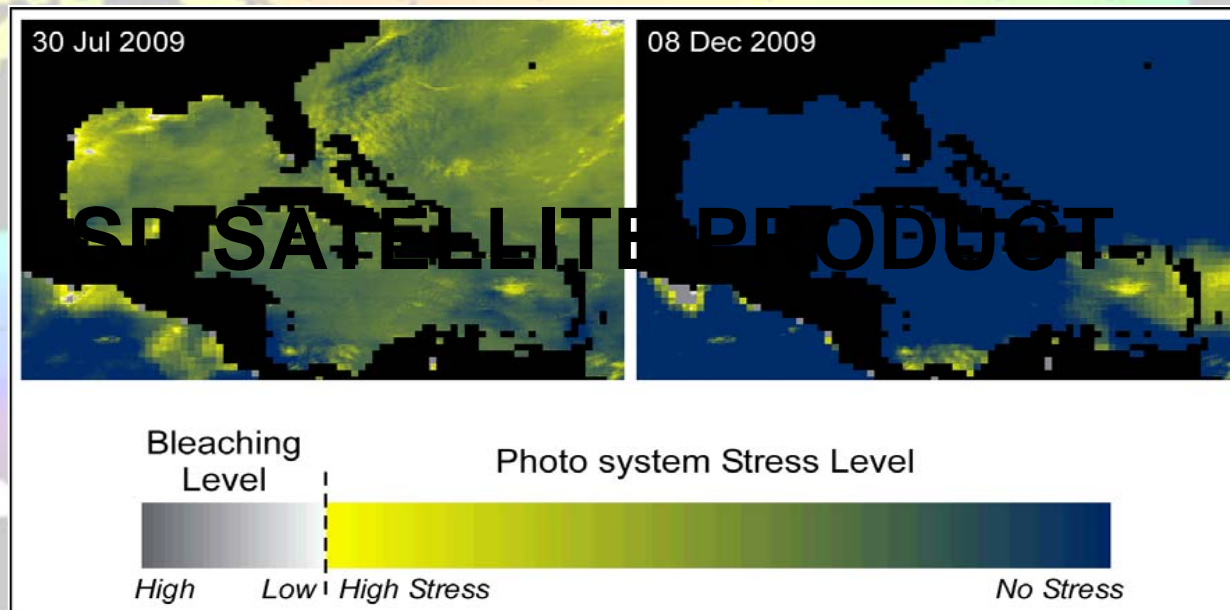
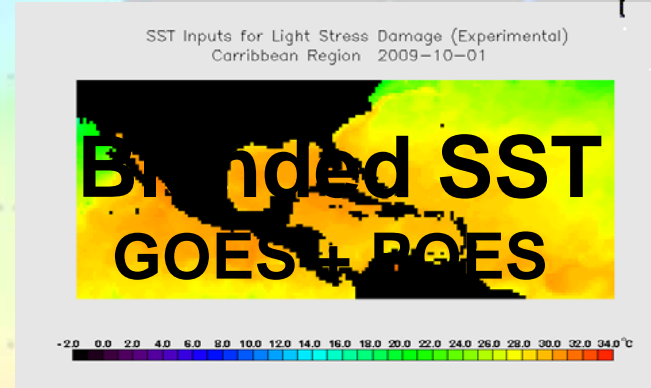
2006



# Satellite Product



+



# Summary

- **LSD algorithm:**
  - nrt predictions of coral bleaching onset, severity, recovery, and resultant mortality
- **Daily tracking of Photosystem health**
- **LSD satellite product is in test phase**
  - Caribbean first
  - Global next
- **Take home message:**
  - Temperature alone is not enough
  - Light is very important



# ARC Industry Linkage Grant

## **NEXT GENERATION SATELLITE TOOLS: Understanding Environmental Stress on Coral Reefs**

### *The Team*

**University of Queensland (UQ)**

**National Oceanic and Atmospheric Administration (NOAA)**

**Australian Institute of Marine Science (AIMS)**

**Great Barrier Reef Marine Park Authority (GBRMPA)**

**Universidad Autonoma Nacional de Mexico (UNAM)**



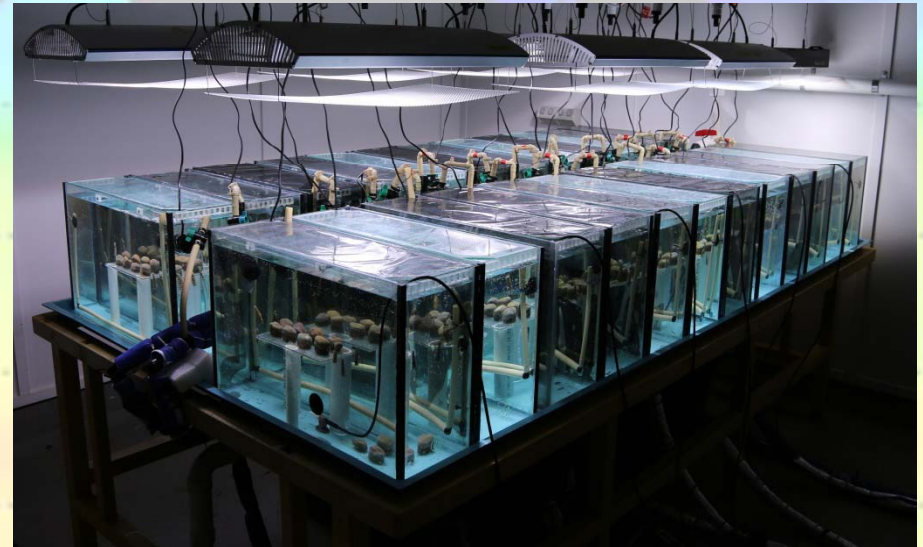
# ARC PROJECT OVERVIEW

- **Development of the current LSD algorithm**
  - Mesocosm experiments
  - Micro-PAM and other ground-truthing
- **Extension of LSD algorithm to other stressors**
- **Future validity of LSD algorithm**



# DEVELOPMENT OF LSD ALGORITHM

## Microcosm Experiments

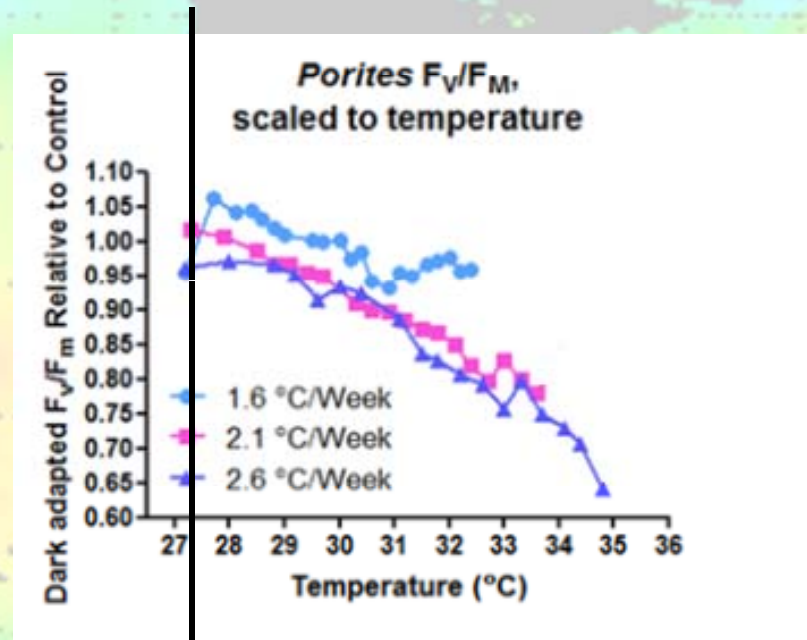
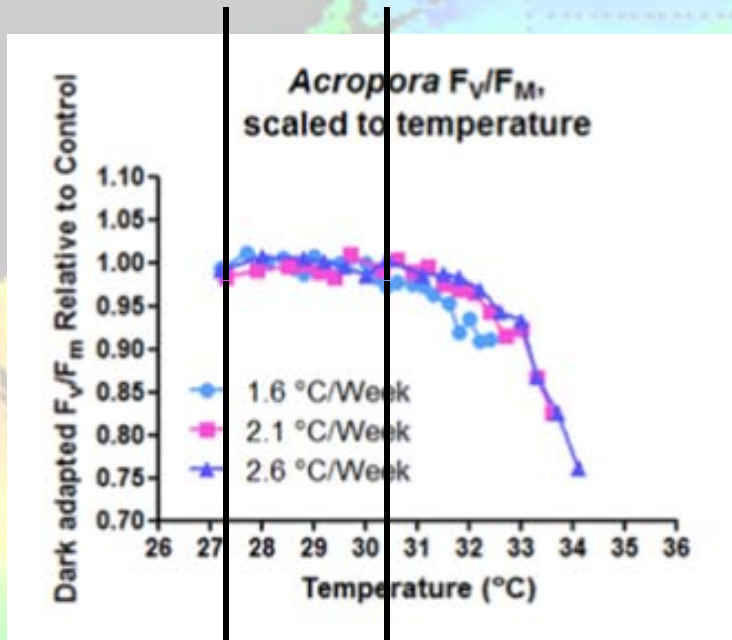


- $F_v/F_m = f(EEE)$
- $F_v/F_m = f(SST)$
- Thermal threshold (*MMM*)
- How to combine stressors



# DEVELOPMENT OF LSD ALGORITHM

## Microcosm Experiments – Preliminary Results



CRW MMM = 27.3°

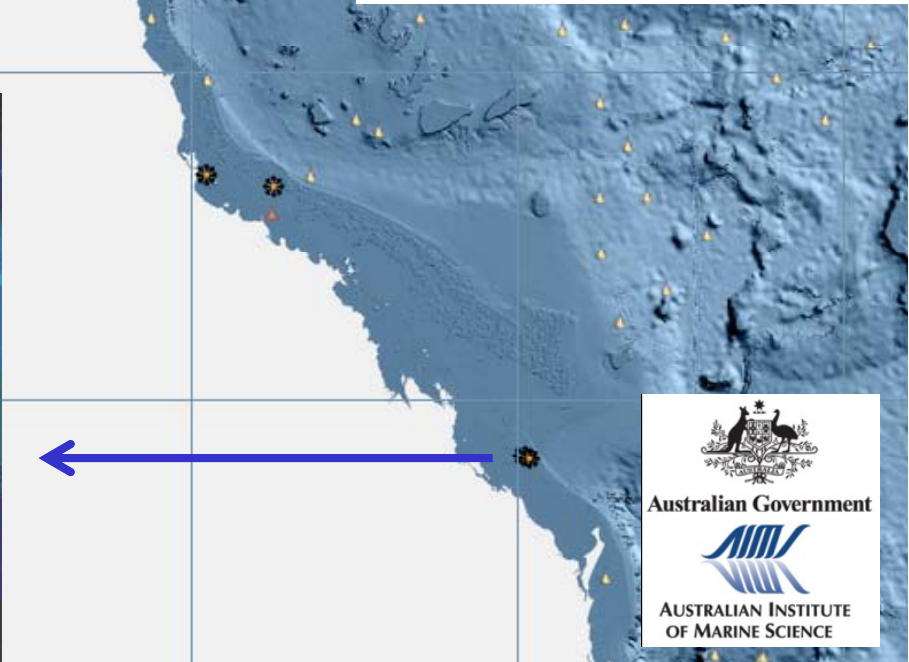
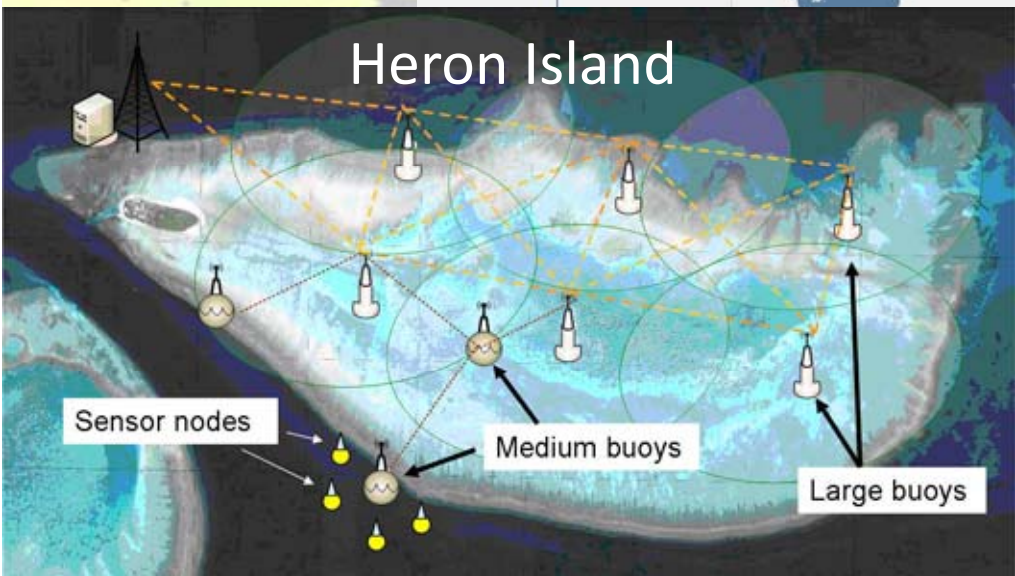
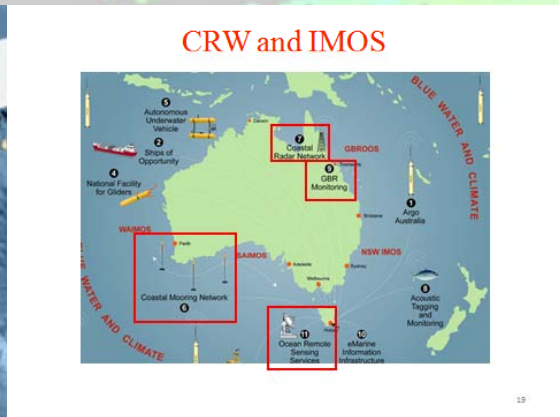
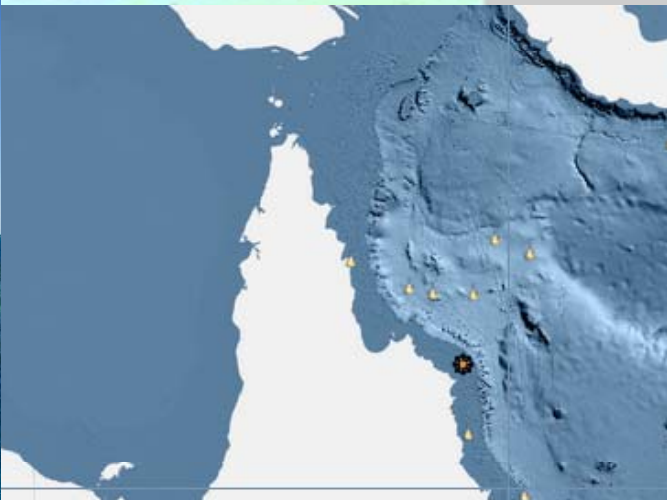
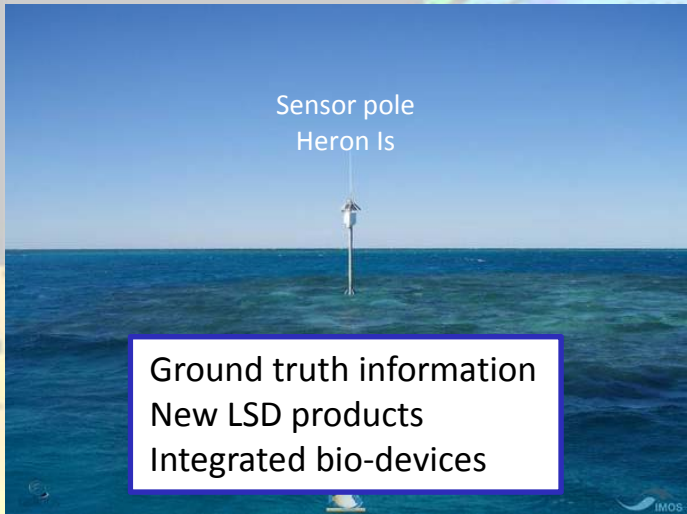




# DEVELOPMENT OF LSD ALGORITHM

## Ground Truthing (micro PAMs and other in situ instruments)

Wireless Sensor Networks (FAIMMS) Great Barrier Reef Ocean Observing System



# LSD EXTENSION AND FUTURE VALIDITY

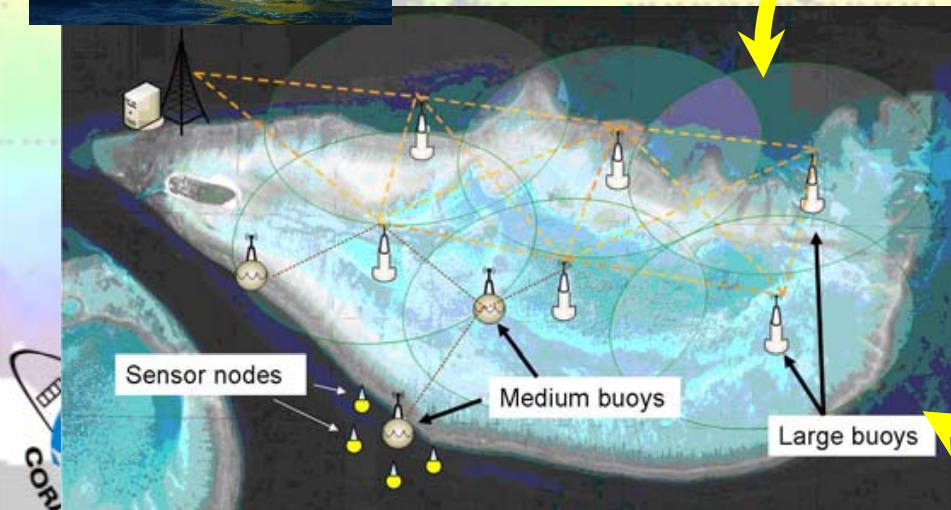
- Extension of LSD algorithm to other stressors
- Future validity of LSD algorithm
- New indices of reef health

Heron Island Research Station



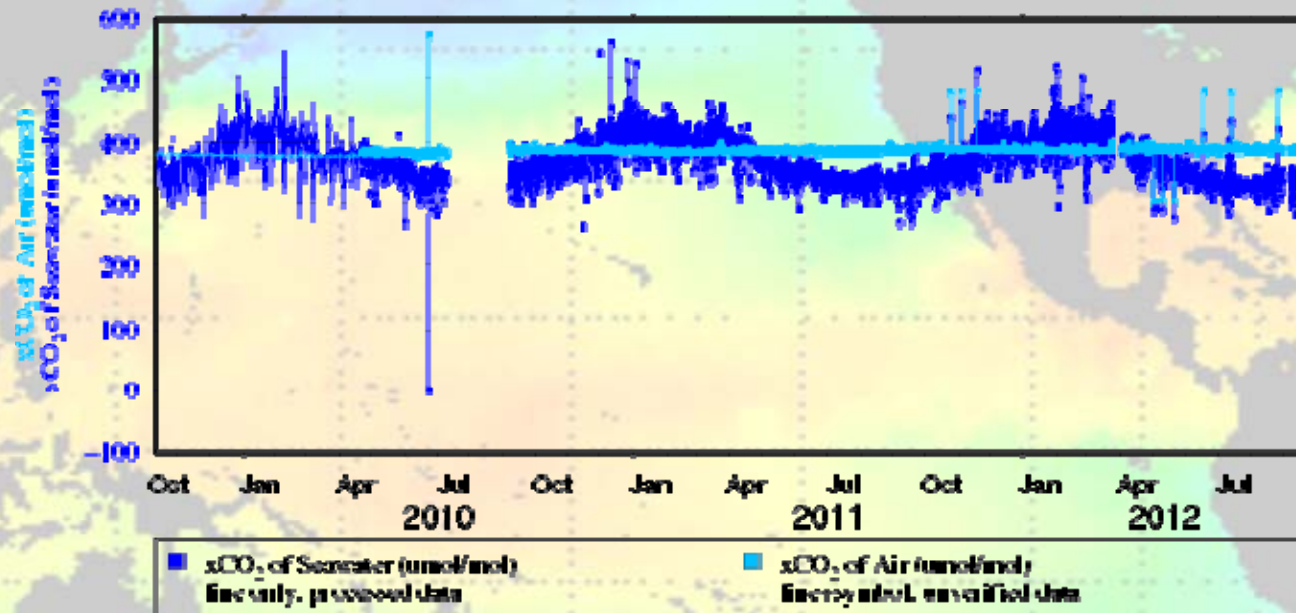
*In situ instruments*

Field measurements

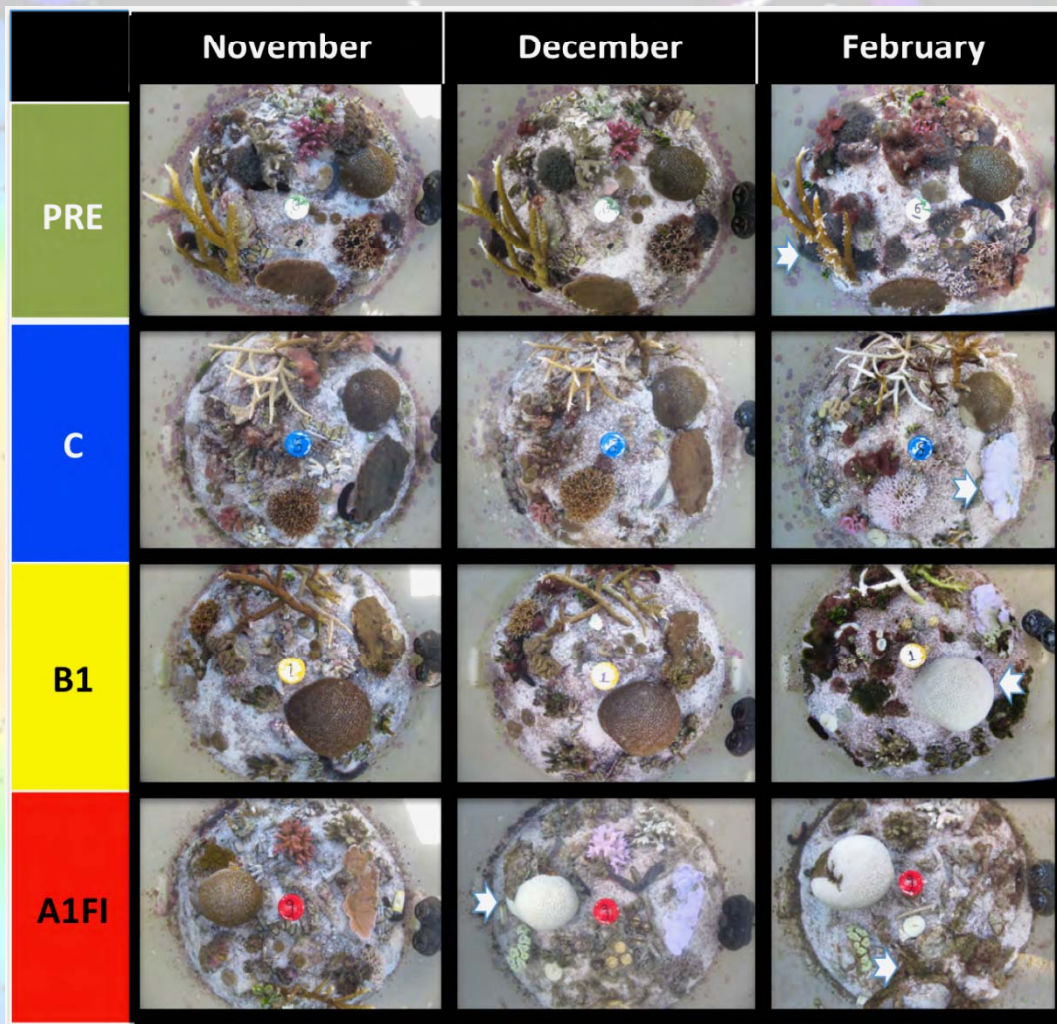
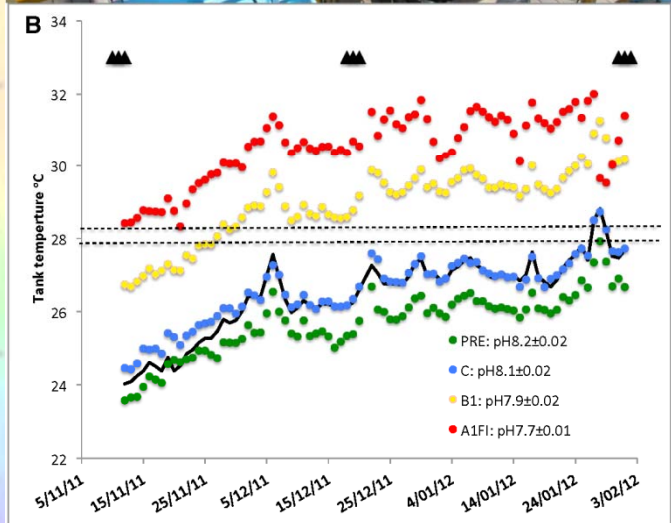


# SOME PRELIMINARY RESULTS

$x\text{CO}_2$  of Seawater &  $x\text{CO}_2$  of Air @ Heron Island (152E, 23.5S)  
[Date: 2009-10-09 to 2012-09-21]



# SOME PRELIMINARY RESULTS



# SUMMARY

- CRW needed assistance to develop LSD
  - Knowledge/Experimental Technique
  - Infrastructure/Resources
  - Funding
- Large ARC-funded project to develop satellite algorithms
- International team

## PROJECT GOALS

- Improve science that underpins the LSD satellite product suite
- Expand the LSD algorithm to include other stressors
- Investigate the validity of the LSD Algorithm into the future
- Seek other indices/algorithms for coral and reef ecosystem health



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