CORAL REEFS AND THE EFFECTS OF INCREASING SEA TEMPERATURE

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THE NIPPON FOUNDATION

pogo Partnership for Observation of the Global Oceans

AWI ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Formation of the coral skeleton

Carbon dioxide is removed from the atmosphere by dissolving in ocean water and forming carbonic acid.

CO_2 (g)+ H_2O (l) ↔ H_2CO_3 (aq) (carbonic acid)

Once dissolved into sea water, carbon dioxide is converted into bicarbonate (HCO_3^-) ions or carbonate (CO_3^{-2}) ions.

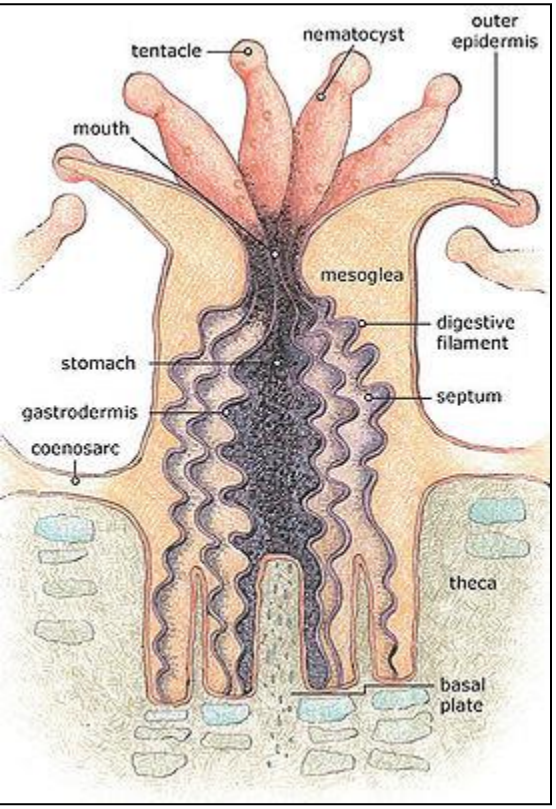
H_2CO_3 (aq) ↔ H^+ (aq) + HCO_3^- (aq)

HCO_3^- (aq) ↔ H^+ (aq) + CO_3^{-2} (aq)

Certain forms of sea life biologically fix bicarbonate with calcium (Ca^{+2}) to produce calcium carbonate ($CaCO_3$).

Ca^{+2}(aq)+2HCO_3^-(aq)↔$CaCO_3$(s)+CO_2 (g)+ H_2O(l)

A single coral is a colony of many individuals called polyps which are genetically identical

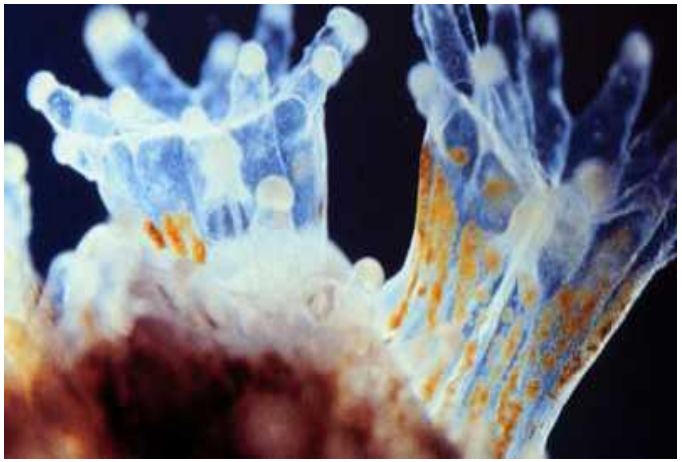


http://seaworld.org/AnimalInfo/Animal-Info/Animal-InfoBooks/Coral-and-Coral-Reefs/Physical-Characteristics

- Budding process (extratentacular & intratentacular)
- Multicellular
- Gastrovascular cavity
- No central nervous system

Zooxanthellae cells provide coral polyps with pigmentation

- endosymbiotic relationship facilitating nutrient cycling.
- Coral host provides a home together with inorganic nitrogen and phosphorous
- Coral host receives ~ 95% of energy in the form of organic compounds and energy rich ATP
- They live within the gastrodermis of the coral



http://www2.estrellamountain.edu/faculty/farabee/BIOBK/biobookdiversity_3.html

http://ethnology.wordpress.com/2011/07/12/e_2011_1_1/

There are three main types of corals:

- **Hard Coral/ Hexacoral / Stony Coral/ Hermatypic-**

These are the reef building corals with scleractinian skeleton comprising of calcium carbonate in the form of crystallized aragonite.

- **Soft Coral/ Alcyonacea / Ahermatypic/ Octocoral-**

Corals which do not produce calcium carbonate skeletons. They thrive in nutrient-rich waters with less intense light

- **Deep Sea Coral-**

include both hard corals and soft corals and do not contain zooxanthellae within their cells because they live too deep to rely upon sunlight.

Theories of reef formation

- Chamisso 1815-1818 - Coral reefs and atolls were formed by corals growing from the ocean floor to the surface of the sea; those on the outside flourished while those in the middle died giving a lagoon.

- Quoy and Gaimard 1823-1825 - Reef-building corals only flourish in shallow water and thus atolls were formed by corals growing on the rim of craters of submerged volcanoes.

- Darwin 1831-1836 – Subsidence theory leading to his idea of evolution of fringing to barrier to atoll reefs.

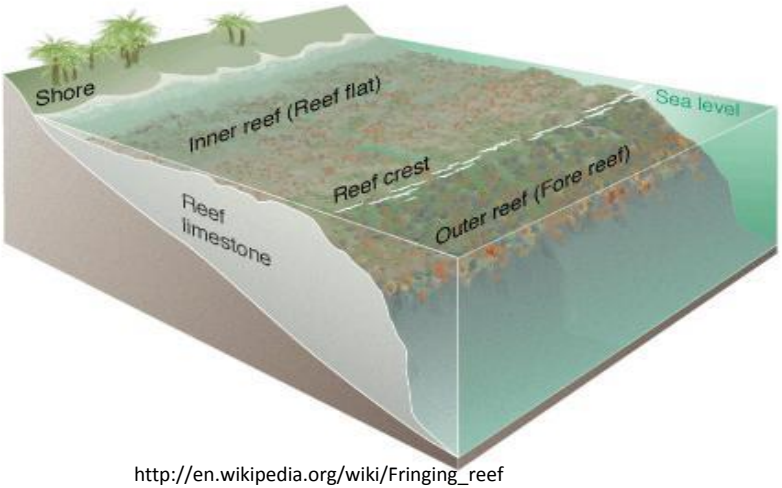
- Daly 1890's- Glacial theory – corals growing up as sea level rose.

- Modern models 1970's – Plate tectonic model, cyclicity of sea-level fluctuations, and rate of reef growth are all important in reef development.

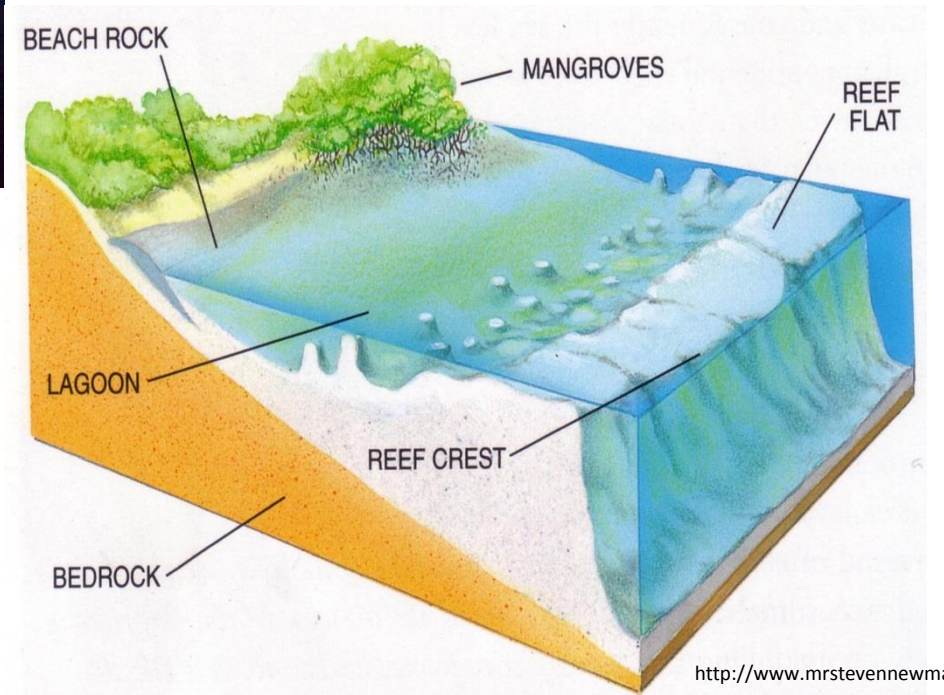
Depending on their structural characteristics coral reefs are generally described using three major reef types

- Fringing reefs

https://www.uwgb.edu/dutchs/EarthSC202Slides/coasslid.htm

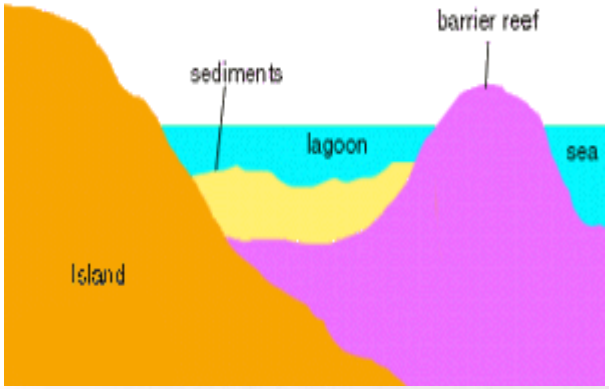


http://en.wikipedia.org/wiki/Fringing_reef



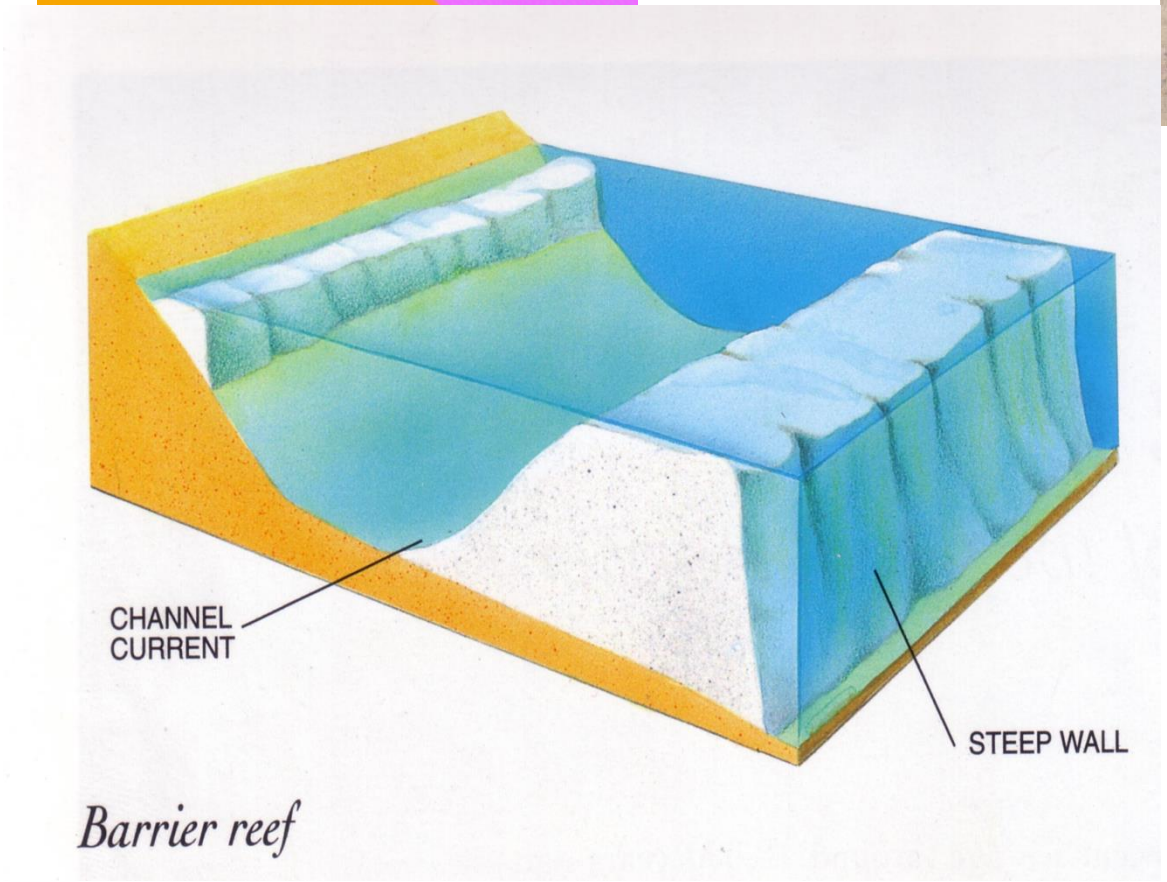
http://www.mrstevennewman.com/geo/GBR/Reefs/Barrier.htm

- **Barrier reefs**



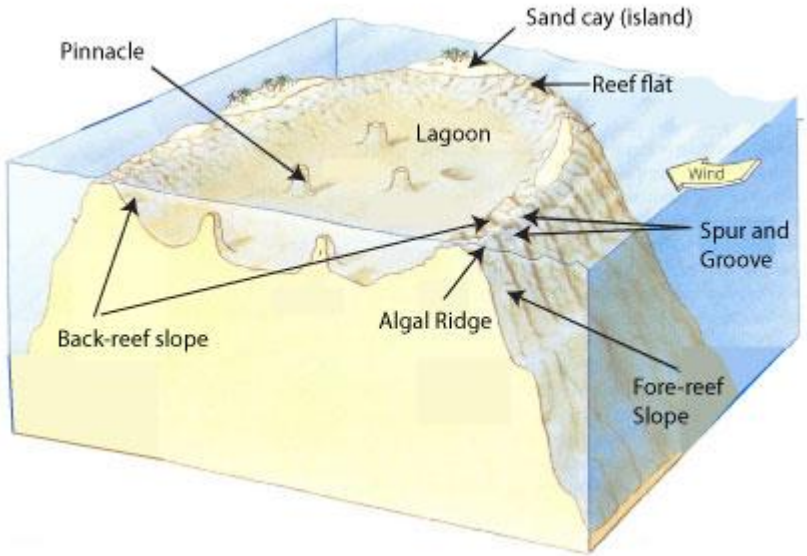
http://www.caribbeanedu.com/images/Viewer/view.asp?link=1948&searchterm=Martinique&CAT=

http://en.wikipedia.org/wiki/File:GreatBarrierReef-EO.JPG



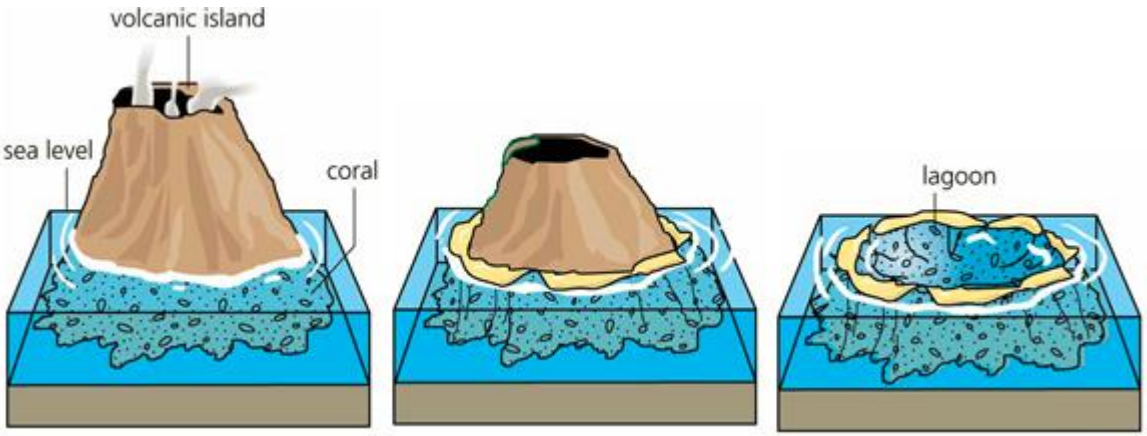
http://www.mrstevennewman.com/geo/GBR/Reefs/Barrier.htm

• Atoll reefs



http://dtc.pima.edu/blc/183/13_183/13_183answers.html

http://ambergriscaye.com/blueholetrip/



http://www.webquest.hawaii.edu/kahihi/sciencedictionary/A/atoll.php

Table 7.2. Classification criteria for main reef types.

Reef Type	Antecedent Shape	Location	Emergent	Lagoon	Control
Fringing Reef	Linear	Near shore	Yes	< 500m wide < 5m deep	Shoreline
Barrier Reef					
Bank Linear		Dictated by oceanography	Yes	>500 m wide >5m deep	Not necessary
Bench	Linear	Along Ante-cedent slope break	Yes	>500 m wide >5m deep	Bench or terrace
Atoll					
Volcanic	~Circular	At platform margin	Yes	central; deep	Volcanic cone
Other	~Equant to sub-circular	Margin of raised tectonic block	Yes	central	Tectonic blocks
Patch Reef	~Equant	Variable, but typically in lagoon	Usually	N/A	Variable; but often over a previous reef
Shelf Reef	Linear to, equant, but shorter than barrier reefs	Anywhere across the shelf	Yes	No	Variable, but often sit atop previous reefs
Submerged Shelf-Edge Reef	Linear	At shelf edge	No*	No	Shelf break

* If emergent, it is a barrier reef

http://geology.uprm.edu/Morelock/7_image/T2class.gif

Other reef formations

- **Patch reef** – common, isolated, comparatively small reef outcrop, usually within a lagoon or embayment, often circular and surrounded by sand or seagrass

- **Apron reef** – short reef resembling a fringing reef, but more sloped; extending out and downward from a point or peninsular shore

- **Bank reef** – linear or semicircular shaped-outline, larger than a patch reef

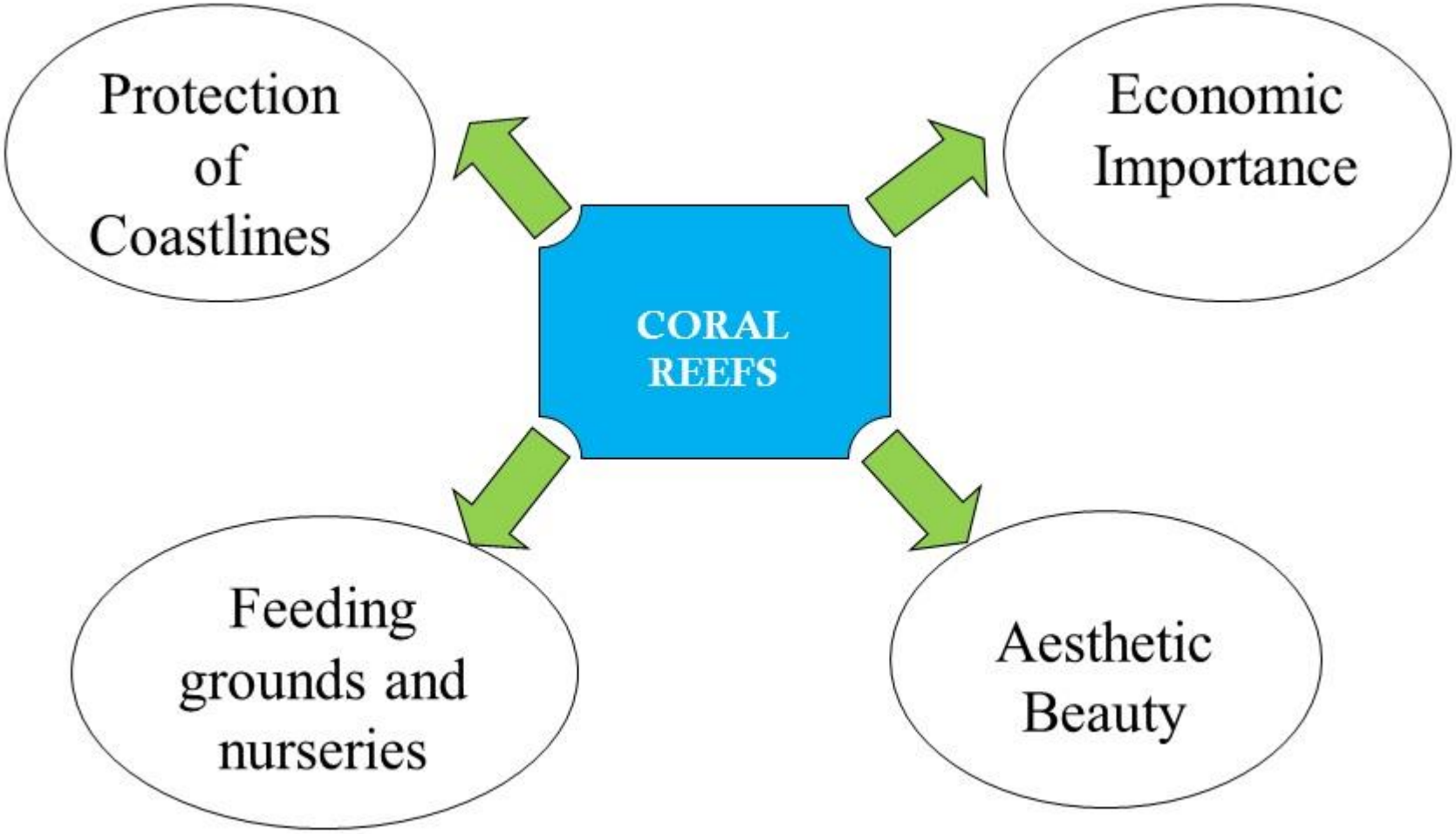
- **Ribbon reef** – long, narrow, possibly winding reef, usually associated with an atoll lagoon

- **Table reef** – isolated reef, approaching an atoll type, but without a lagoon

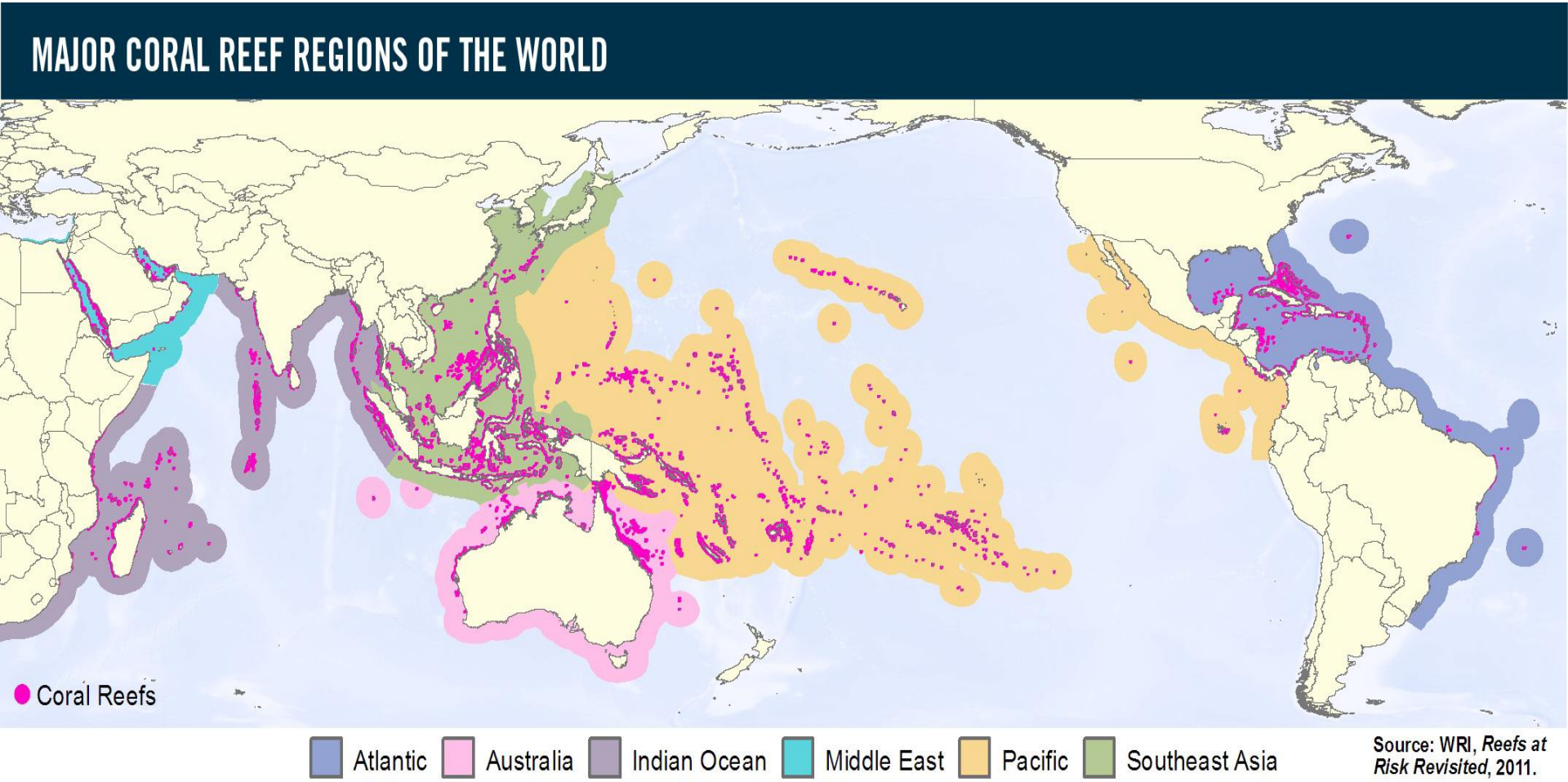
- **Habili** – reef specific to the Red Sea; does not reach the surface near enough to cause visible surf; may be a hazard to ships

- **Microatoll**– community of species of corals; vertical growth limited by average tidal height; growth morphologies offer a low-resolution record of patterns of sea level change; fossilized remains can be dated using radioactive carbon dating and have been used to reconstruct Holocene sea levels
- **Cays** – small, low-elevation, sandy islands formed on the surface of coral reefs from eroded material that piles up, forming an area above sea level; can be stabilized by plants to become habitable; occur in tropical environments throughout the Pacific, Atlantic and Indian Oceans (including the Caribbean and on the Great Barrier Reef and Belize Barrier Reef), where they provide habitable and agricultural land
- **Seamount** or **guyot** – formed when a coral reef on a volcanic island subsides; tops of seamounts are rounded and guyots are flat; flat tops of guyots, or *tablemounts*, are due to erosion by waves, winds, and atmospheric processes

Why are coral reefs important?



Global distribution of coral reefs



Corals exists with narrow tolerance limits

- Requires temperature within the general range of 20- 30 degrees Celsius. Extremely optimal conditions are within the range 25-29 degrees Celsius.
- They strive in high salinity (34-39 ppt)
- Moderate wave action and continuous currents
- Low of none existent turbidity levels

Reef are however sensitive species

http://article.wn.com/view/2010/12/09/Climate_goal_may_spell_end_for_some_coral_reefs/

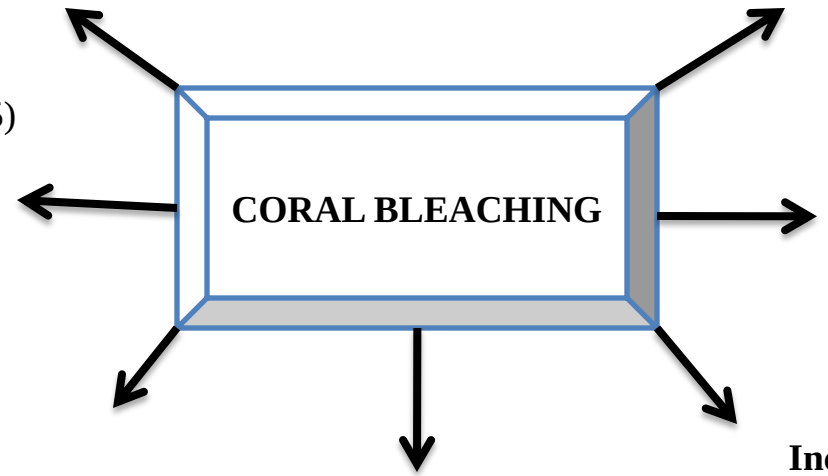
http://www.mytobago.info/diving06.php

- Reefs are environmentally sensitive species.
- Exposure to natural and anthropogenic threats has been degrading the reef at an alarming rate.

There are numerous stressors that can induce coral bleaching

Increased sea temperature
(Glynn & D'Croz 1991;
Fitt et al. 2001;
Coles & Jokiel 1978;
Eakin et al. 2010;
Brown 1997;
McWilliams et al. 2005)

Oil Contamination
(Guzman et al. 1991)



Low Salinity
(Goreau 1964;
Coles and Jokiel 1978)

Exposure to Low Tide
(Vaughan 1914;
Yonge and Nicholls 1931b)

Sedimentation
(Meehan & Ostrander 1997;
Phillip and Fabricius 2003)

Infectious Disease
(Kushmaro el al. 1996, 1998;
Ben-Haim and Rosenberg 2002)

Increase Irradiance
(Lesser et al. 1990)

What is coral bleaching?

- It is a condition that disrupts the symbiosis between the algal symbiont (zooxanthellae) and its coral host.

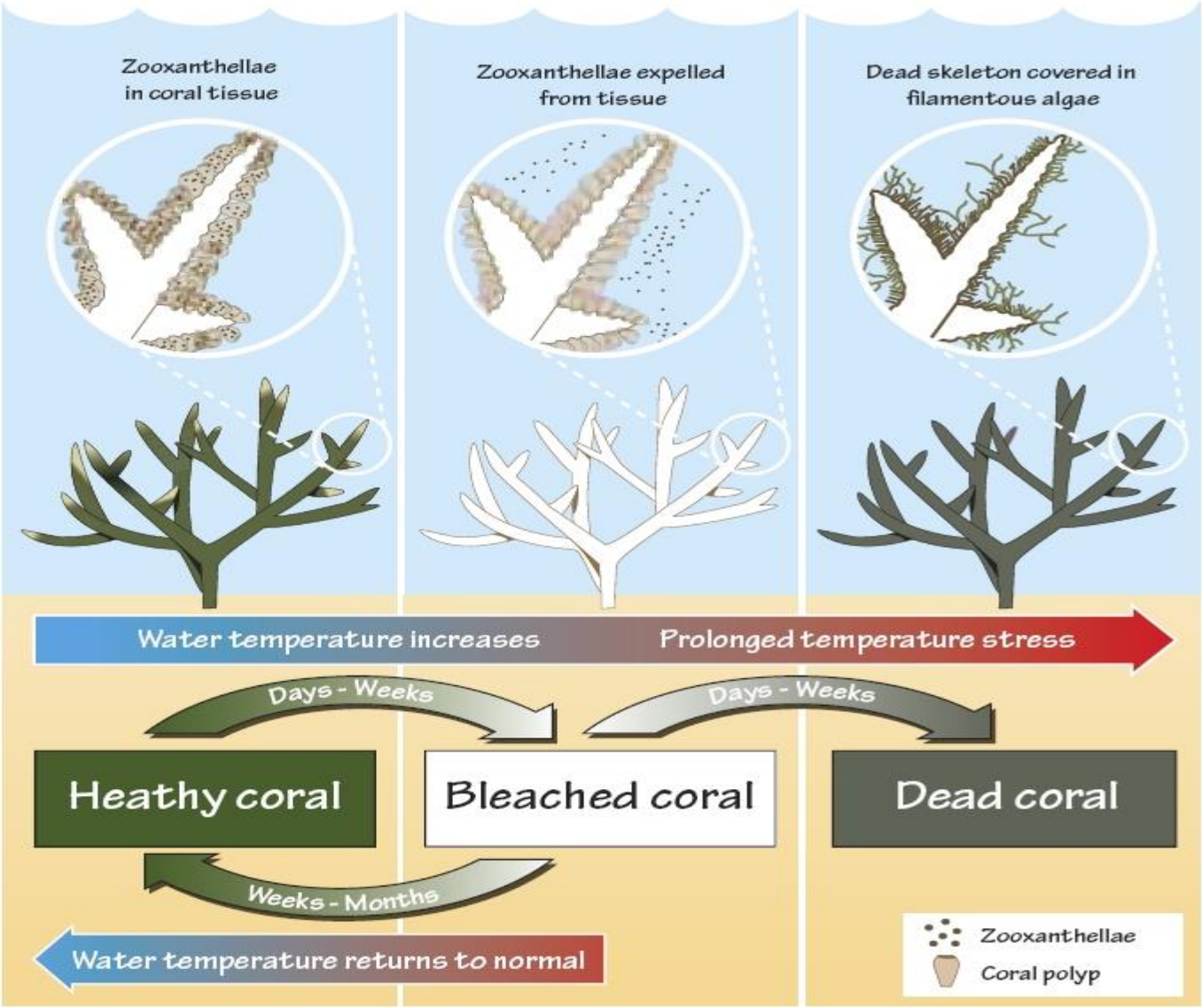
- Many corals can recover from bleaching but this may not be so if the events are severe, frequent and prolonged resulting in coral mortality.

The effects of elevated sea temperature on coral bleaching

Healthy coral

Bleached coral

Dead coral

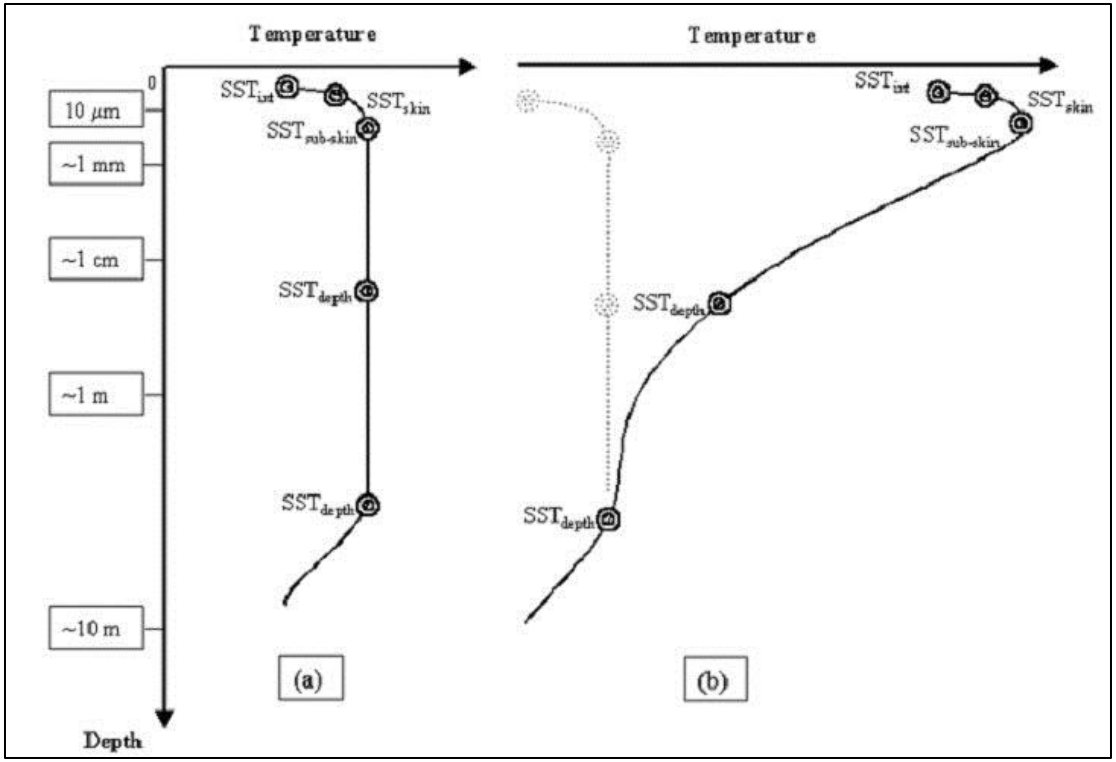


http://www.reefteach.com.au/about-the-reef/climate-change/coral-bleaching/

WHY USE SATELLITE DERIVED SST DATASET?

IN – SITU DATA		SATELLITE SST DATA	
ADVANTAGE	**DISADVANTAGE**	**ADVANTAGE**	**DISADVANTAGE**
Data can be taken at different points to determine temperature gradients within the reef.	Limited spatial coverage	Ability of providing the synoptic view of large areas	High temperatures in shallow waters near coast tend to be underestimated.
	It enlarges the margin of error between one measurement and the next	Has been performed routinely	
	Expensive	Free and accessible	

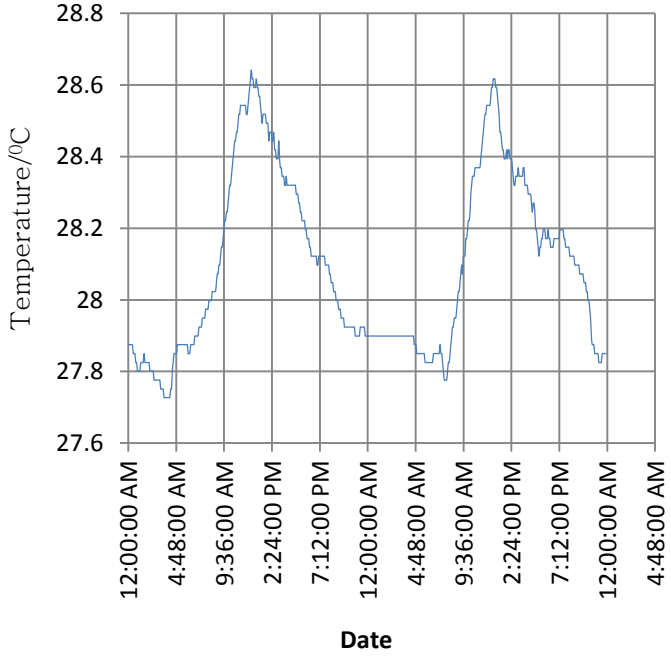
Vertical profile of temperature variations with depth during the night and the day



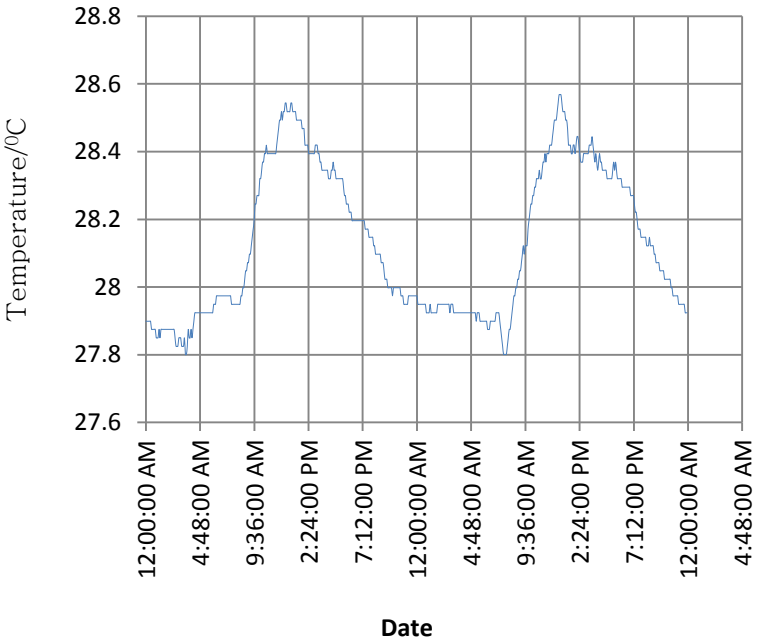
http://disc.sci.gsfc.nasa.gov/oceans/science-focus/modis/MODIS_and_AIRS_SST_comp.shtml

(a) represents the vertical profile of temperature at night with low winds and (b) represents the vertical profile of temperature during the daytime with high solar radiation and low winds.

Differences between Daytime and Nighttime Sea Temperatures at 2m and 5m benthic areas



Temperature variability at the 2m depth in Buccoo Reef, Tobago from the 23rd-24th June, 2013.



Temperature variability at the 5m depth in Buccoo Reef, Tobago from the 23rd-24th June, 2013.

Monitoring coral bleaching

- NOAA CRW has been providing real-time 50km global satellite coral bleaching monitoring since 1997.

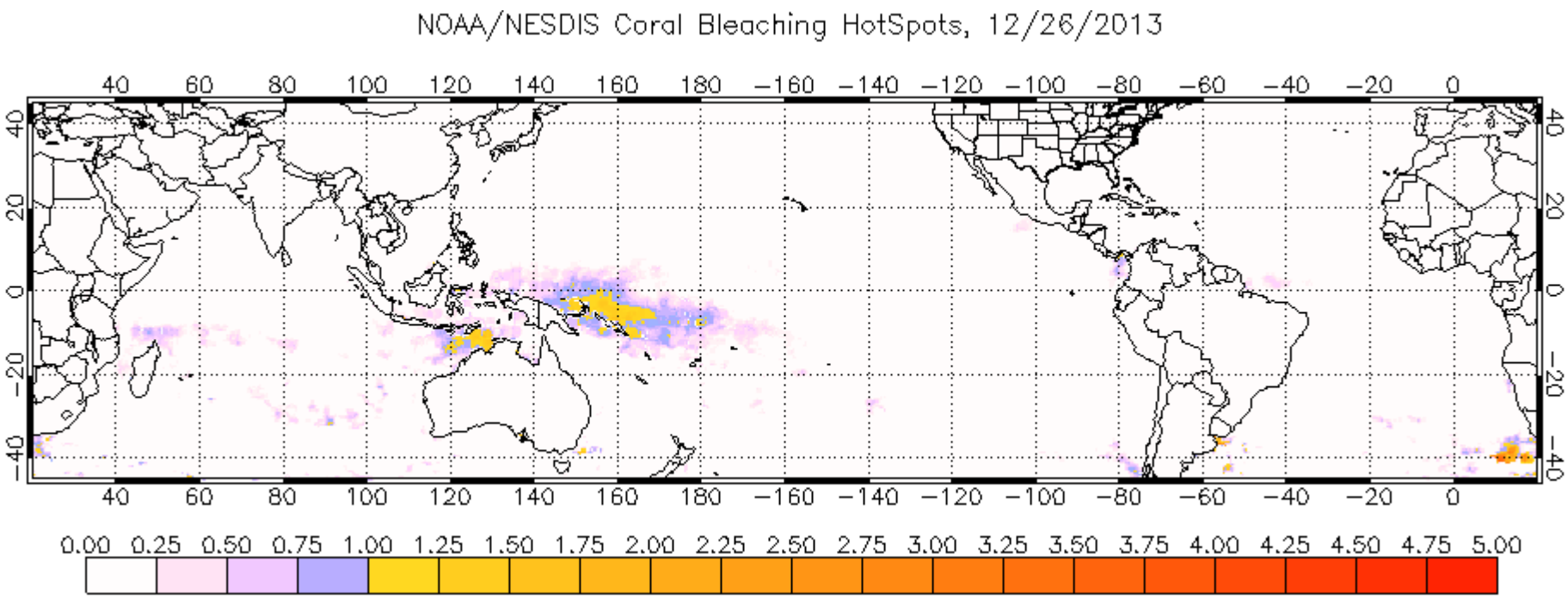
- NOAA Coral Reef Watch (CRW) methodology for 50km SST are used to create the following products :

1) **Maximum Monthly Mean (MMM)**

1) **HotSpot (HS)**

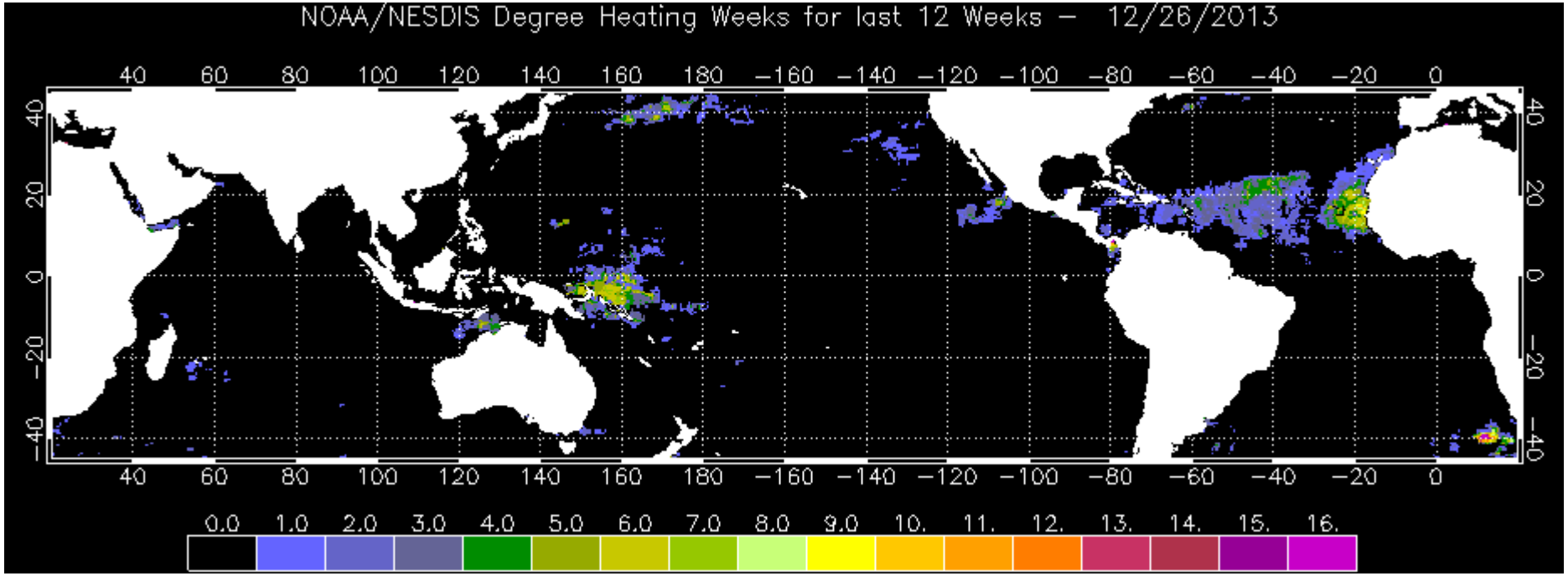
1) **Degree Heating Week (DHW)**

- **HS**- measure the occurrence and magnitude of thermal stress potentially conducive to coral bleaching. This means corals are vulnerable to bleaching when SST exceeds the temperature normally experienced in the hottest month.



http://coralreefwatch.noaa.gov/satellite/hotspot.php

- **DHW**- this basically sums up the HS greater than 1°C and is recorded over the past 12weeks. It is therefore a cumulative measurement of the intensity and duration of thermal stress.



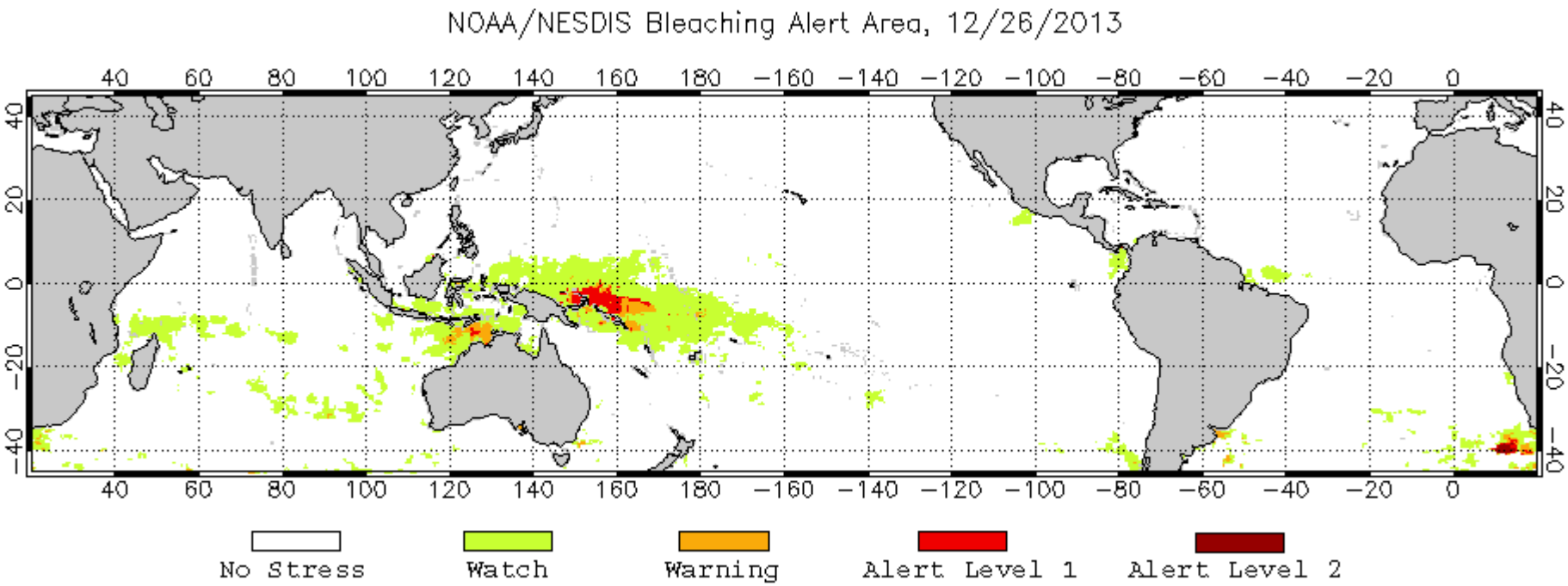
http://coralreefwatch.noaa.gov/satellite/hotspot.php

Criteria for coral bleaching warning alert

HOTSPOTS (^{o}C)	DEGREE HEATING WEEKS (^{o}C-Weeks)	ALERT STRESS
HS <=0	--	NO STRESS
0<HS<1	--	WATCH
1<=HS	1<=DHW<4	WARNING
	4<=DHW<8	ALERT LEVEL1
	8<=DHW	ALERT LEVEL 2

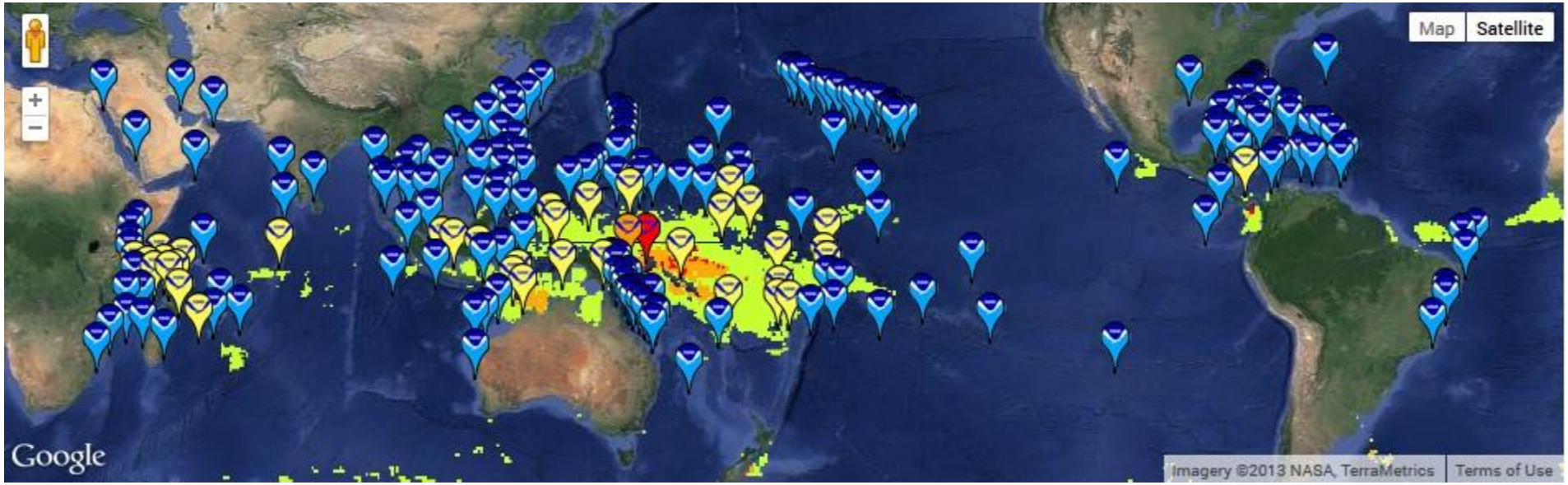
http://www.incois.gov.in/portal/images/Coral%20Bleaching%20Alert%20System%20technical%20document.pdf

Global thermal stress for 26/12/2013



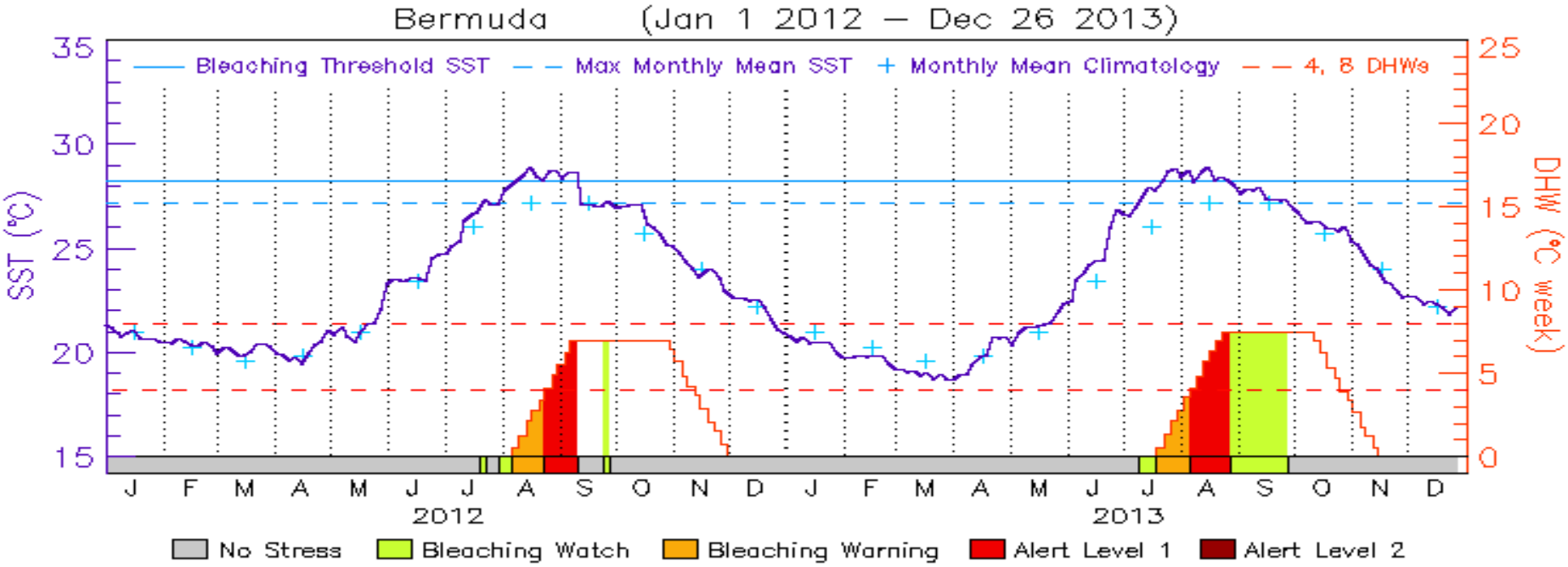
http://coralreefwatch.noaa.gov/satellite/hotspot.php

Coral reefs monitoring stations around the globe



http://coralreefwatch.noaa.gov/satellite/vs/index.php

Thermal stress observed in Bermuda 2012-2013



http://www.ospo.noaa.gov/data/cb/TS_vs/vs_ts_2yr_Bermuda.png

Pogonian countries monitored by this system

Stations

- 6 Brazil
- 1 Trinidad & Tobago
- 2 Cuba
- 16 Florida (USA)
- 11 Indonesia
- 2 India
- 2 Tanzania
- 3 Thailand

http://www.ospo.noaa.gov/data/cb/EAS_vs/vs_summary_stress_current.txt

THANK YOU