Predicting coral bleaching from satellite retrievals of sea surface light and temperature

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Light/temp product development team

NOAA CRW
World Bank (Remote Sensing and Bleaching WGs)
Australian Research Council Linkage Grant

Team includes:

- **NOAA CRW/STAR**
- **Universidad Autonoma Nacianal de Mexico**
- **University of Exeter – UK**
- **University of Queensland – Australia**
- **University of Tasmania – Australia**

Overview

- Setting up the algorithm
- Algorithm development
- Testing the algorithm

Goal of Project

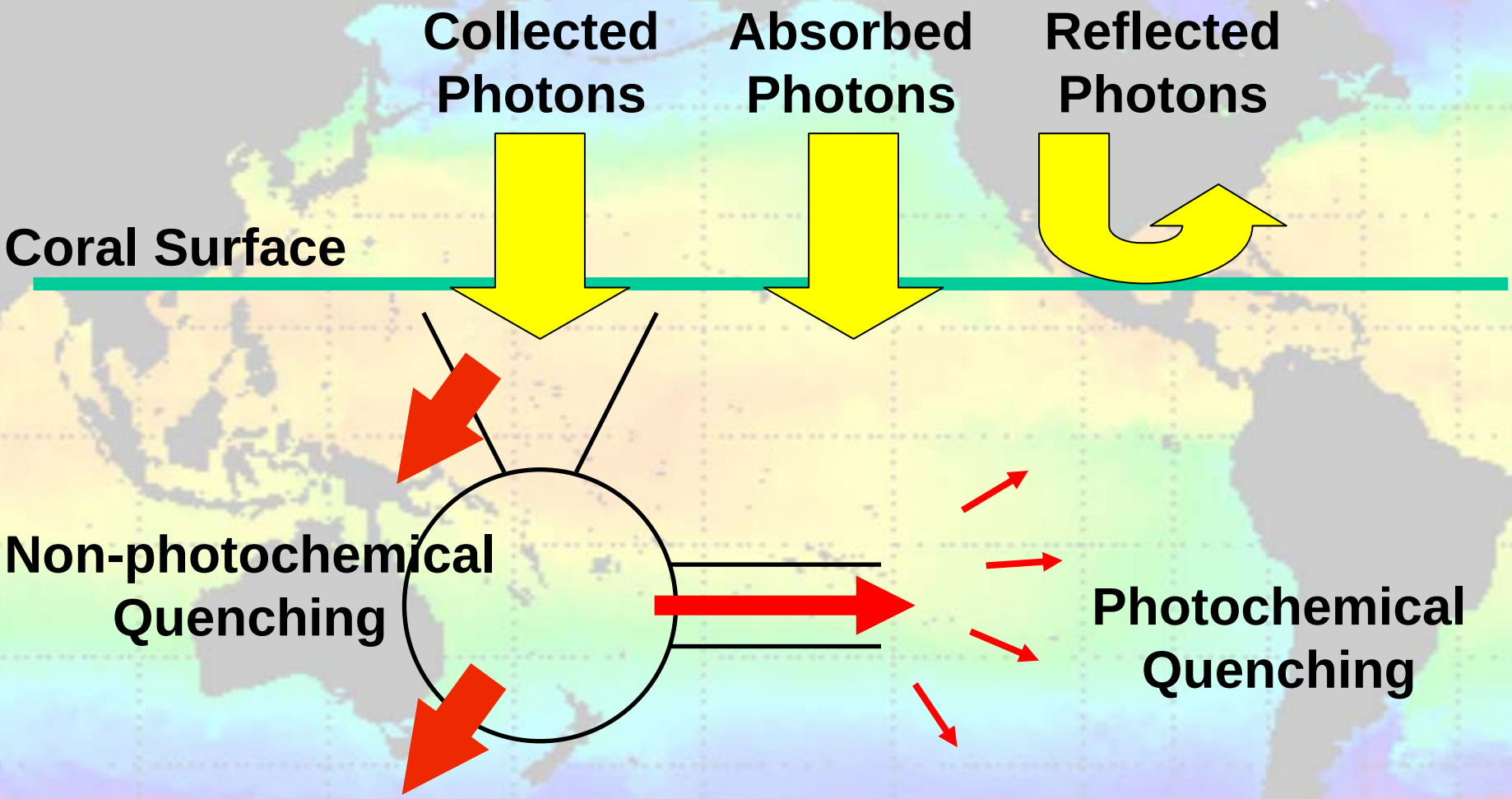
Current satellite-based bleaching algorithms

- Based on SST only
- Not physiology based
  - ONSET – yes
  - SEVERITY – indication
  - MORTALITY – not really

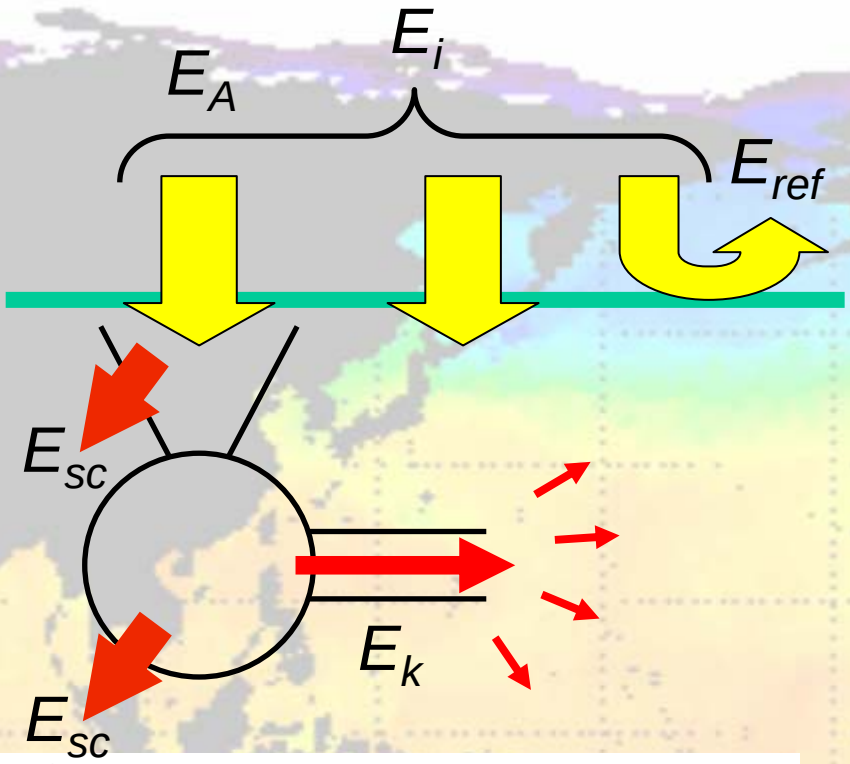
Goal of new satellite-based bleaching Algorithm

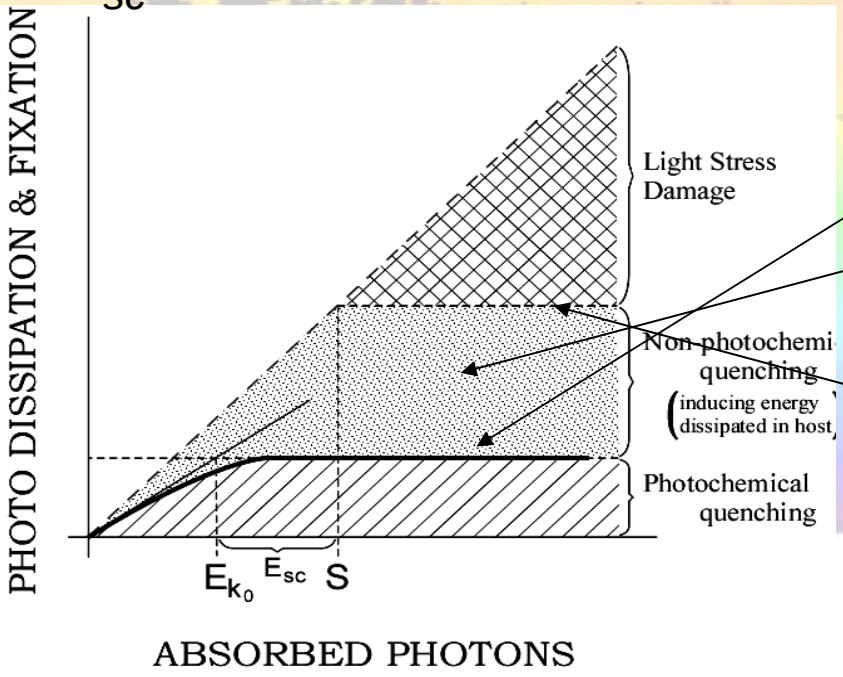
- Based on light and SST
- Physiology based
  - ONSET – yes
  - SEVERITY – yes
  - MORTALITY – yes

Simplified Photosynthetic System



Defining terms





E_i = Irradiance above coral's surface

E_{max} = Expected max E_i

E_{ref} = Reflected radiation from coral surface

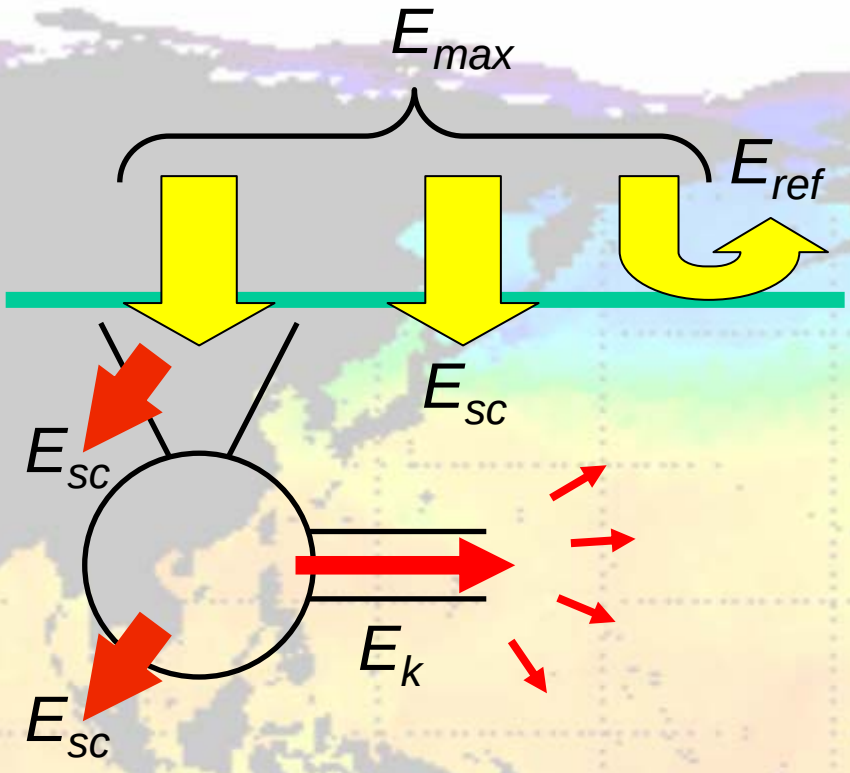
E_A = Radiation absorbed by coral photo system

E_k = Saturation irradiance

E_{sc} = Stress compensation irradiance

S = Photic stress threshold ($S = E_k + E_{sc}$)

Shuffling terms



E_{max} = Expected max E_i

E_{ref} = Reflected radiation from coral surface

E_k = Saturation irradiance

E_{sc} = Stress compensation irradiance

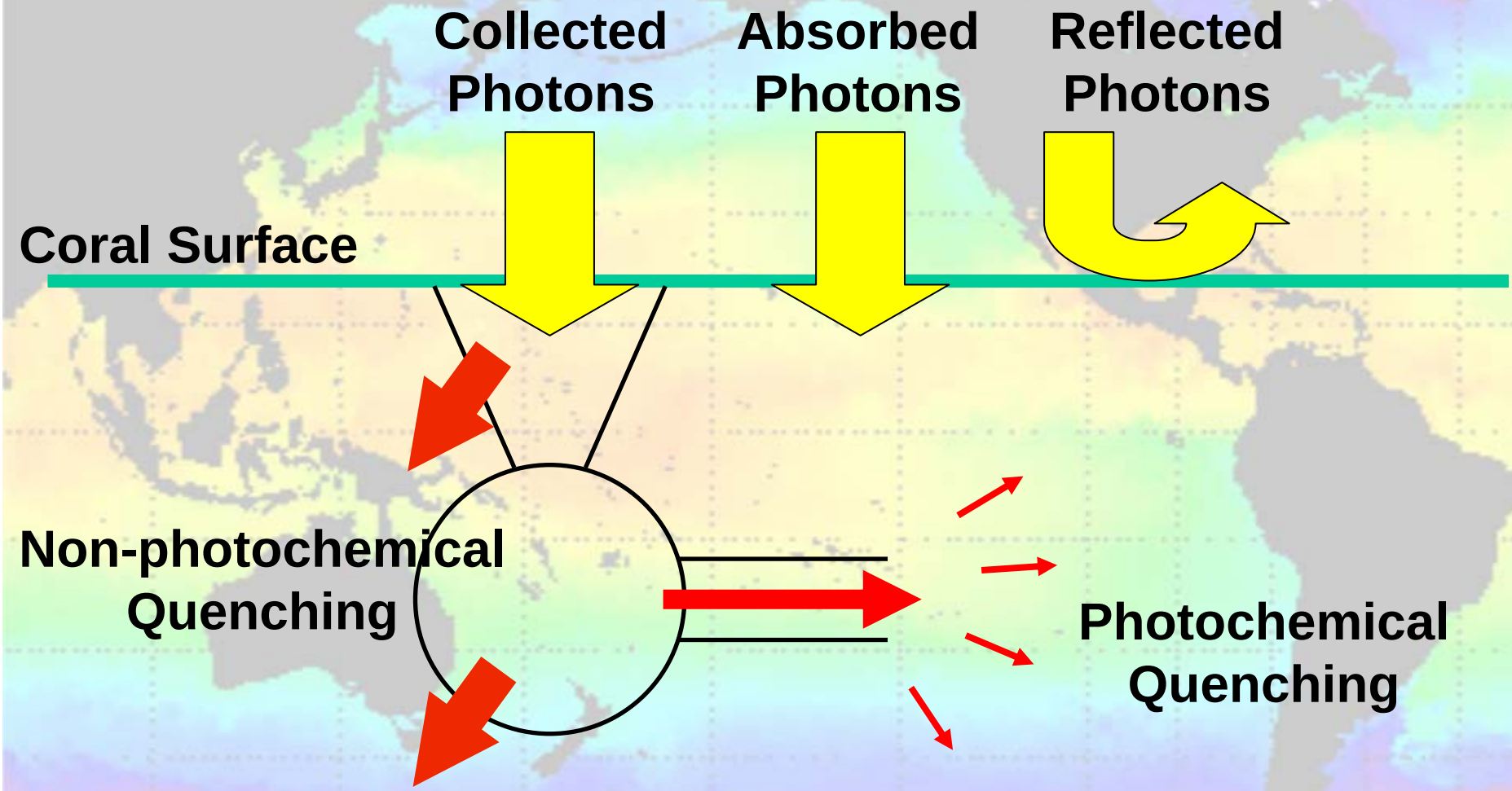
$$E_{max} = E_{k_0} + E_{sc} + E_{stress} + E_{ref}$$

If temp < threshold ⇨ $E_{stress}=0$

$$E_{max} - E_{k_0} = E_{sc} + E_{ref}$$

measurable **not measurable**

Effect of extreme temperatures



E_k

Effect of extreme temperatures

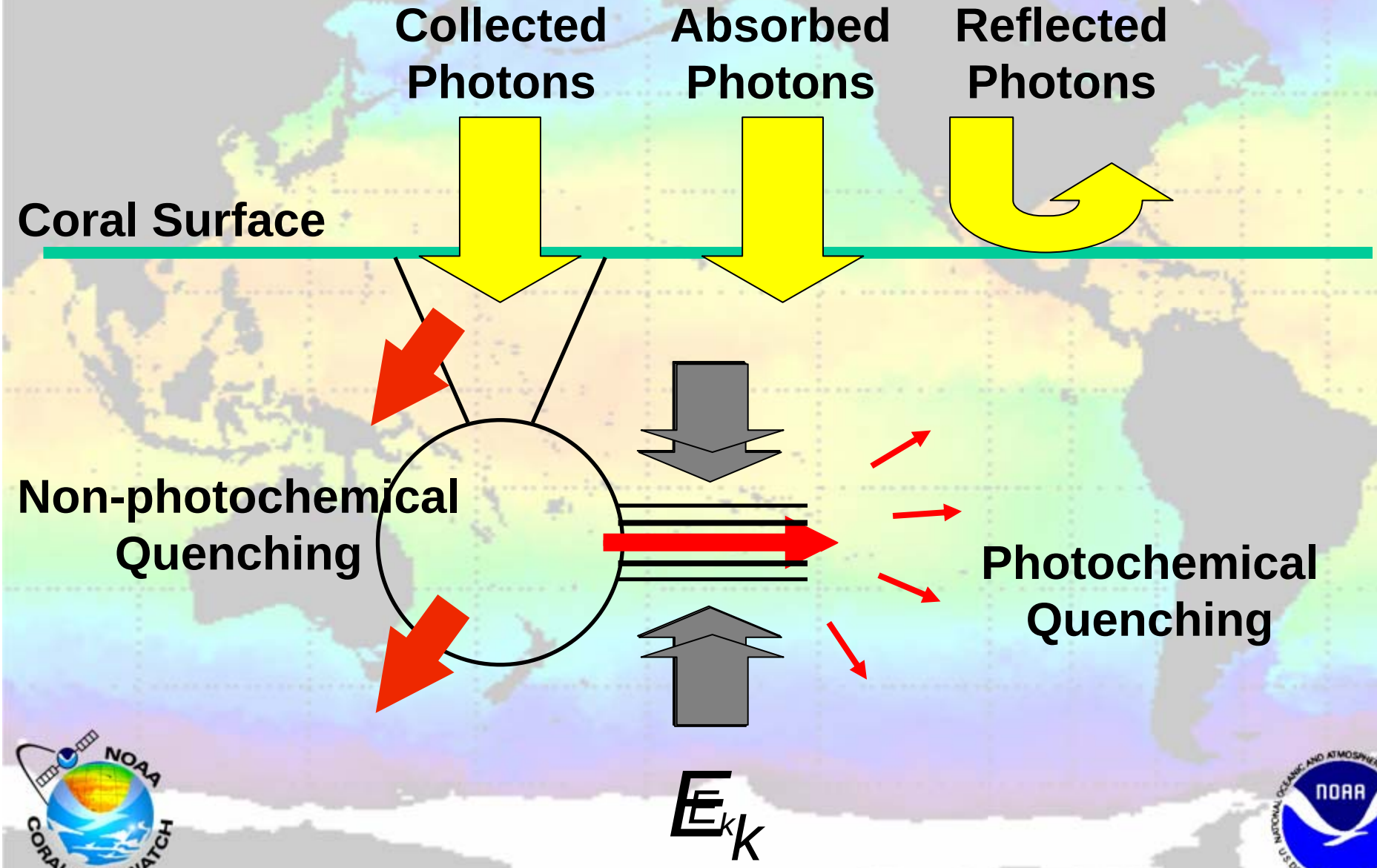
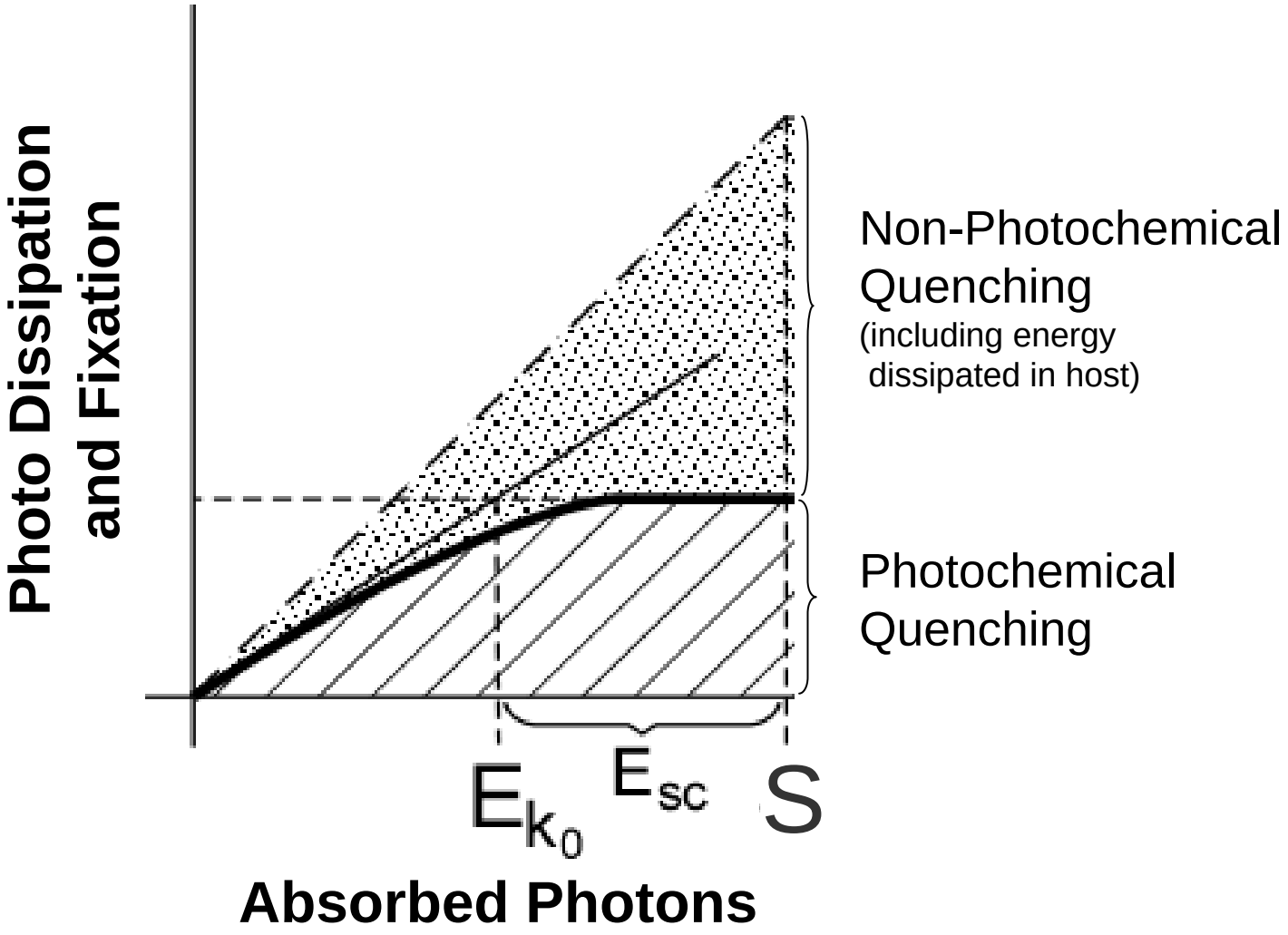


Photo Dissipation and Fixation



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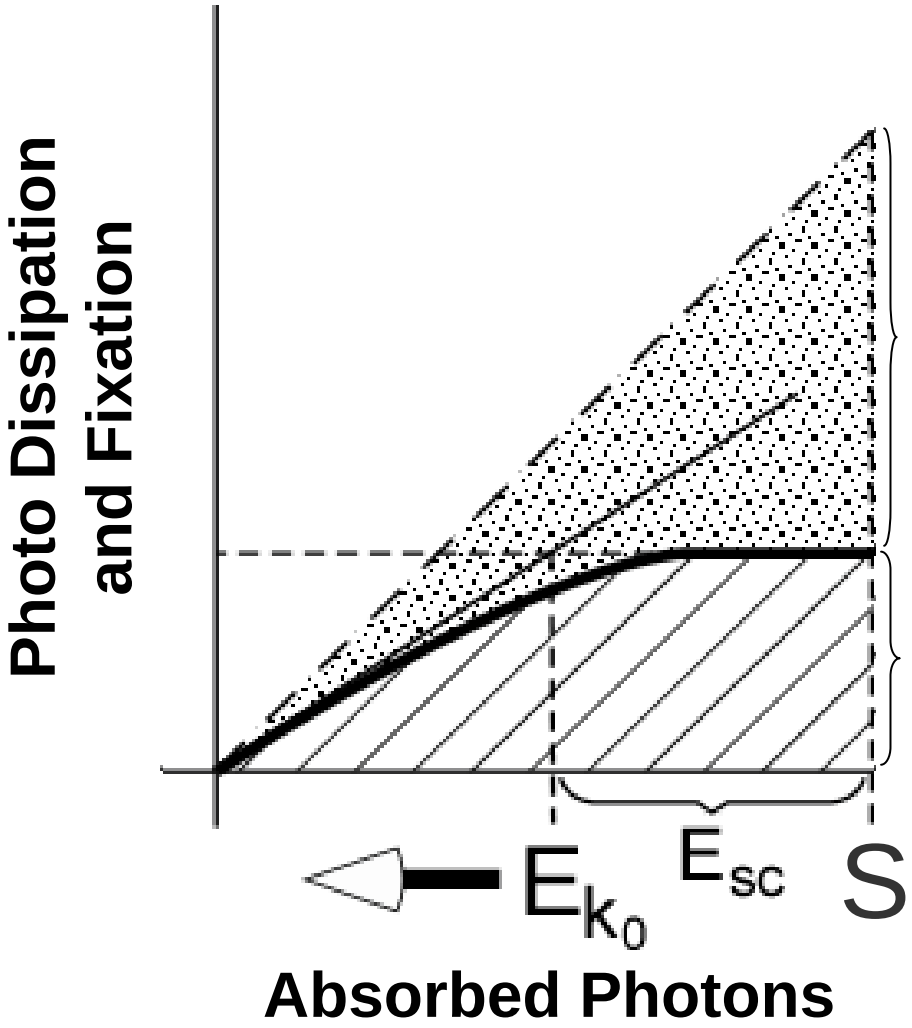

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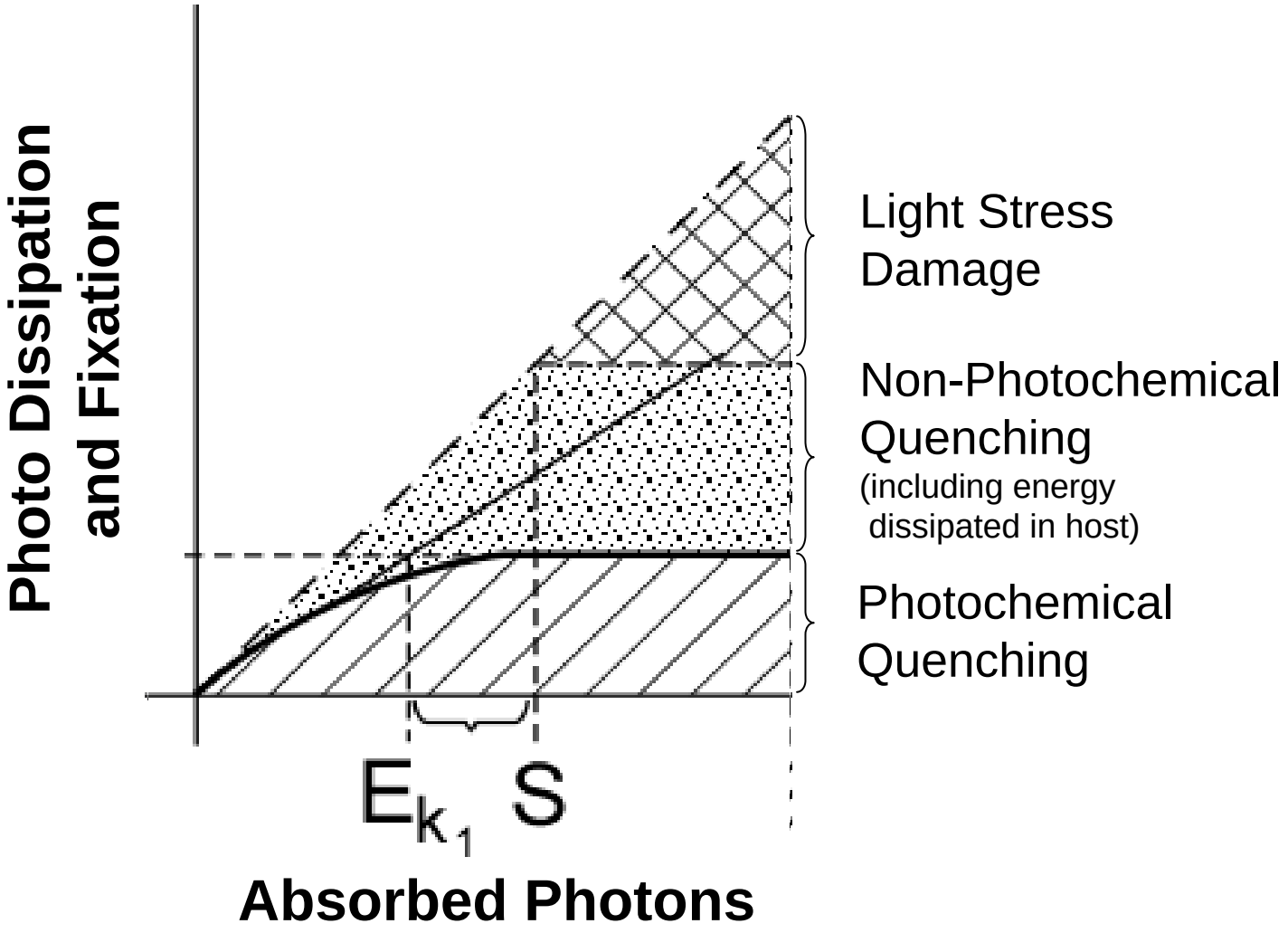
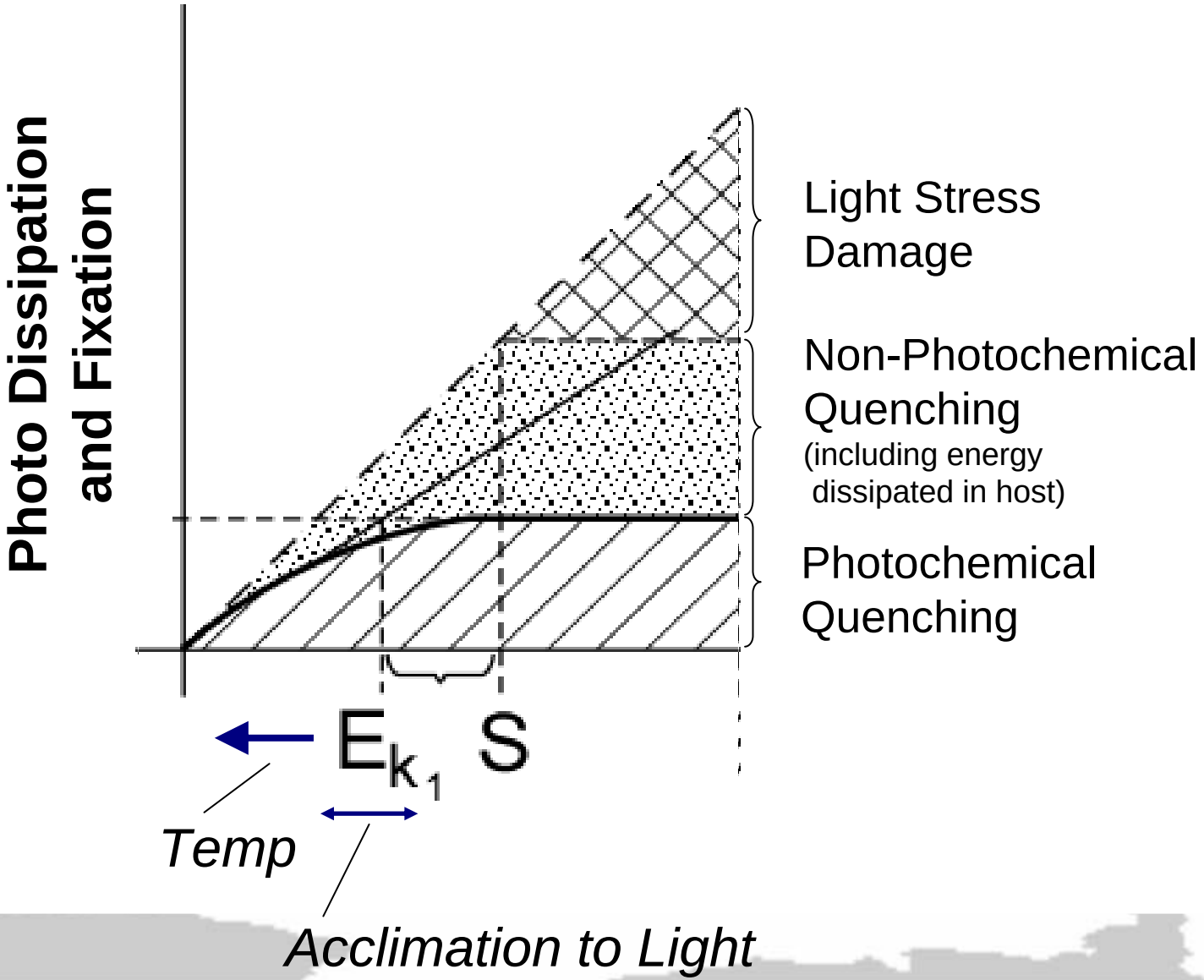


Photo Dissipation and Fixation



The Algorithm

LSD = D at a specific site for a specific coral

$$D(t+1) = D(t) + \Delta t \times P(t) - \Delta t \times R(t)$$

Where LSD = Light Stress Damage

D = accumulated damage

(time, location and coral specific damage)

P = instantaneous light damage

R = Repair (ability of coral to repair damage)

Δt *= time step*

The Algorithm

LSD = D at a specific site for a specific coral

$$D(t+1) = D(t) + \Delta t \times P(t) - \Delta t \times R(t)$$

$$P(t) = E_A(t) - E_k(t) - E_{sc}$$

where E_A *= photons absorbed by photo system*

E_k *= saturation irradiance*

E_{sc} *= compensation irradiance*

The Algorithm

LSD = D at a specific site for a specific coral

$$D(t+1) = D(t) + \Delta t \times P(t) - \Delta t \times R(t)$$

$$E_k(t) = (1 - {}^{HS}/_{4}) \times E_k(t)$$ *- effect of temperature*

& $$E_k(t) = E_k(t) + C(E_k - E_k(t))$$

where E_k *= saturation irradiance*

C *= rate of acclimation to light*

The Repair Term

The repair is constant

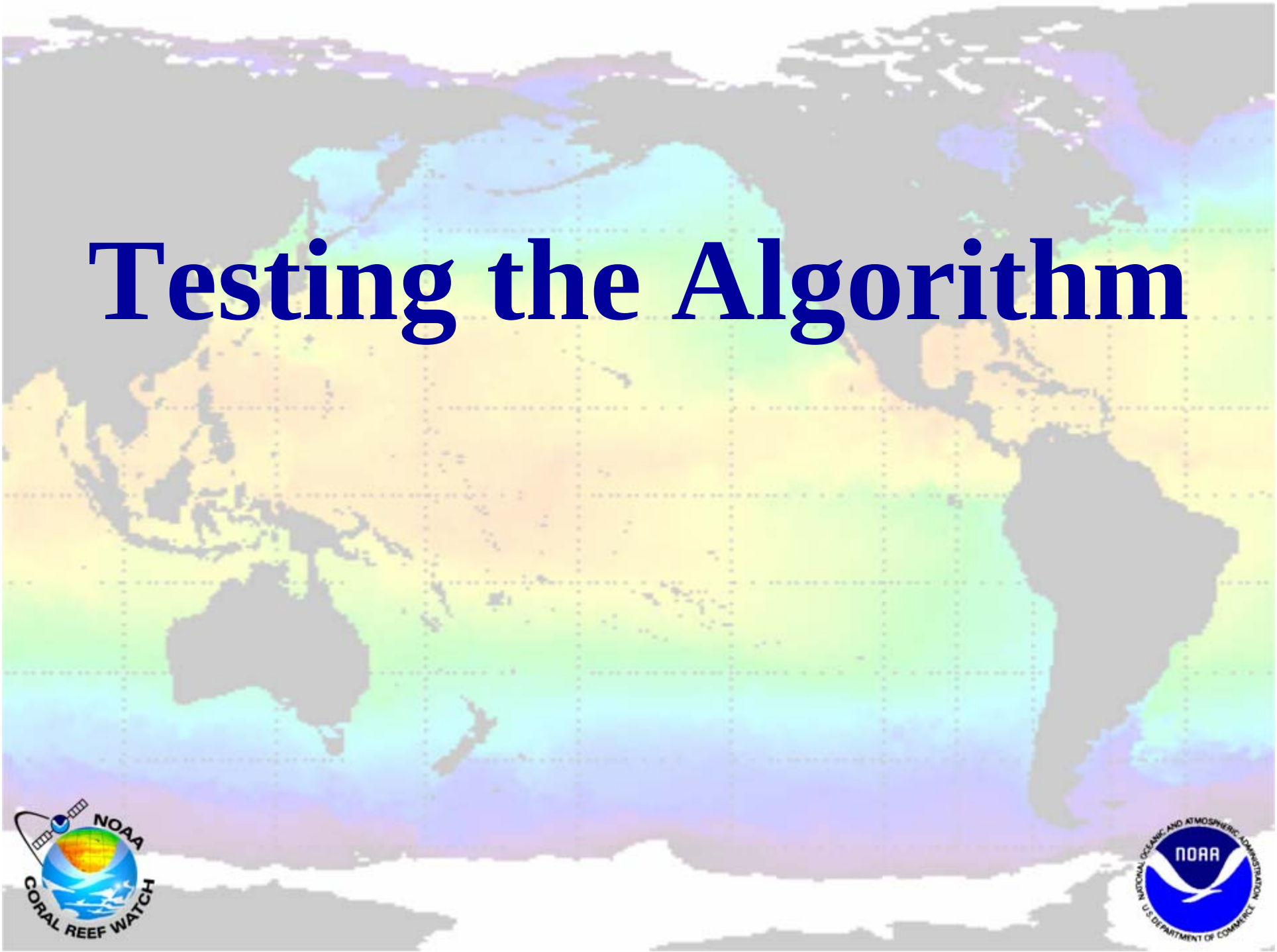
A coral with no repair capability experiencing E_{max} will die in one day.

But the current version of this algorithm does not accumulate all of this "normal" daily damage.

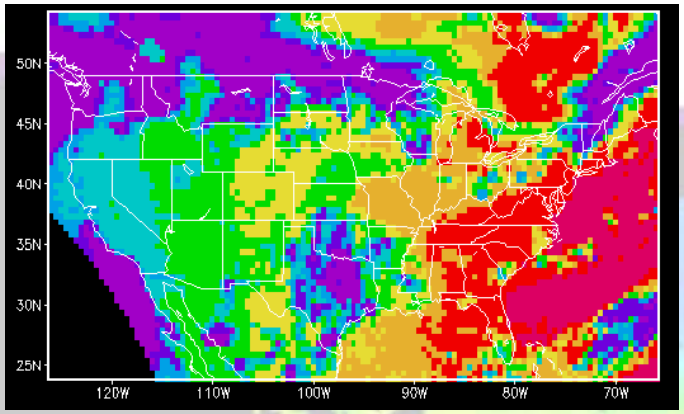
Form of Repair term:

$$R = E_{max} - E_i$$

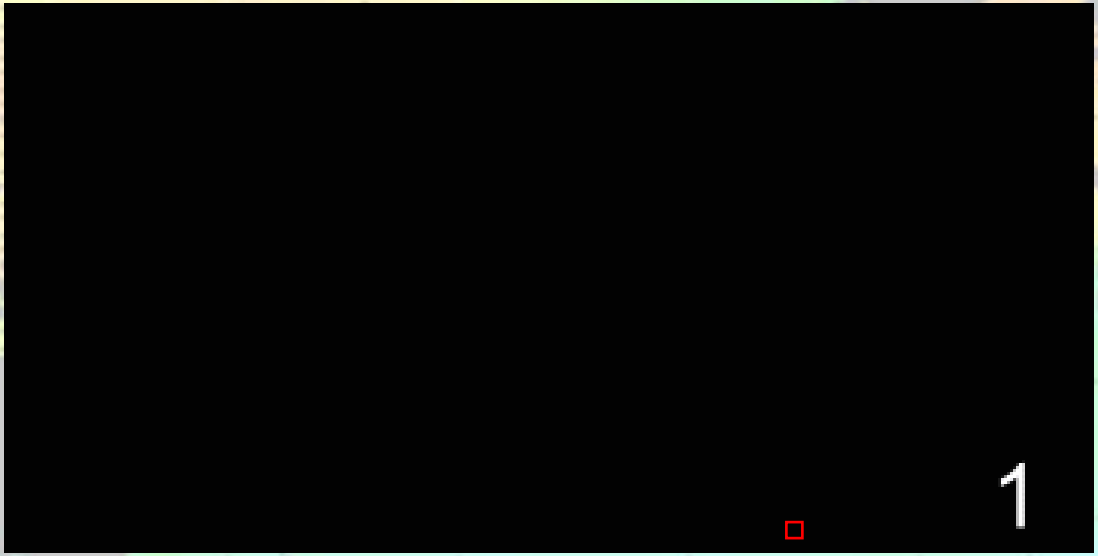
Testing the Algorithm



The Great Barrier Reef



(location reference, since I didn't put land outline on my test image)



Hourly surface downward flux data

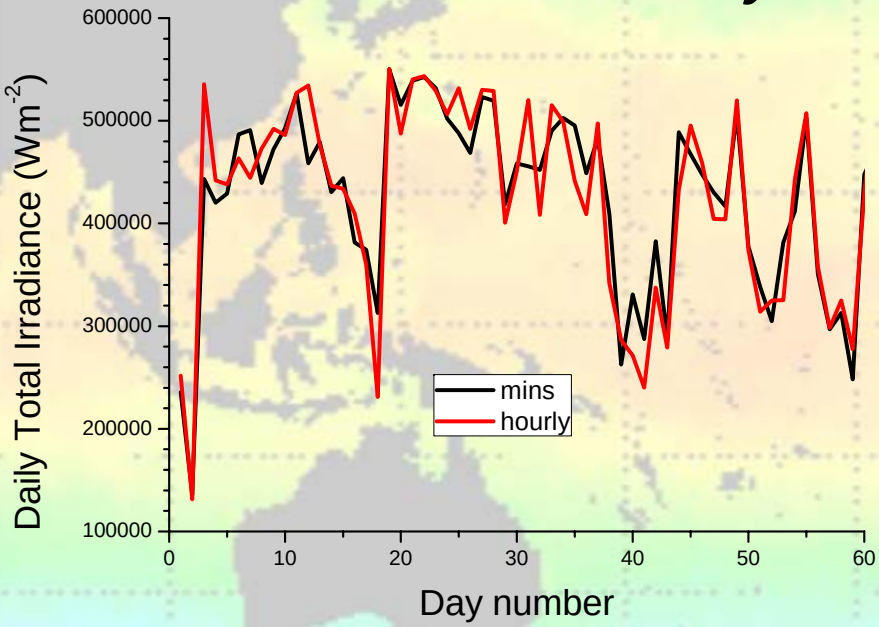
example data for 01 Aug, 2005

(red box is approximate location of Sombrero Reef pixel)

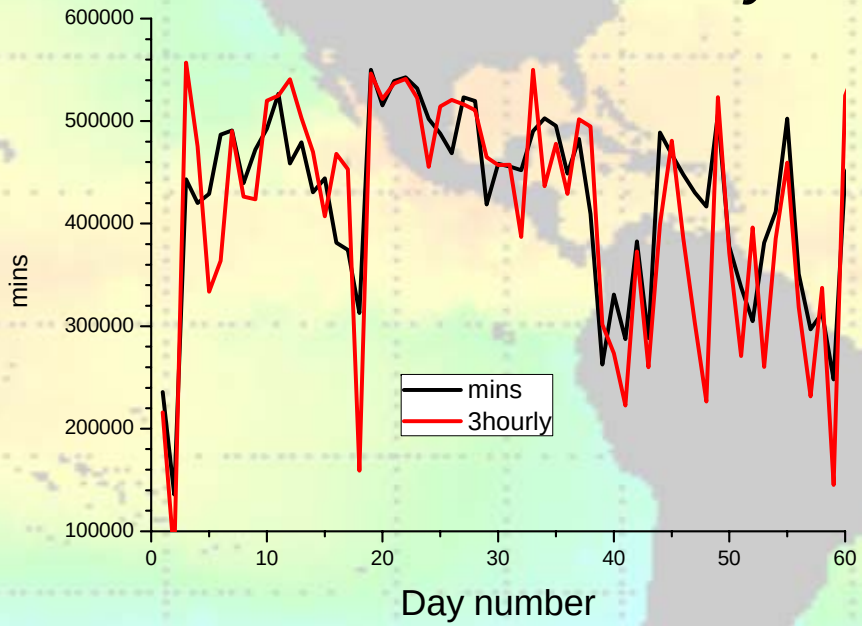
Issues of Temporal Resolution

Daily Total Irradiance for Rockhampton

Minute and Hourly



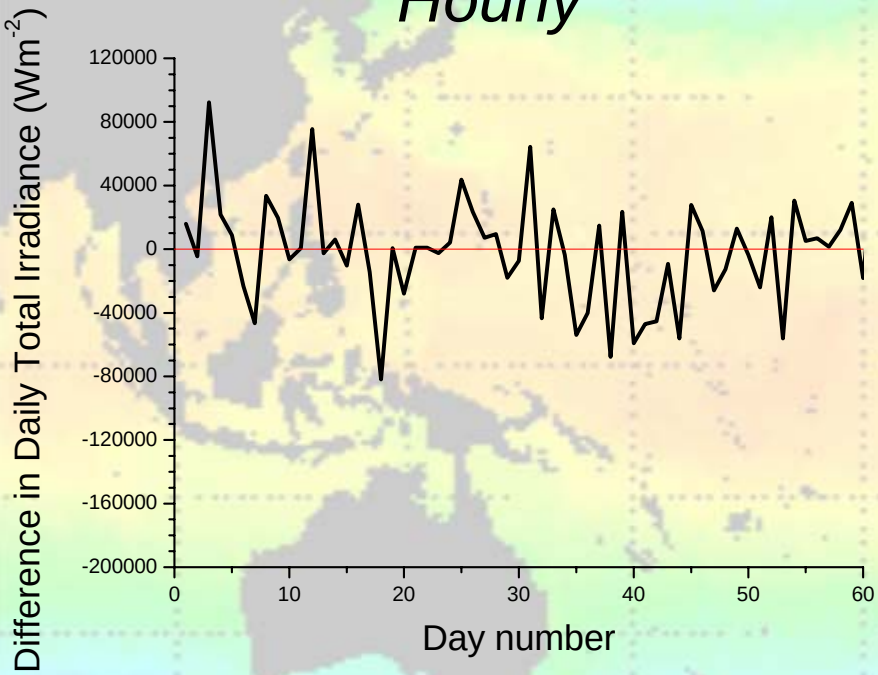
Minute and 3-hourly



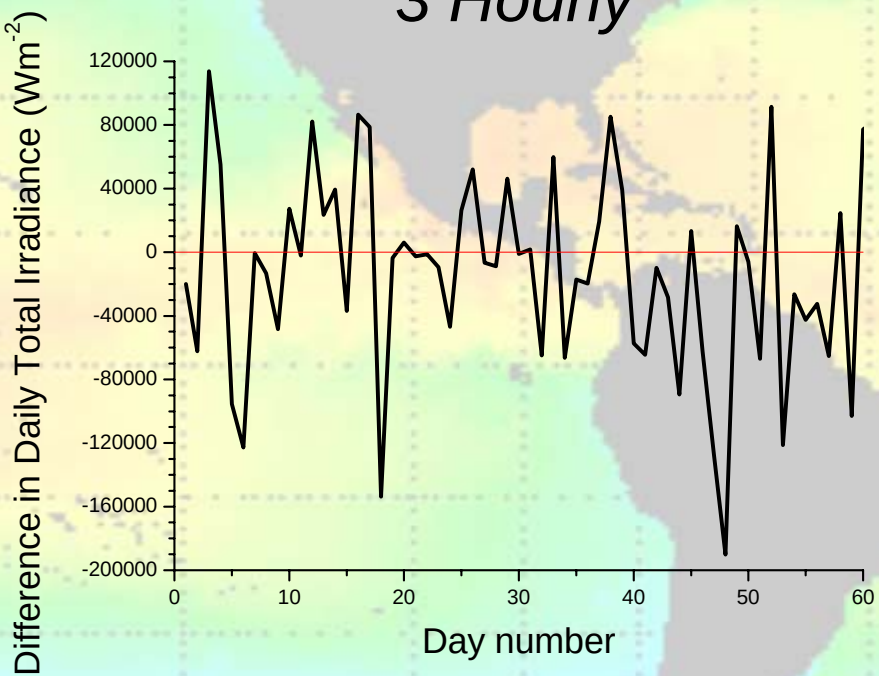
Issues of Temporal Resolution

Difference in Daily Total Irradiance

Hourly

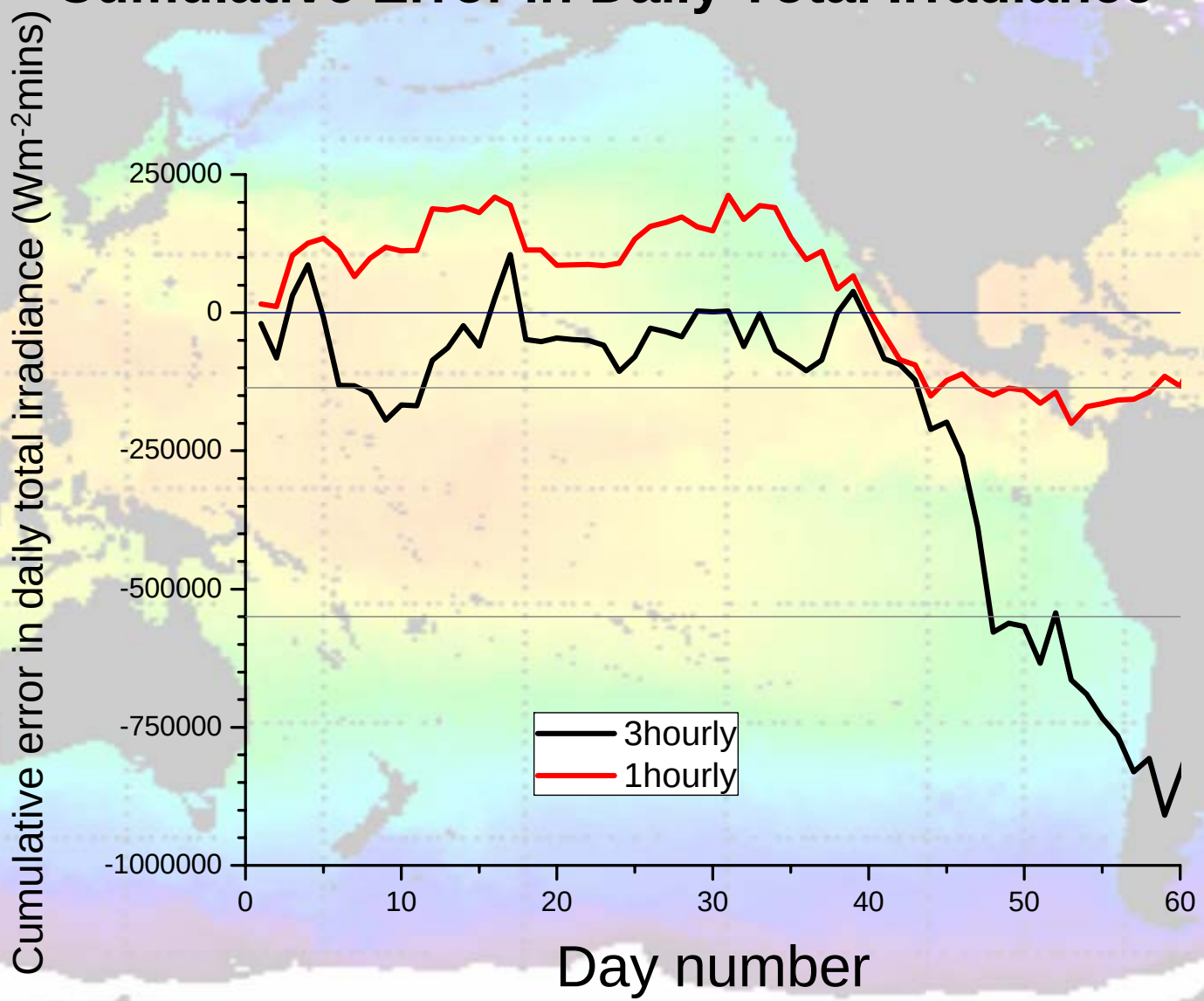


3 Hourly



Issues of Temporal Resolution

Cumulative Error in Daily Total Irradiance



Summary

- LSD algorithm goal: nrt predictions of coral bleaching onset, severity and resultant mortality
- Multi-national team as a result of World Bank/GEF CRTR Project
- LSD algorithm is nearing completion
- Aim is to use satellite data only
- 1st Test phase at Keppel Islands on GBR
- 2nd Test phase in Caribbean (Bermuda?)
- 3rd Test phase at selected global sites using satellite data (Carribean 2005 data?)