Temperature anomaly trends correlate with coral reef trajectories across the Pacific

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3) Khaled bin Sultan Living Oceans
Foundation

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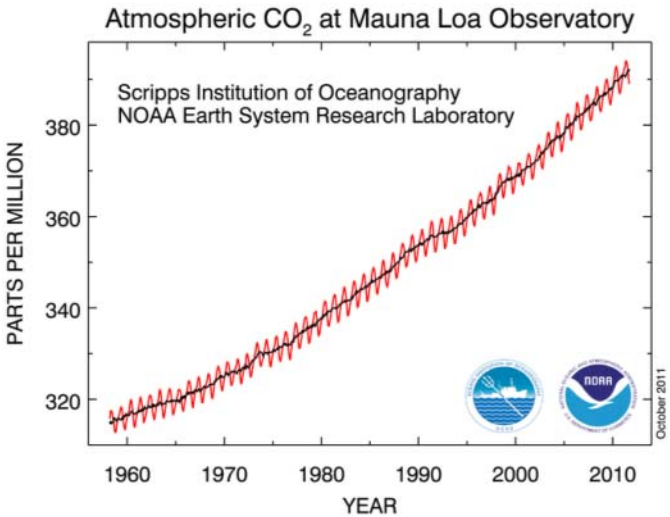

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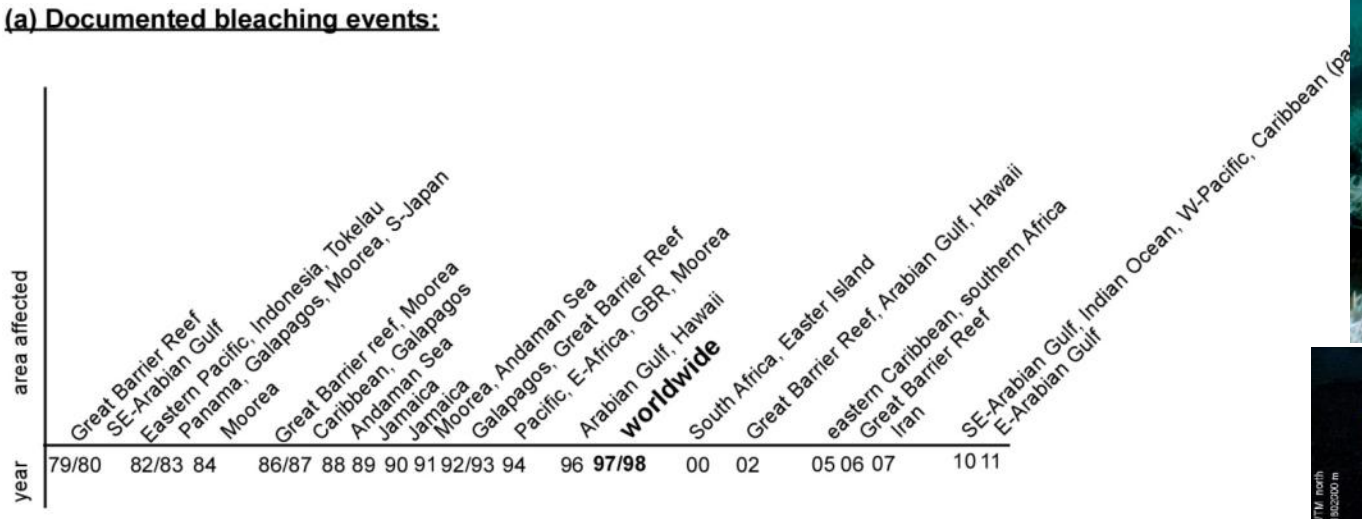
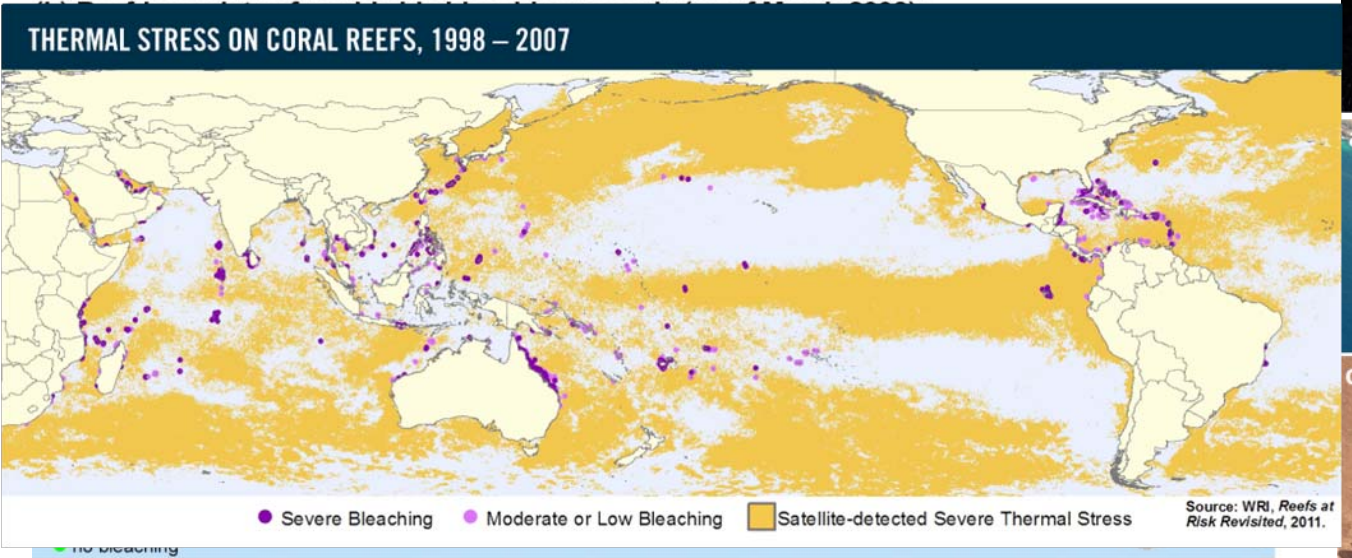
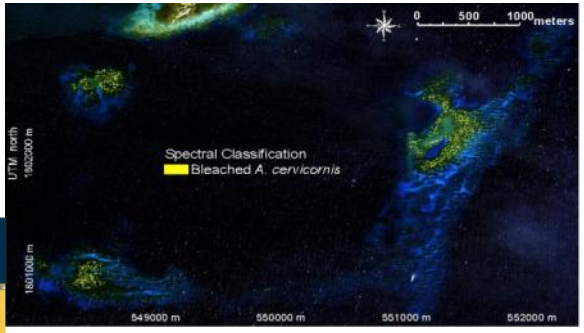
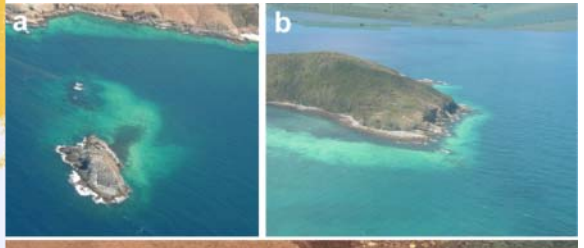
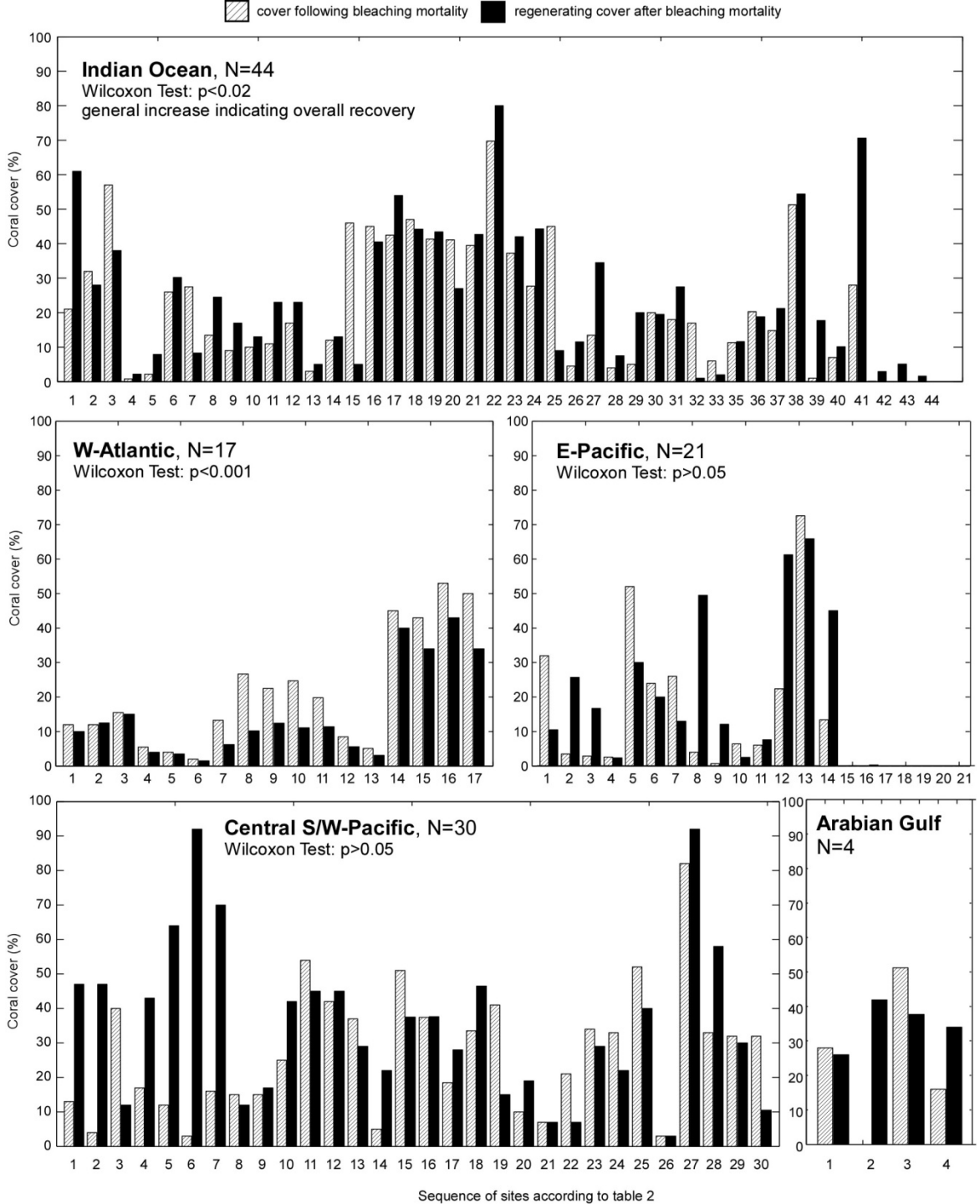
The issue: coral death by bleaching….but why?

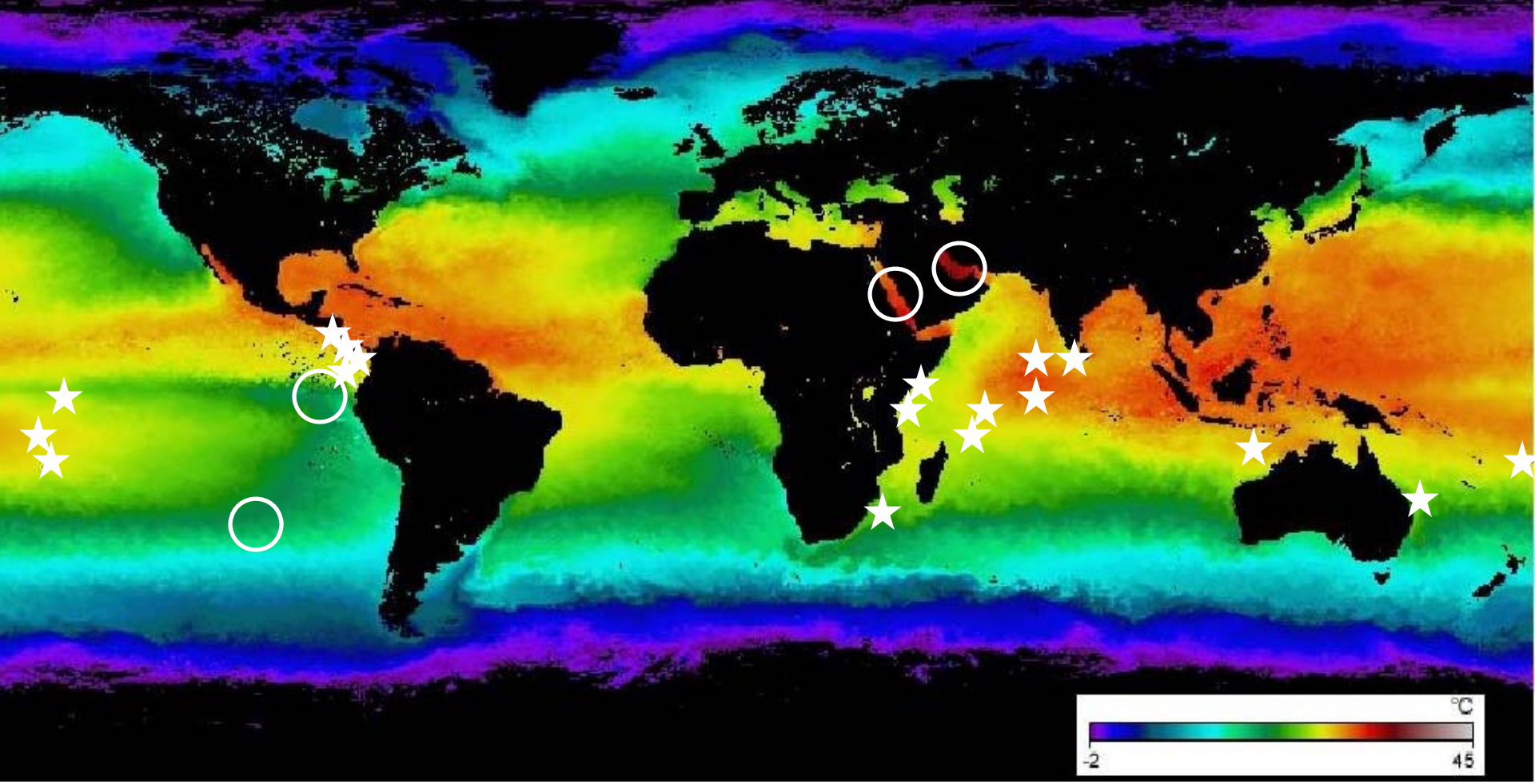









cover following bleaching mortality
regenerating cover after bleaching mortality
Indian Ocean, N=44
Wilcoxon Test: p<0.02
general increase indicating overall recovery
W-Atlantic, N=17
Wilcoxon Test: p<0.001
E-Pacific, N=21
Wilcoxon Test: p>0.05
Central S/W-Pacific, N=30
Wilcoxon Test: p>0.05
Arabian Gulf
N=4
Coral cover (%)
Sequence of sites according to table 2

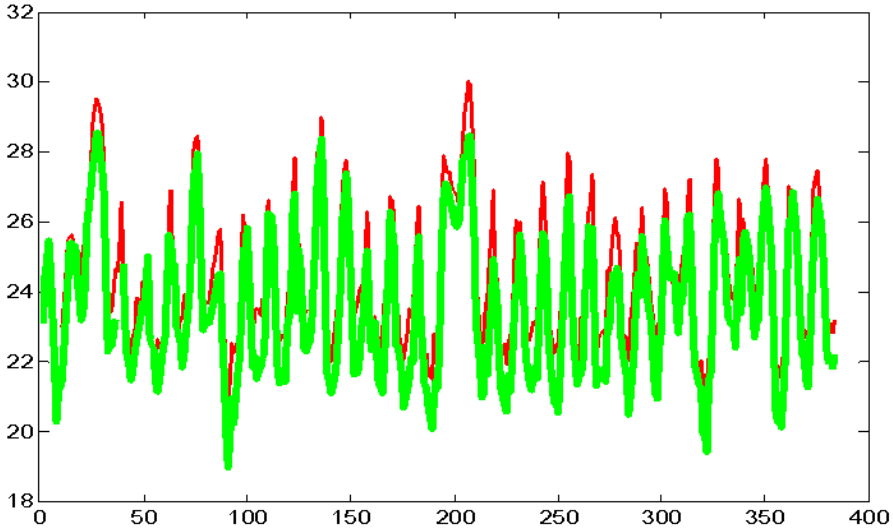


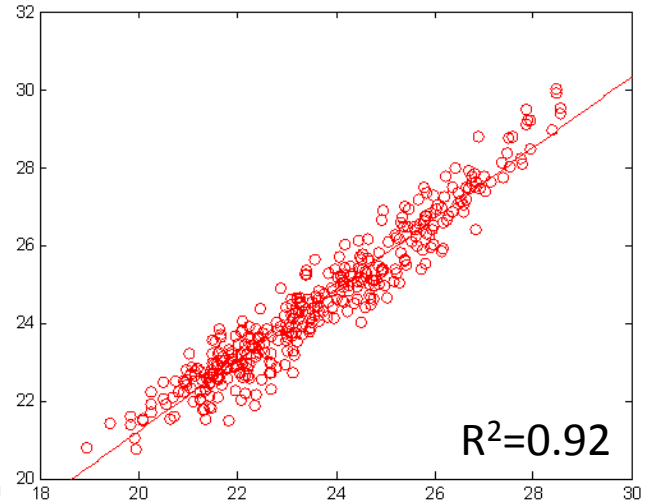
Gulf and Red Sea are the hottest Coral seas on Earth (in summer)

Galapagos and Easter Island the coldest

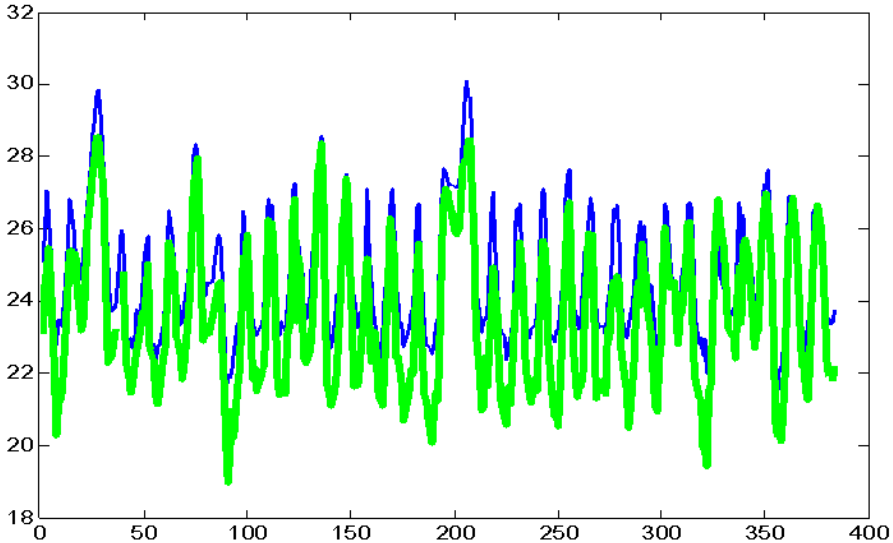
Q1: Are the data any good?

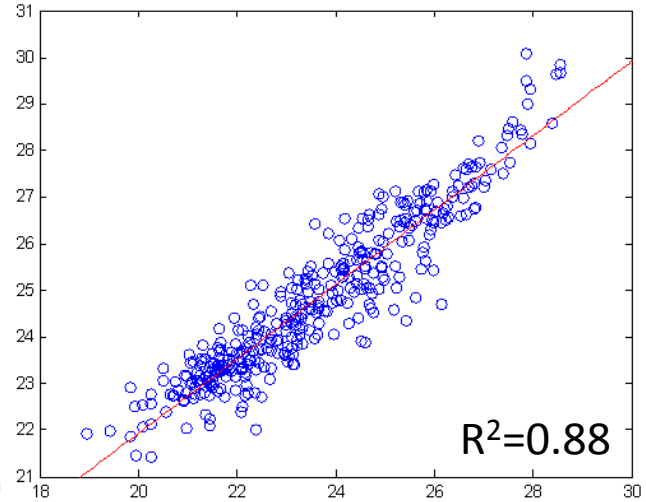
Reynolds OISST v.2 against in-situ data (1981-2012),
Puerto Ayora, Galapagos





HadISST v.2 against in-situ data (1981-2012),
Puerto Ayora, Galapagos



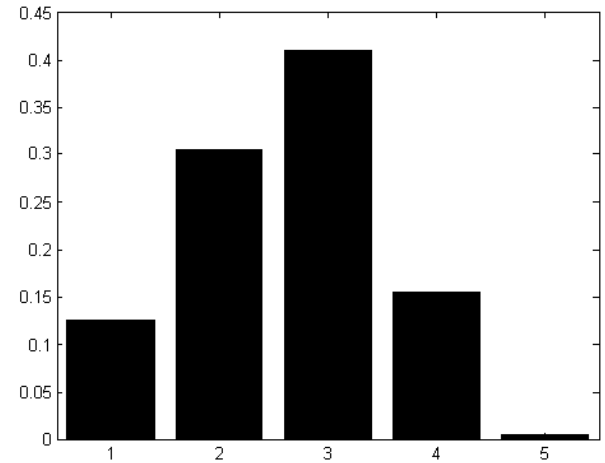


Q2: If good, are the data sufficient?

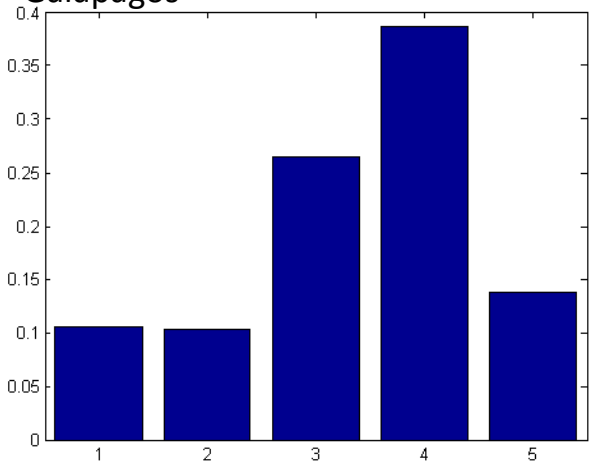
Size classes (radius):

1=1-5cm
2=5-10cm
3=10-20cm
4=20-50cm
5=>50cm

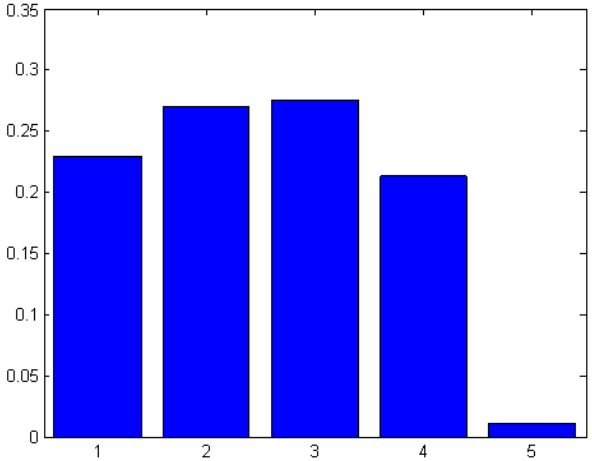
Arabian Gulf



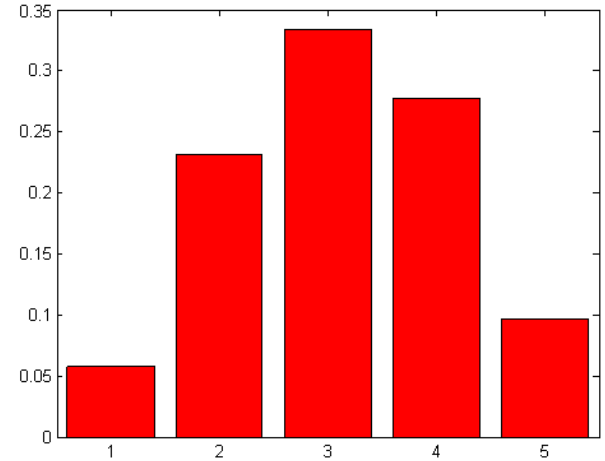
Galapagos

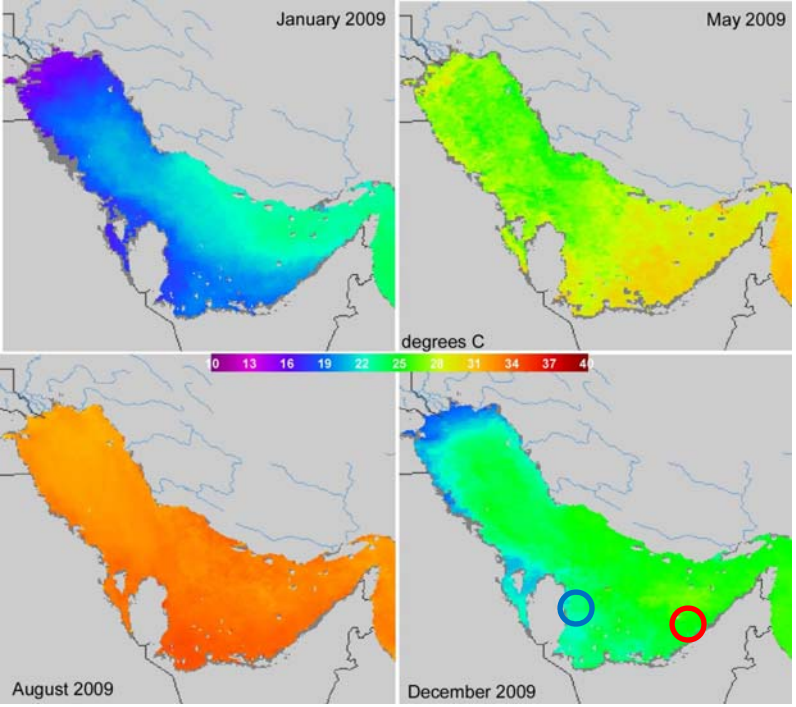


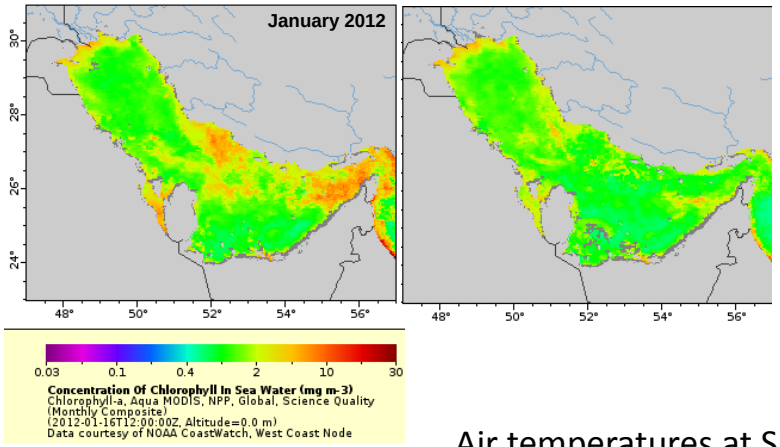
Easter Island



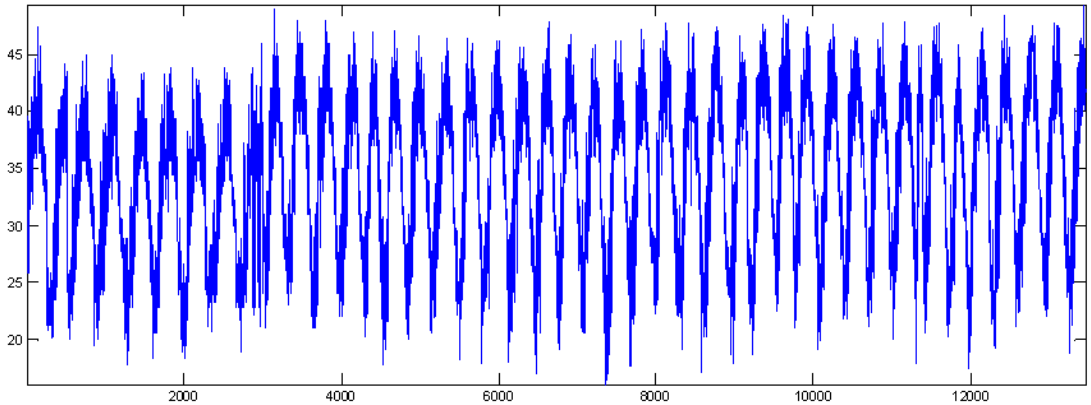
Red Sea

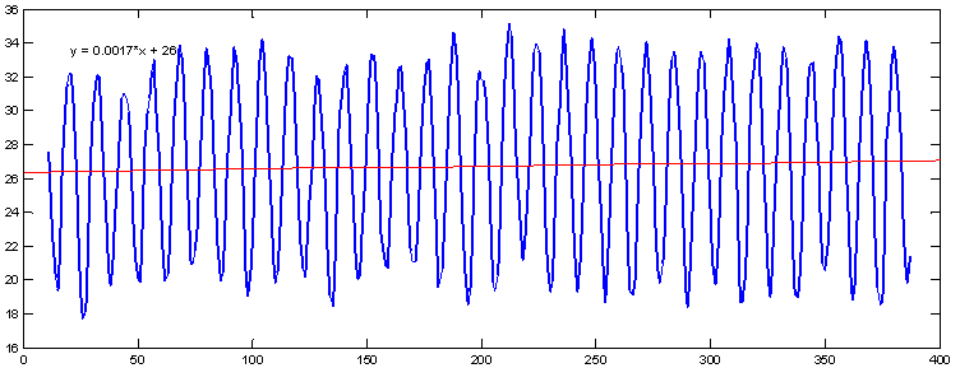


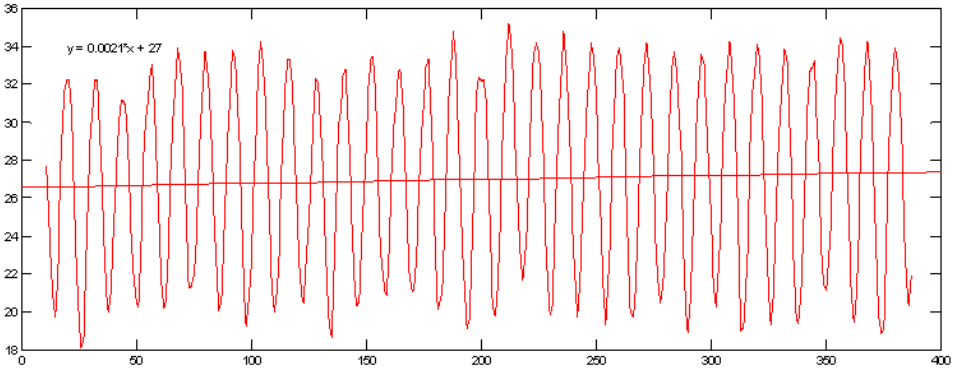


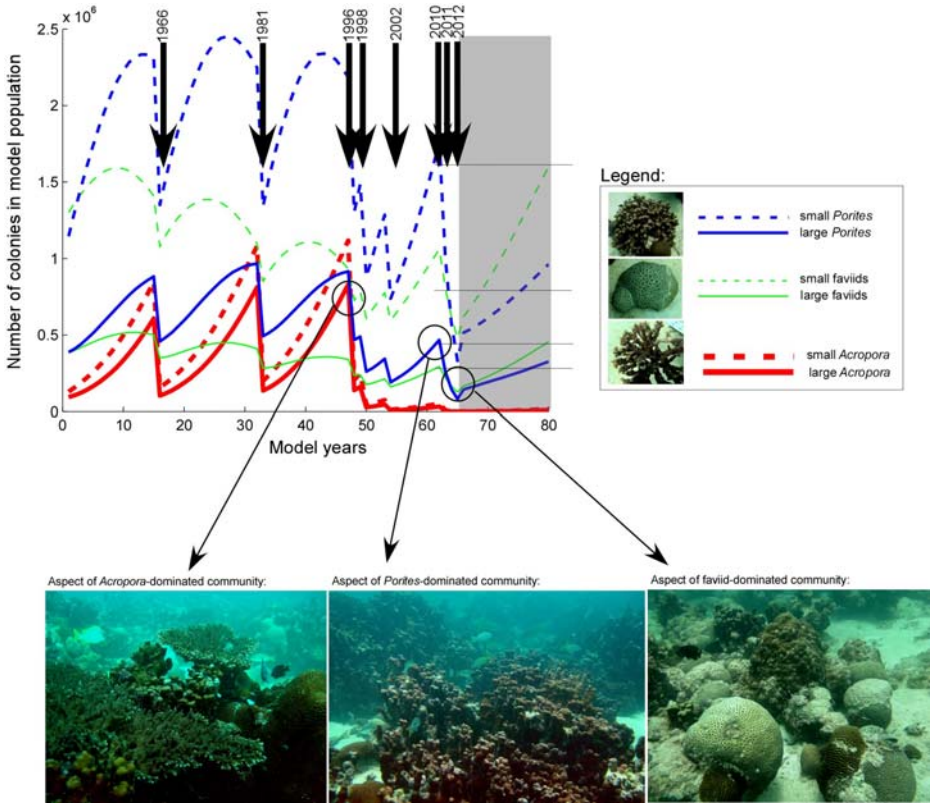


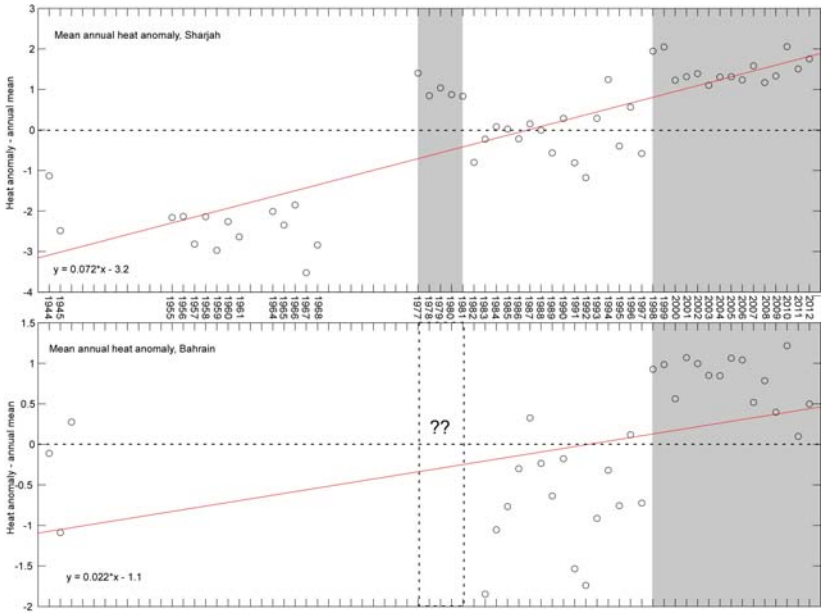
Air temperatures at Sharjah Airport

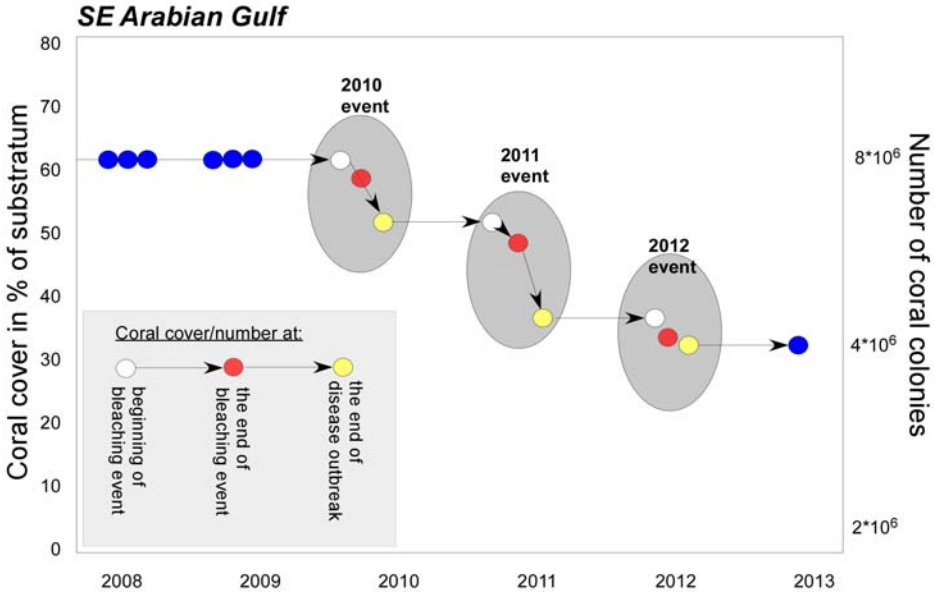


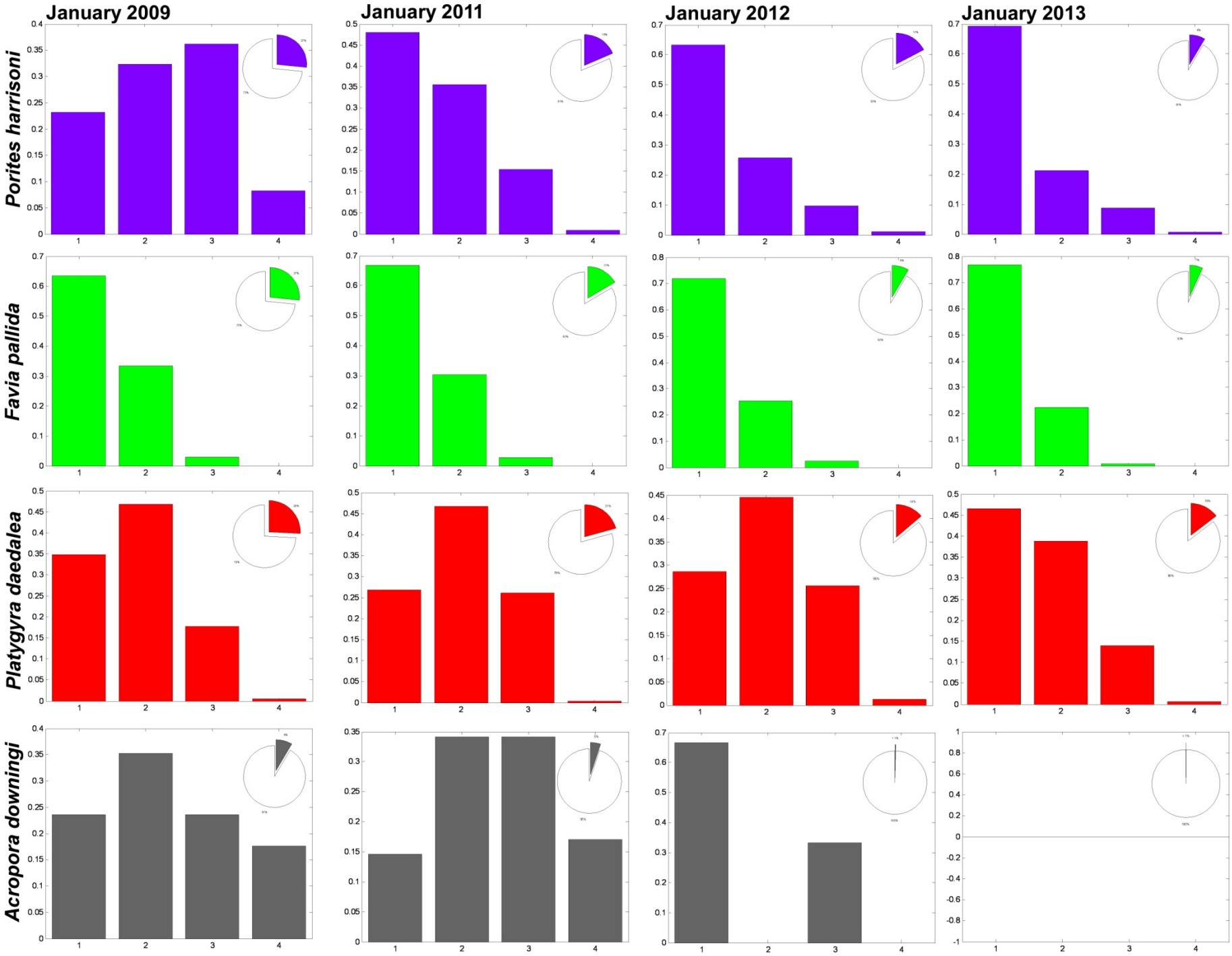


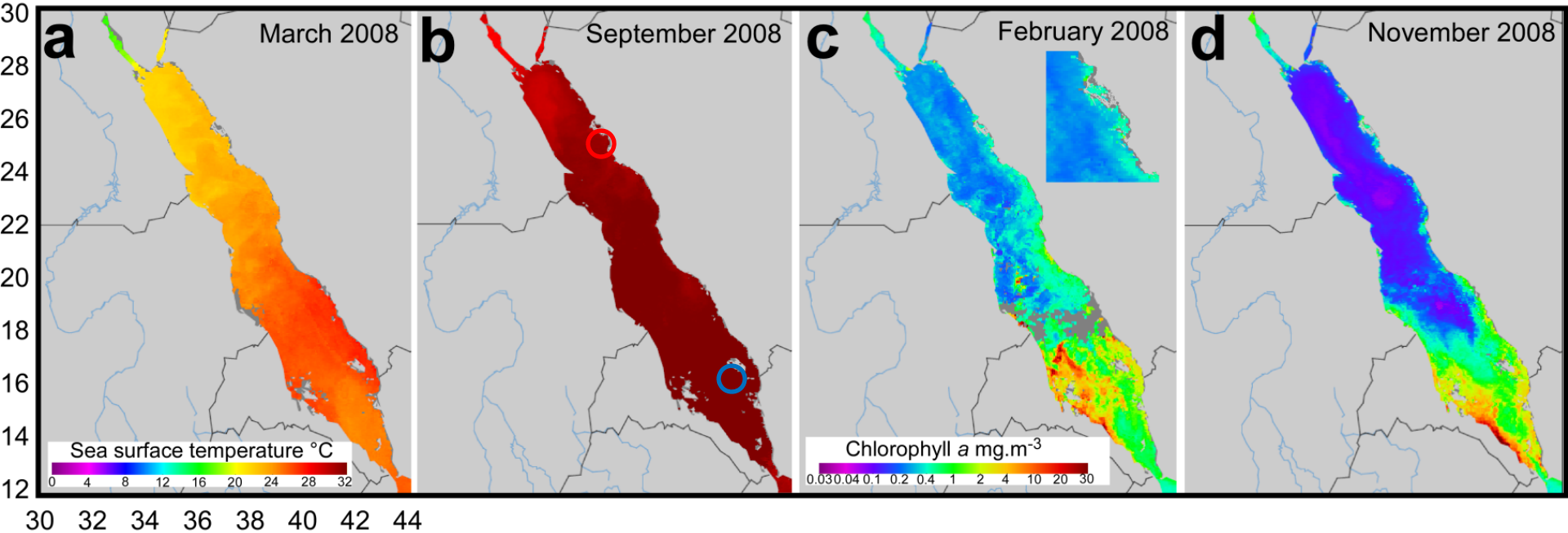


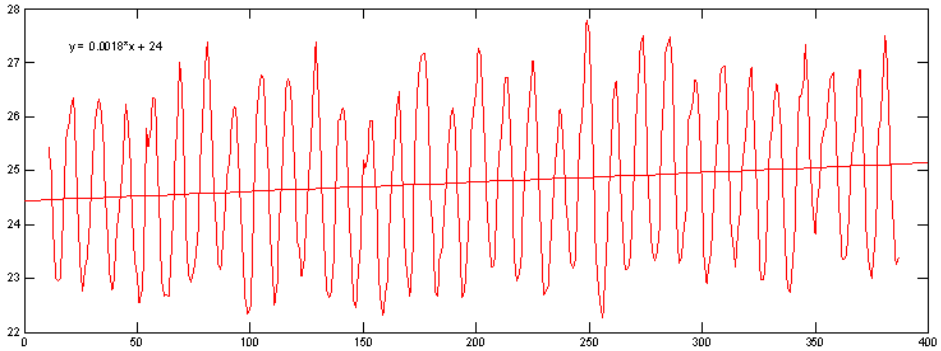

x 10^6
1966
1981
1996
1998
2002
2010
2011
2012
Number of colonies in model population
Model years
Legend:
small Porites
large Porites
small faviids
large faviids
small Acropora
large Acropora
Aspect of Acropora-dominated community:
Aspect of Porites-dominated community:
Aspect of faviid-dominated community:

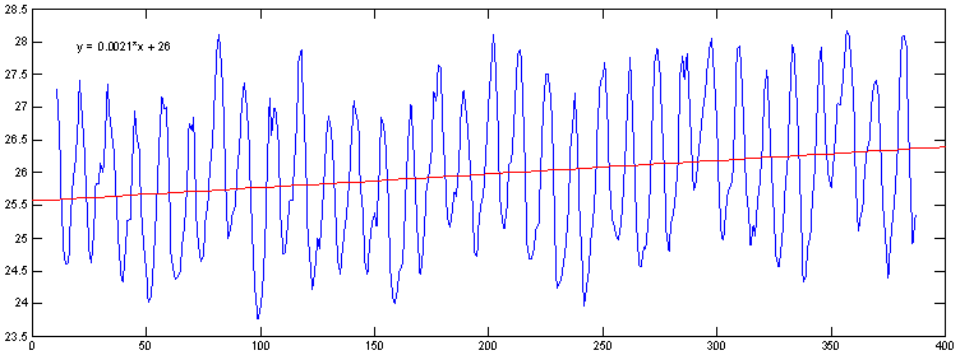

Mean annual heat anomaly, Sharjah
Heat anomaly - annual mean
y = 0.072*x - 3.2
Mean annual heat anomaly, Bahrain
??
y = 0.022*x - 1.1

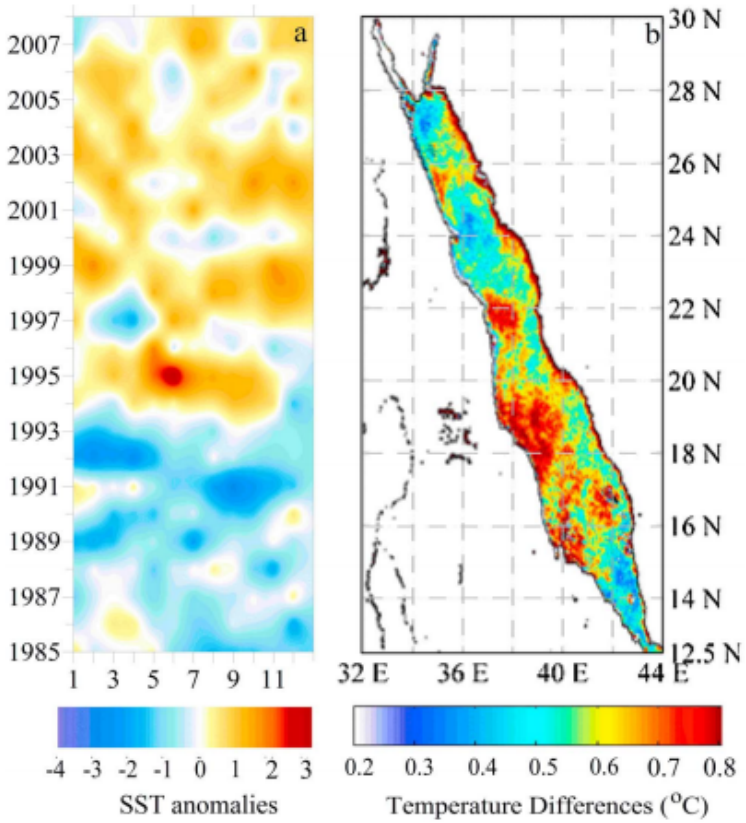

SE Arabian Gulf
Coral cover in % of substratum
Number of coral colonies
2010 event
2011 event
2012 event
Coral cover/number at:
beginning of bleaching event
the end of bleaching event
the end of disease outbreak
8*10^6
4*10^6
2*10^6
2008
2009
2010
2011
2012
2013

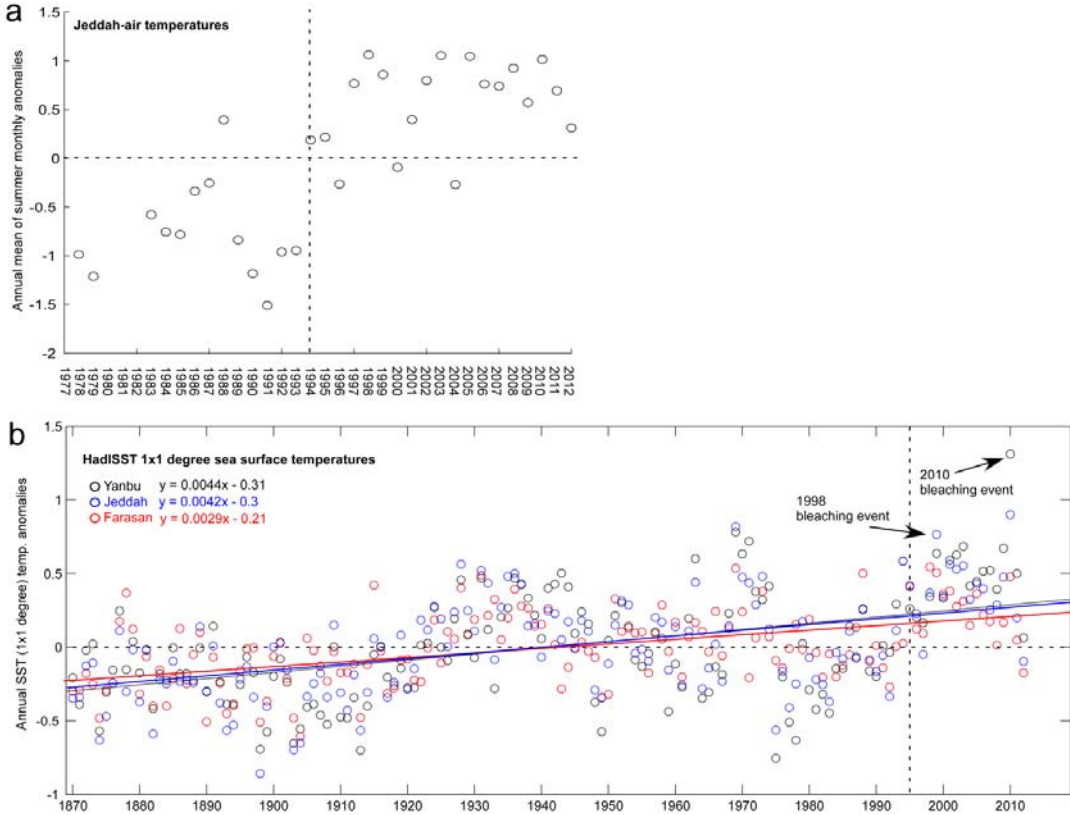

January 2009
January 2011
January 2012
January 2013
Porites harrisoni
Favia pallida
Platygyra daedalea
Acropora downingi

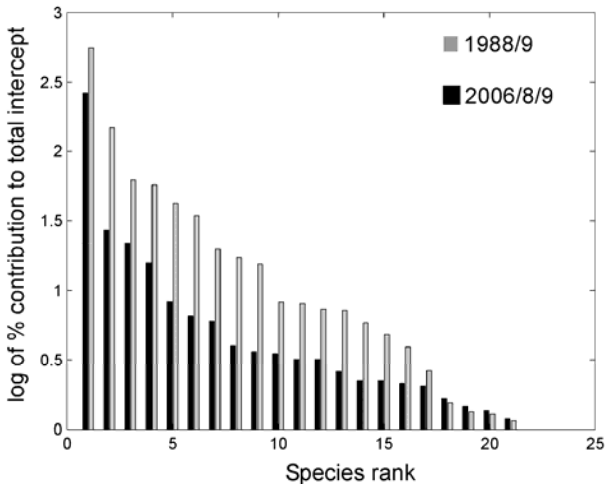

a
March 2008
b
September 2008
c
February 2008
d
November 2008
Sea surface temperature °C
0 4 8 12 16 20 24 28 32
Chlorophyll a mg.m-3
0.03 0.04 0.1 0.2 0.4 1 2 4 10 20 30
30 28 26 24 22 20 18 16 14 12
30 32 34 36 38 40 42 44

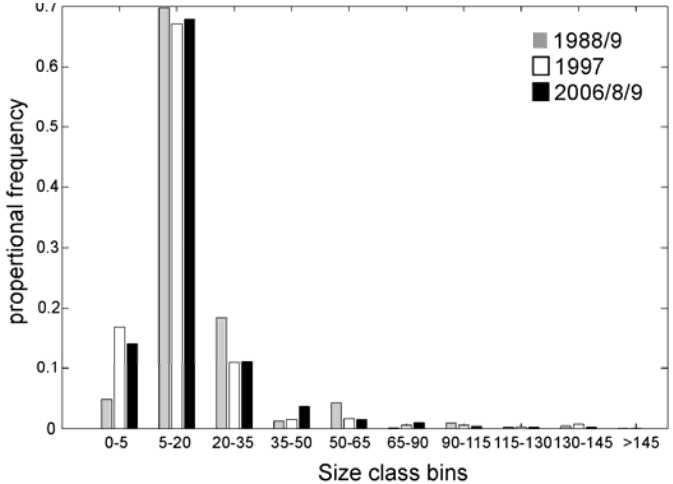

y = 0.0018*x + 24

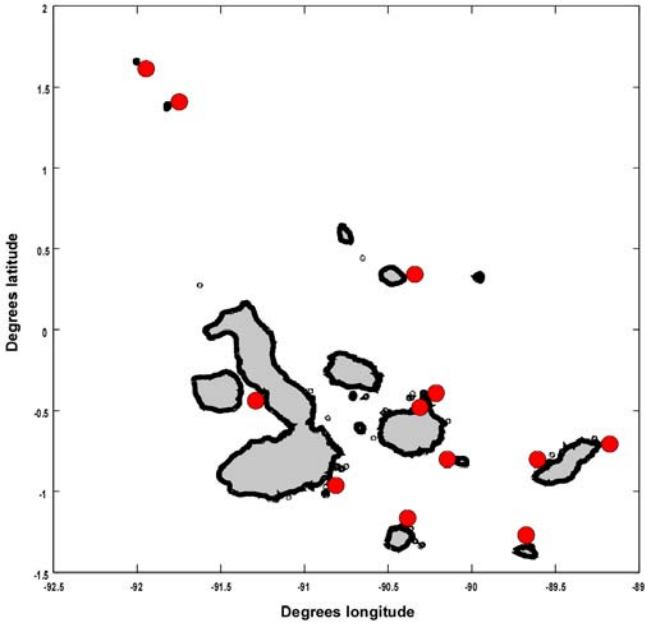

y = 0.0021*x + 26

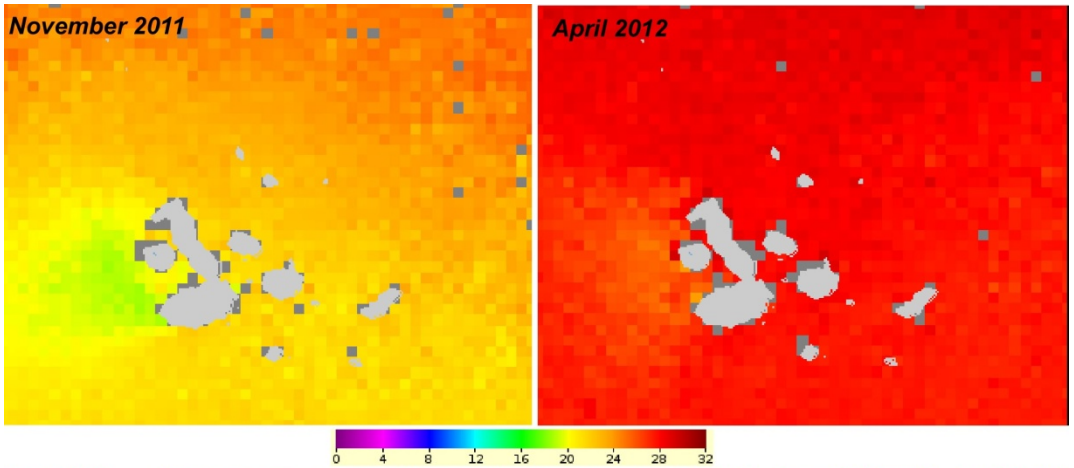

a
b
2007
2005
2003
2001
1999
1997
1995
1993
1991
1989
1987
1985
1 3 5 7 9 11
30 N
28 N
26 N
24 N
22 N
20 N
18 N
16 N
14 N
12.5 N
32 E
36 E
40 E
44 E
-4 -3 -2 -1 0 1 2 3
SST anomalies
0.2 0.3 0.4 0.5 0.6 0.7 0.8
Temperature Differences (°C)

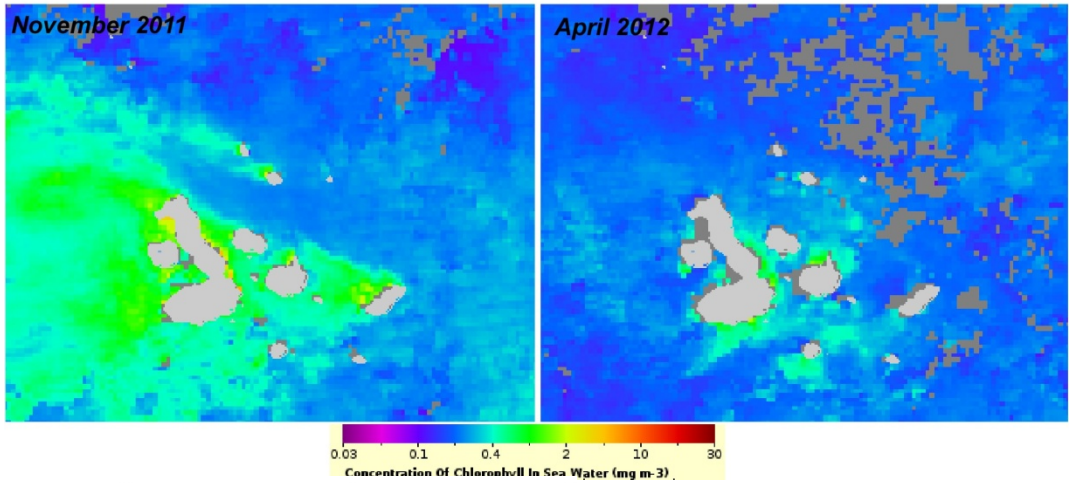

a
Jeddah-air temperatures
Annual mean of summer monthly anomalies
b
HadISST 1x1 degree sea surface temperatures
Yanbu y = 0.0044x - 0.31
Jeddah y = 0.0042x - 0.3
Farasan y = 0.0029x - 0.21
1998 bleaching event
2010 bleaching event
Annual SST (1x1 degree) temp. anomalies

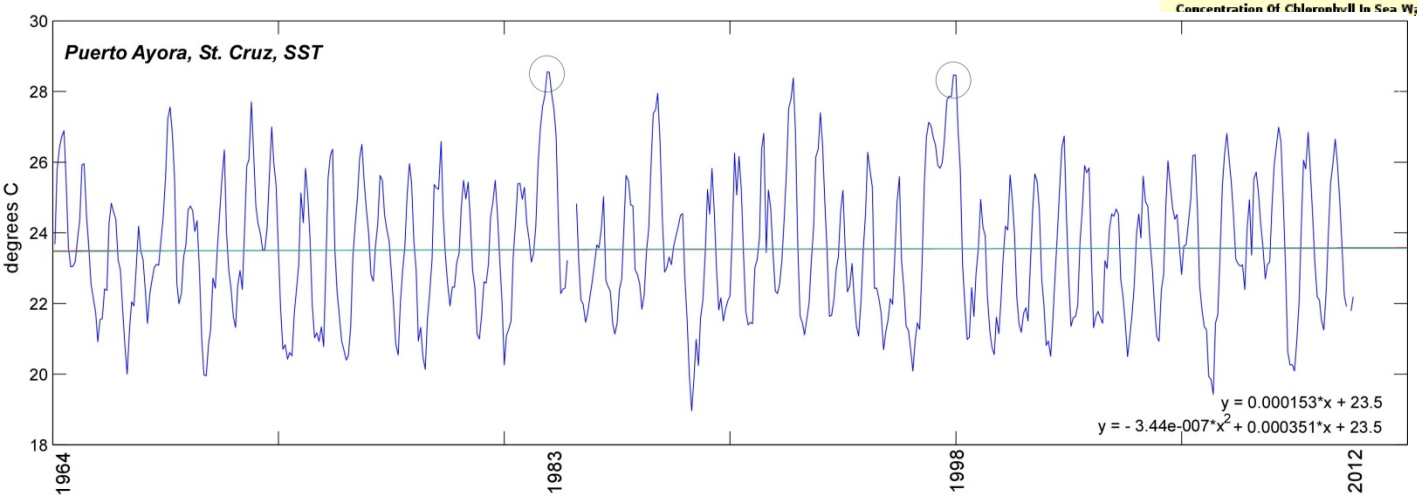

1988/9
2006/8/9
log of % contribution to total intercept
Species rank


1988/9
1997
2006/8/9
propertional frequency
0-5
5-20
20-35
35-50
50-65
65-90
90-115
115-130
130-145
>145
Size class bins

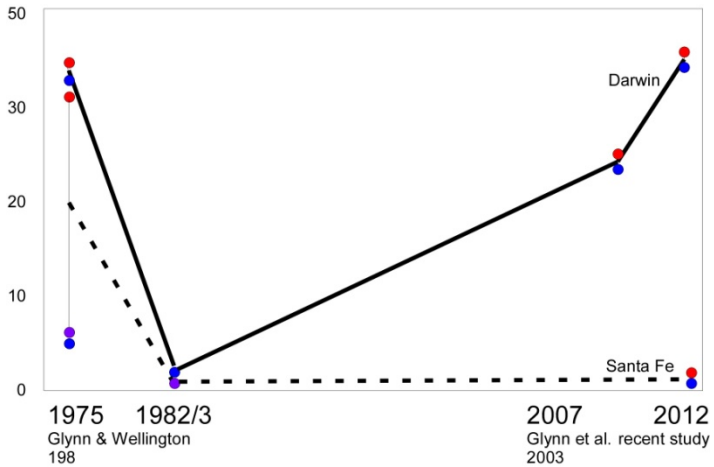

Degrees latitude
Degrees longitude
2
1.5
1
0.5
0
-0.5
-1
-1.5
-92.5
-92
-91.5
-91
-90.5
-90
-89.5
-89


November 2011
April 2012
0
4
8
12
16
20
24
28
32

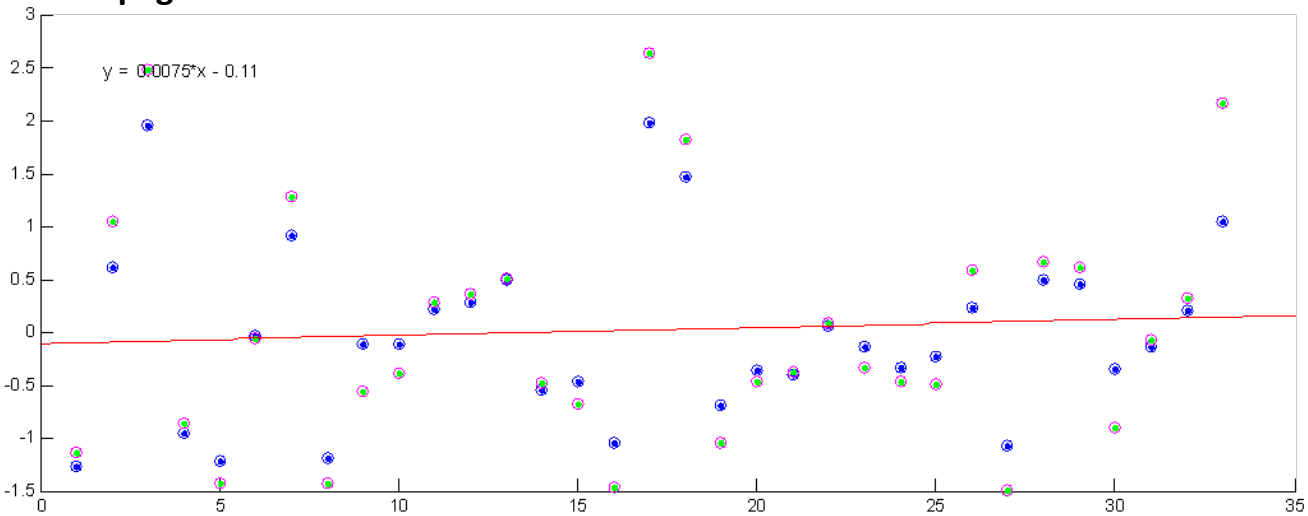

November 2011
April 2012
0.03
0.1
0.4
2
10
30
Concentration Of Chlorophyll In Sea Water (mg m-3)

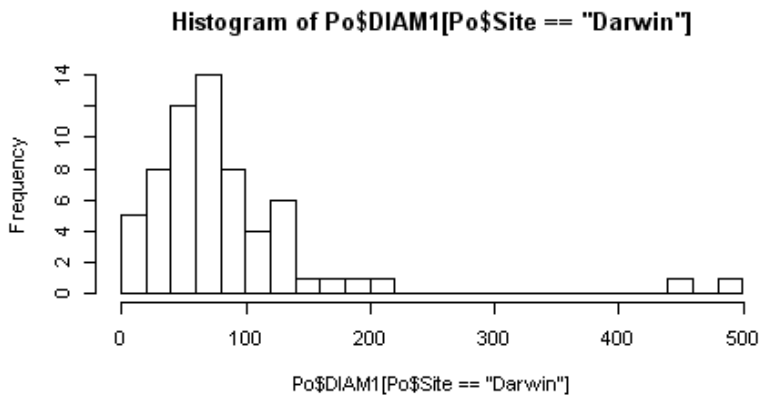

Puerto Ayora, St. Cruz, SST
degrees C
30
28
26
24
22
20
18
1964
1983
1998
2012
y = 0.000153*x + 23.5
y = - 3.44e-007*x^2 + 0.000351*x + 23.5

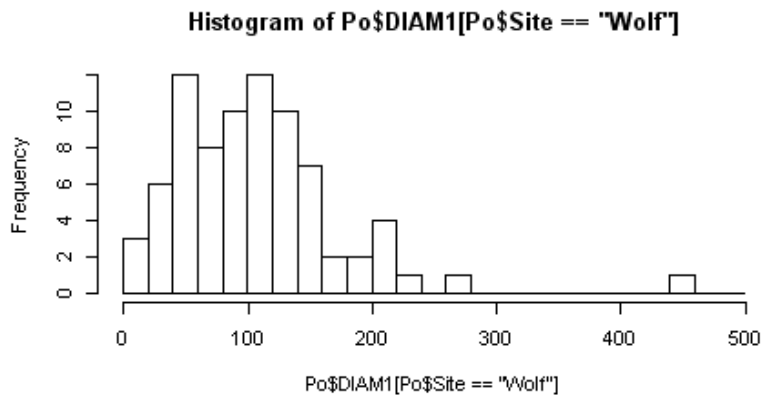
Coral cover trend

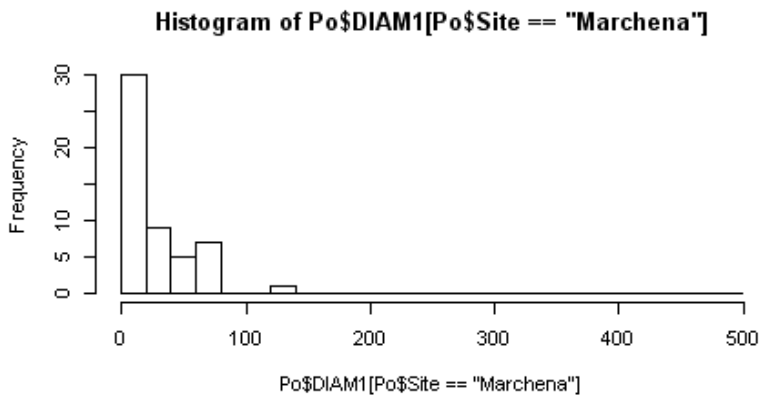


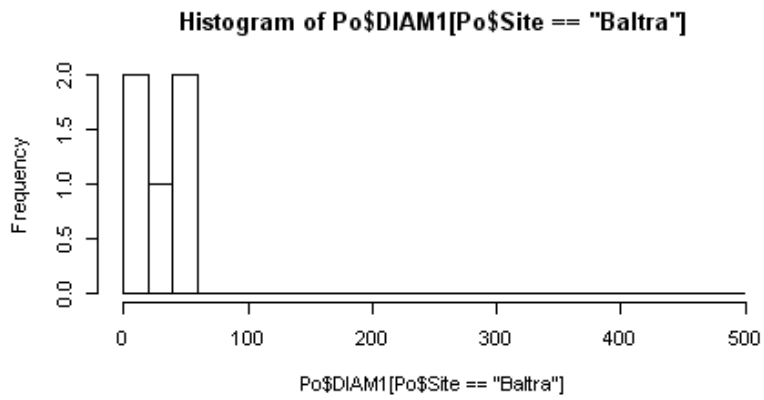
Galapagos annual anomalies

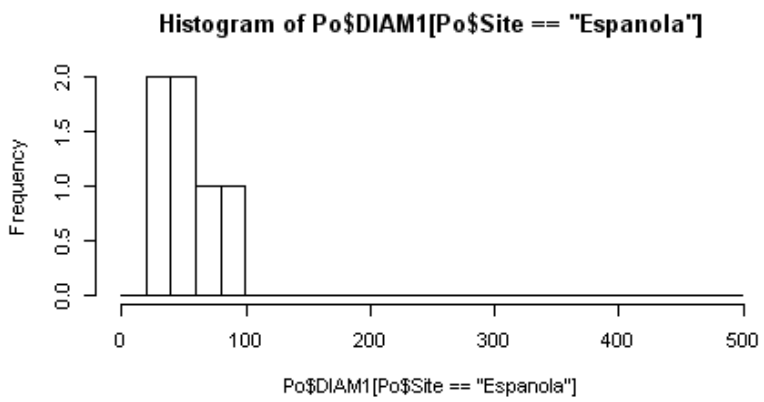


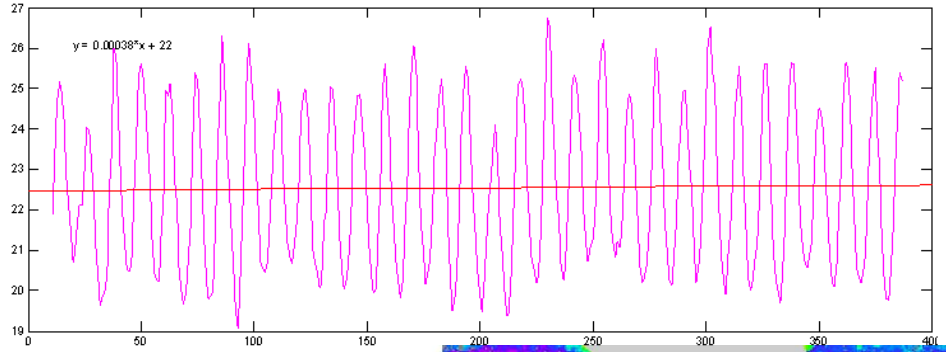

Histogram of Po$DIAM1[Po$Site == "Darwin"]
Frequency
0
2
4
6
8
10
14
0
100
200
300
400
500
Po$DIAM1[Po$Site == "Darwin"]

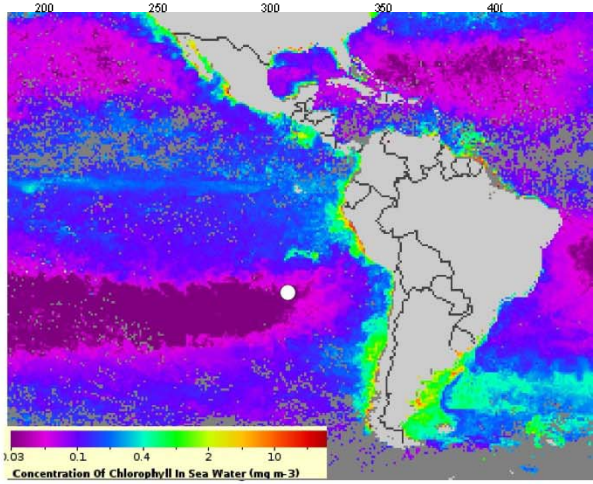

Histogram of Po$DIAM1[Po$Site == "Wolf"]
Frequency
0
2
4
6
8
10
0
100
200
300
400
500
Po$DIAM1[Po$Site == "Wolf"]

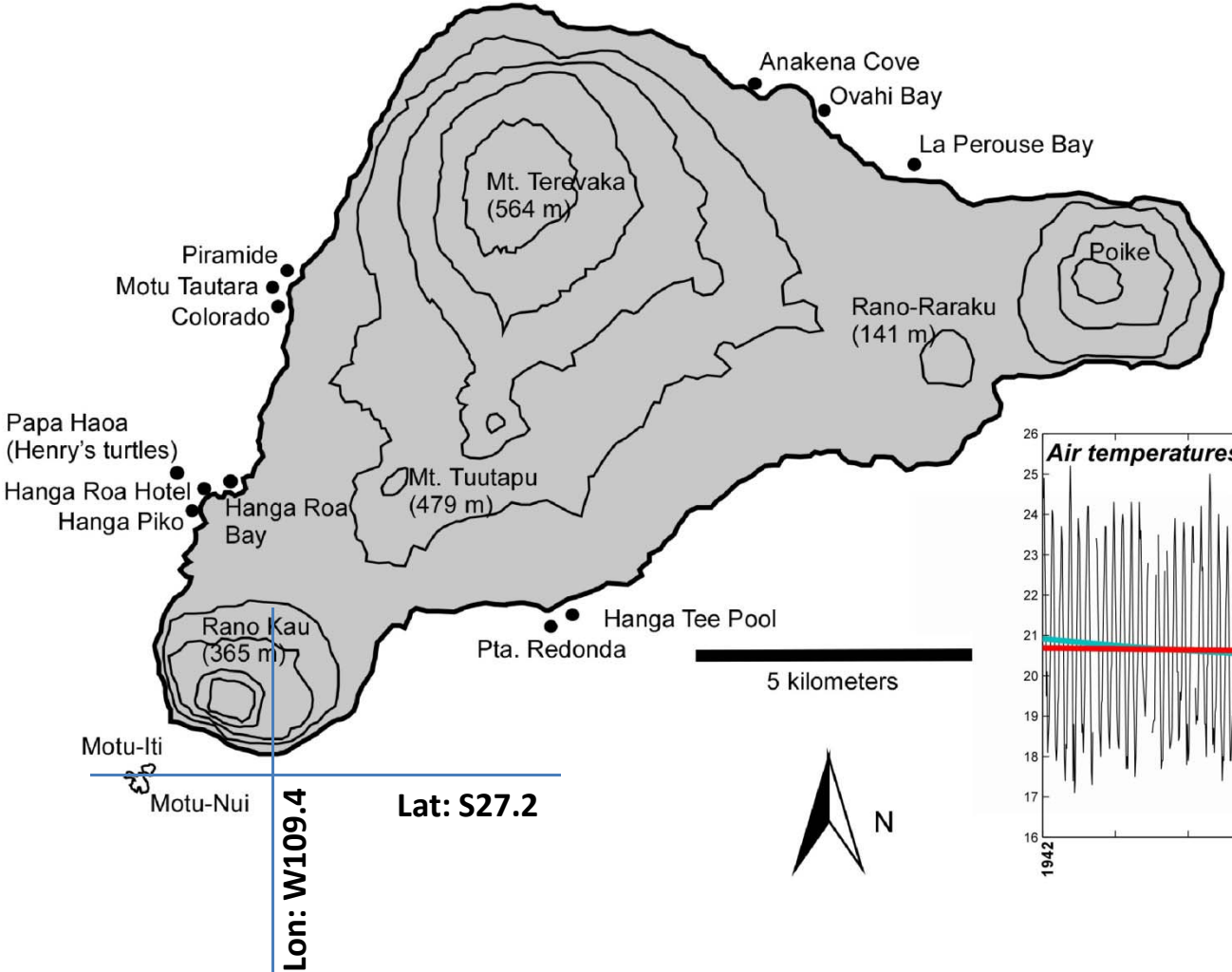

Histogram of Po$DIAM1[Po$Site == "Marchena"]
Frequency
0
5
10
20
30
0
100
200
300
400
500
Po$DIAM1[Po$Site == "Marchena"]

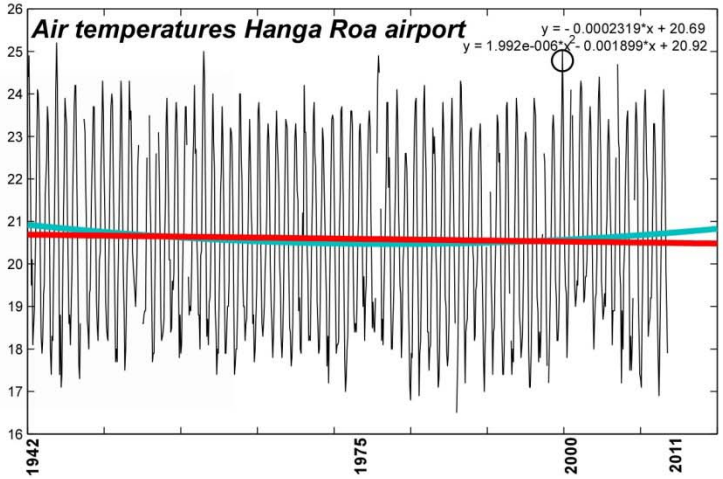

Histogram of Po$DIAM1[Po$Site == "Baltra"]
Frequency
0.0
0.5
1.0
1.5
2.0
0
100
200
300
400
500
Po$DIAM1[Po$Site == "Baltra"]


Histogram of Po$DIAM1[Po$Site == "Espanola"]
Frequency
0.0
0.5
1.0
1.5
2.0
0
100
200
300
400
500
Po$DIAM1[Po$Site == "Espanola"]

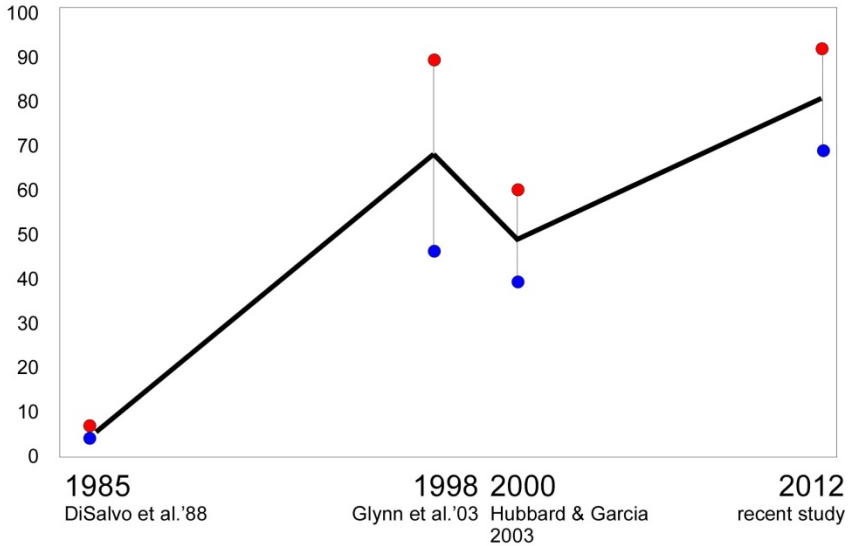

y = 0.00038*x + 22

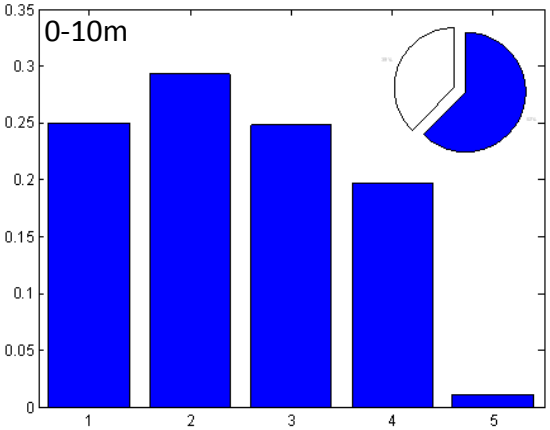

Concentration Of Chlorophyll In Sea Water (mg m-3)

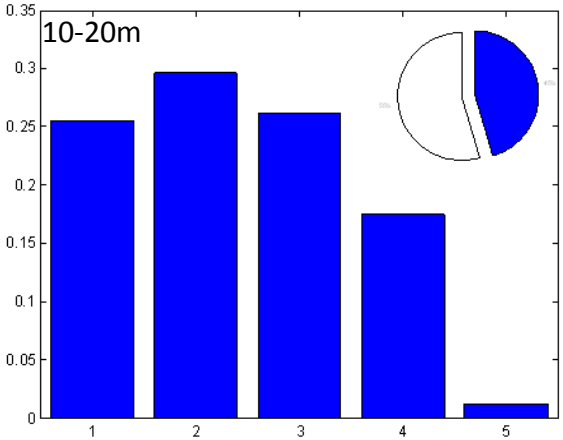

Anakena Cove
Ovahi Bay
La Perouse Bay
Mt. Terevaka
(564 m)
Poike
Piramide
Motu Tautara
Colorado
Rano-Raraku
(141 m)
Papa Haoa
(Henry's turtles)
Hanga Roa Hotel
Hanga Piko
Hanga Roa
Bay
Mt. Tuutapu
(479 m)
Rano Kau
(365 m)
Hanga Tee Pool
Pta. Redonda
5 kilometers
Motu-Iti
Motu-Nui
Lat: S27.2
Lon: W109.4
N


Air temperatures Hanga Roa airport
y = - 0.0002319*x + 20.69
y = 1.992e-006*x^2 - 0.001899*x + 20.92
1942
1975
2000
2011

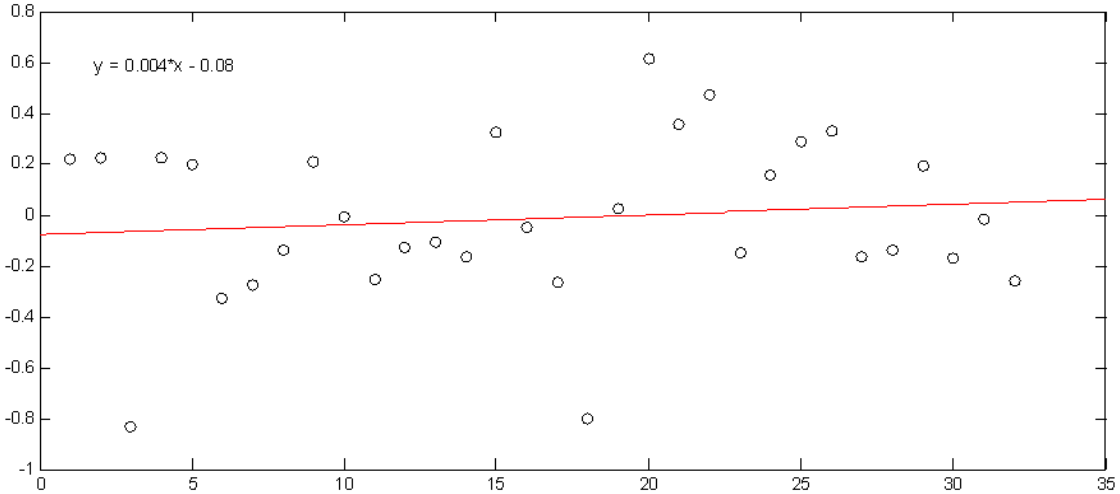
Coral cover trend

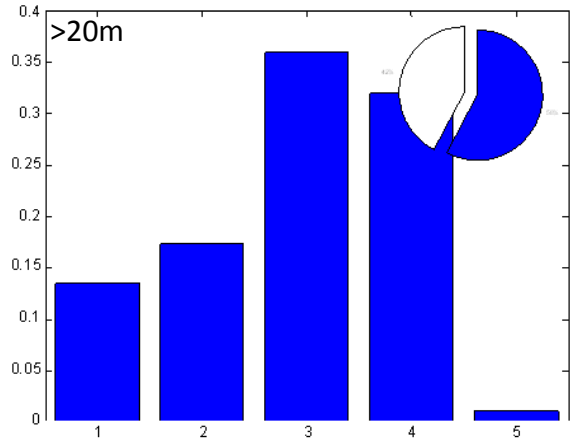






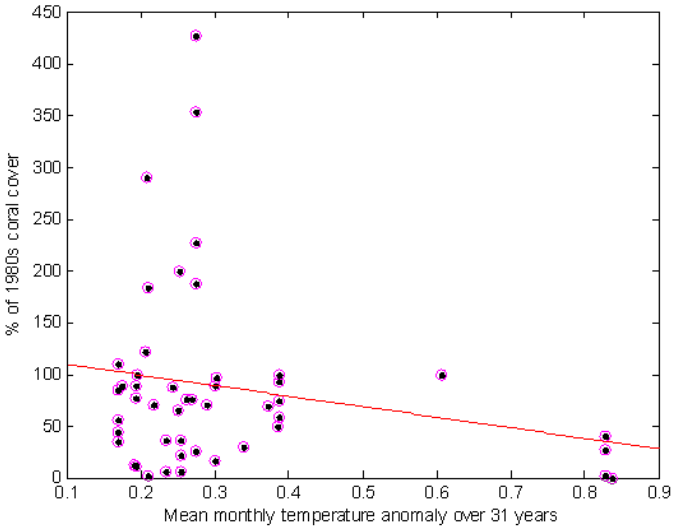
Easter Island annual anomalies



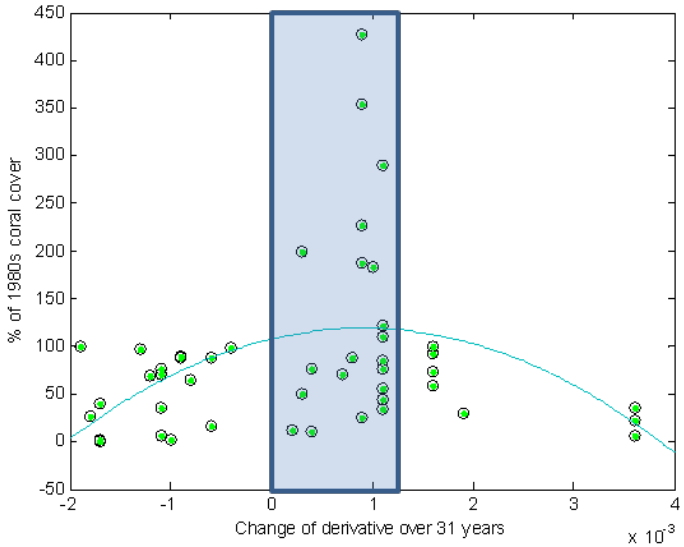


How does temperature variability correlate with coral recovery/decline?

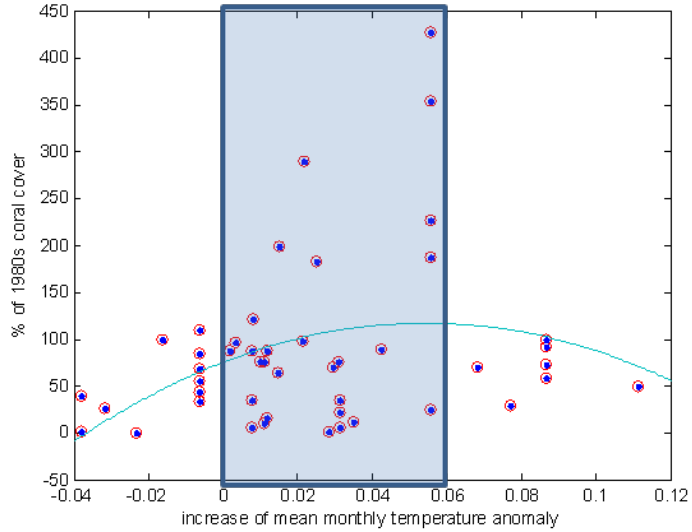
a) Does total temperature variability matter??



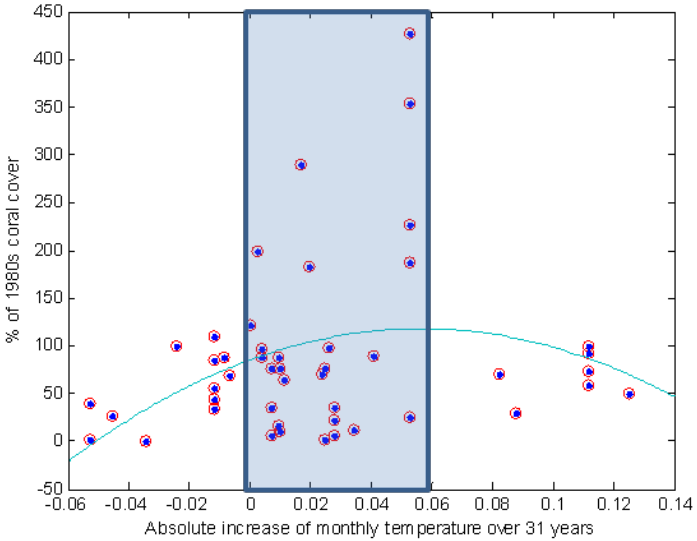
b) Does it matter how quickly temperatures change?

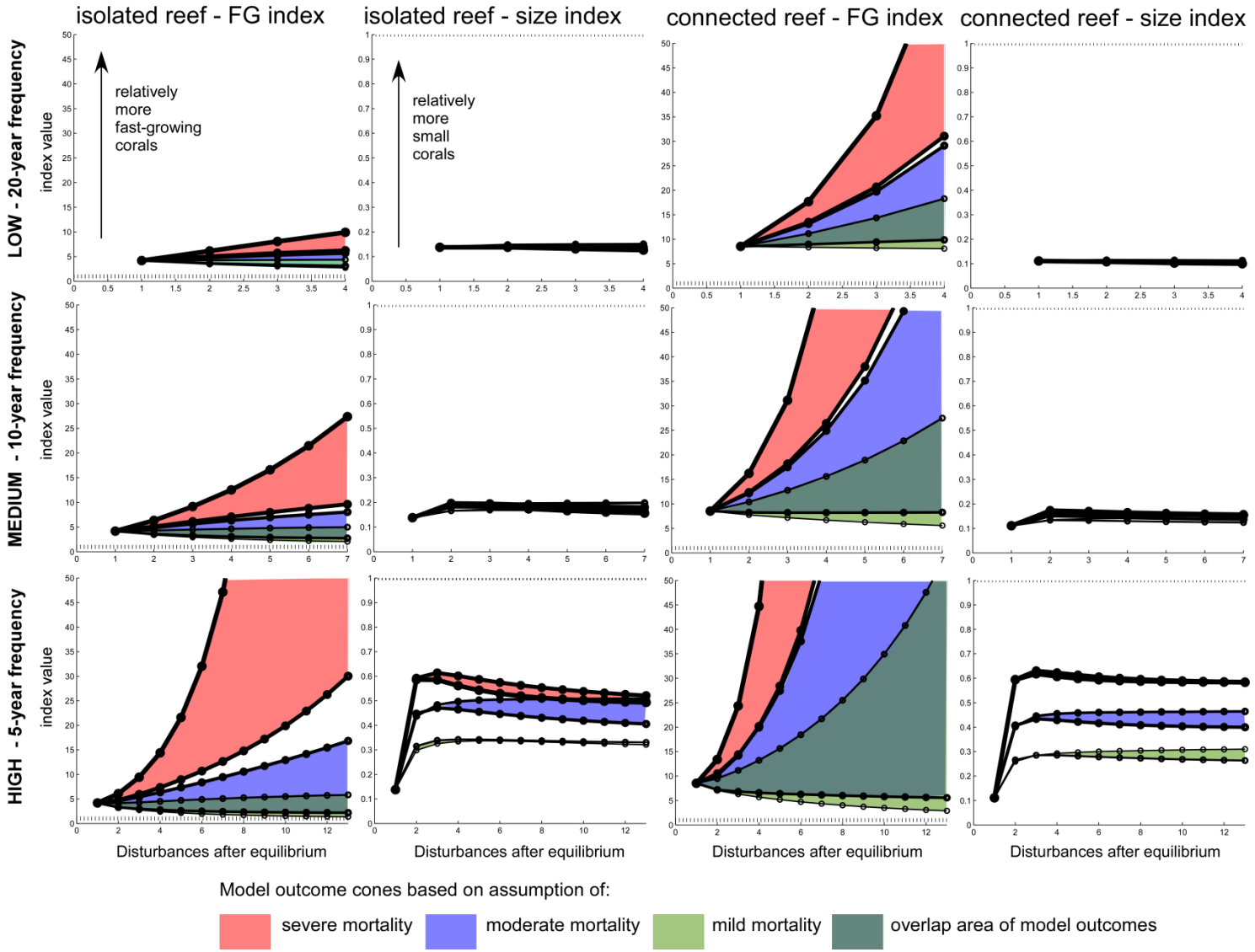


c) Does it matter how much anomalies changed?



d) Does it matter how much temperatures changed?





Red Sea

Arabian Gulf

<u>Mortality scenaria:</u>
Mild mortality= fast 20%, slow 15%
Medium mortality=fast 40%, slow 25%
Fast mortality=fast 70%, slow 60%

"Since all models are wrong, the scientist must be alert to what is importantly wrong. It is inappropriate to be concerned about mice when there are tigers around." Box, 1976.

CONCLUSION:

-Coral regeneration from disturbances varies strongly across the Indo-Pacific

-It reacts to a multitude of local forcings and teleconnections

-Temperature anomalies have increased across the Indo-Pacific BUT
--most in the W-Indo-Pacific (Red Sea, Arabian/Persian Gulf)
--least in E-Pacific

-Coral regeneration trajectories track the size of temperature anomalies, more than absolute temperature increase

- Increased cold anomalies as bad as increased heat anomalies

-- projected trajectory is towards smaller, weedy, corals

-- this community shift has occurred in parts of the SE Gulf
-- may be underway in parts (or all?) of the (southern) Red Sea
--has occurred in S-Galapagos, but not in N-Galapagos
--Easter Island has unbroken upward trajectory since 1980s