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# Outline of climate and oceanographic conditions in the Indian Ocean: an update to August 2011

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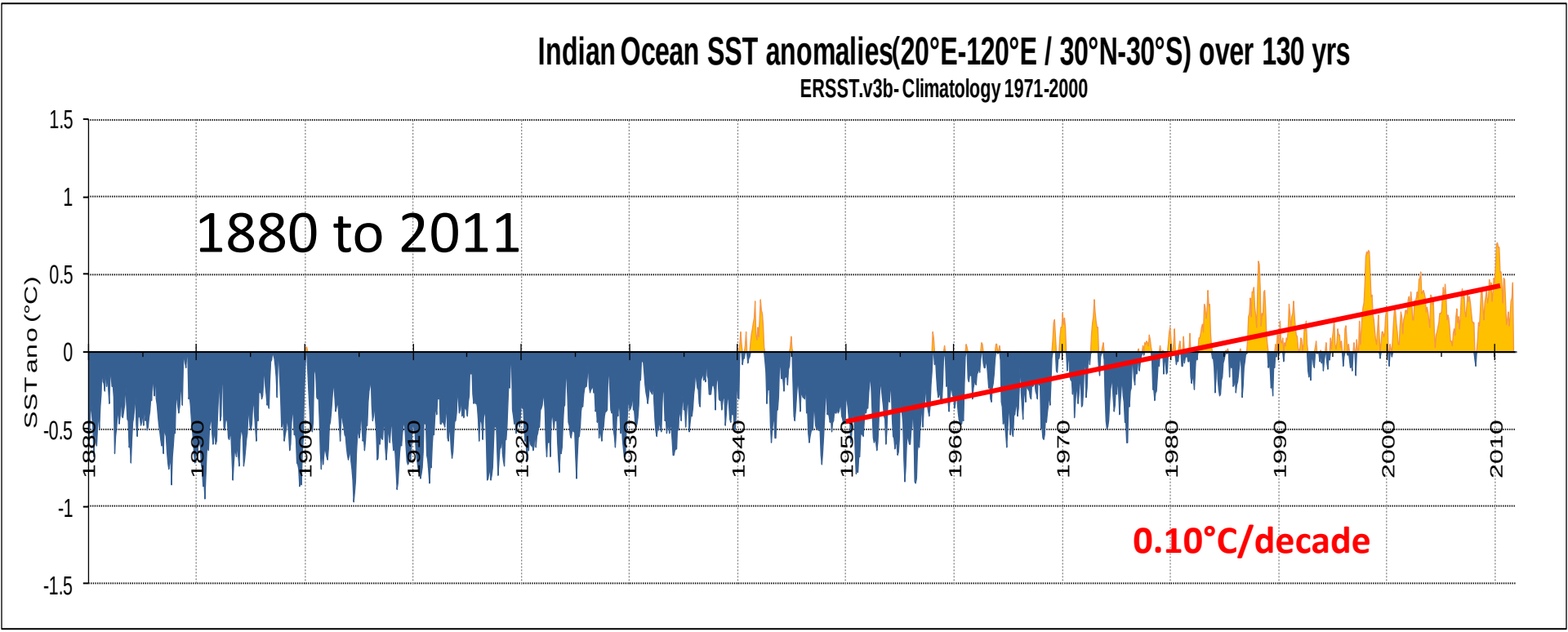
# 1- Long term, basin-scale trends

*Variables used :*

- SST
  - NOAA-NESDIS Extended Reconstructed Seas Surface Temperature (ERSST.v3b) based on the International Comprehensive Ocean-Atmosphere Data Set, release 2.4 (Smith et al 2008, J. Climate)
  - In situ SST data (no satellite) and improved statistical methods that allow stable reconstruction using sparse data
  - Climatology 1971-2000
  - Series 1854-2011, but more reliable from 1880 onwards
  - SST by 2° area boxes and month
- Wind stress
  - FSU fluxes : Centre for Ocean-Atmospheric Prediction Studies (COAPS)
  - In situ based fields:  VOS, moored buoys, drifting buoys
  - Climatology 1971-2000
  - Series 1970-2011
  - Variable : zonal wind stress, by 1° area boxes and month

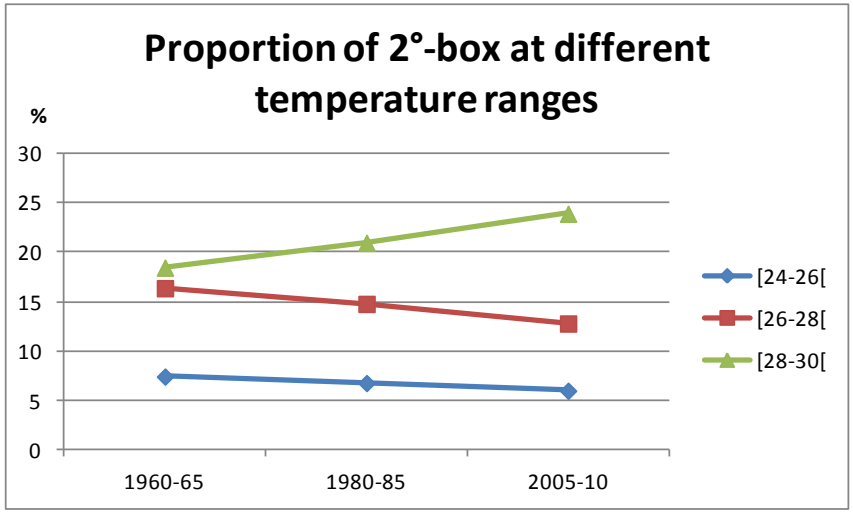
# SST trend

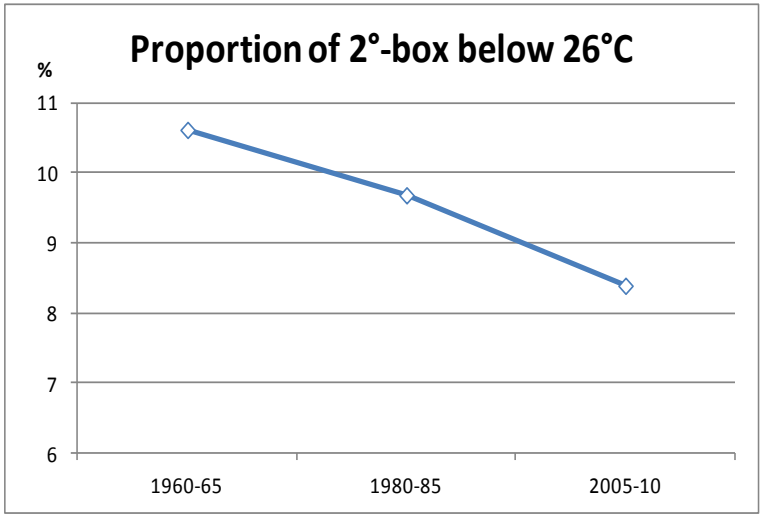



- The West IO gets warmer at a higher rate than the whole IO: 0.13°C/decade

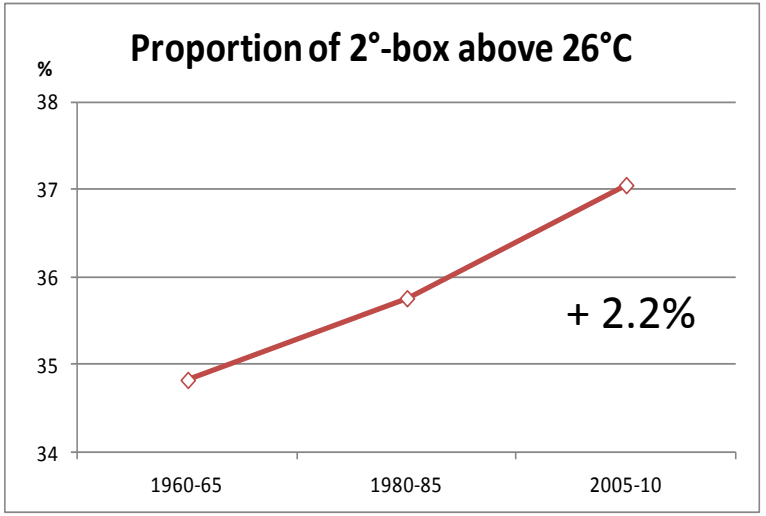
# A greater occurrence of warm waters :

## comparing 1960-65, 1980-85 and 2005-10

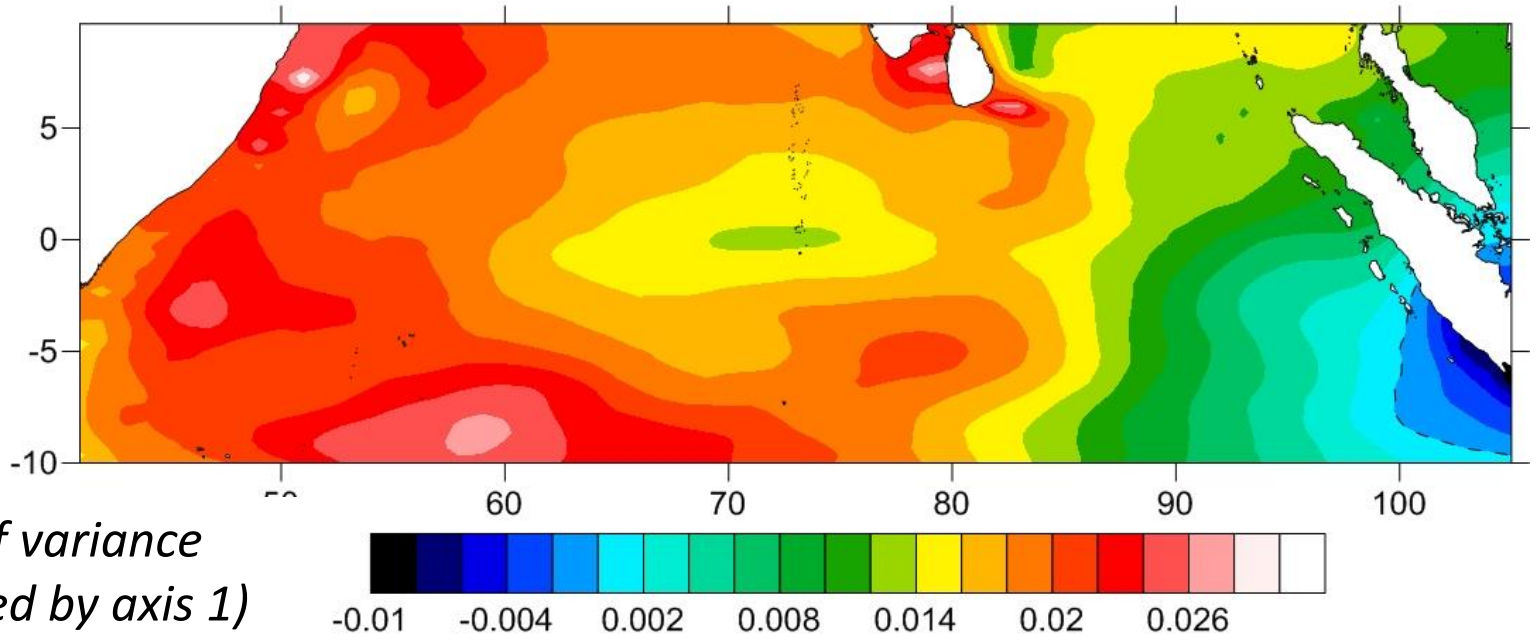


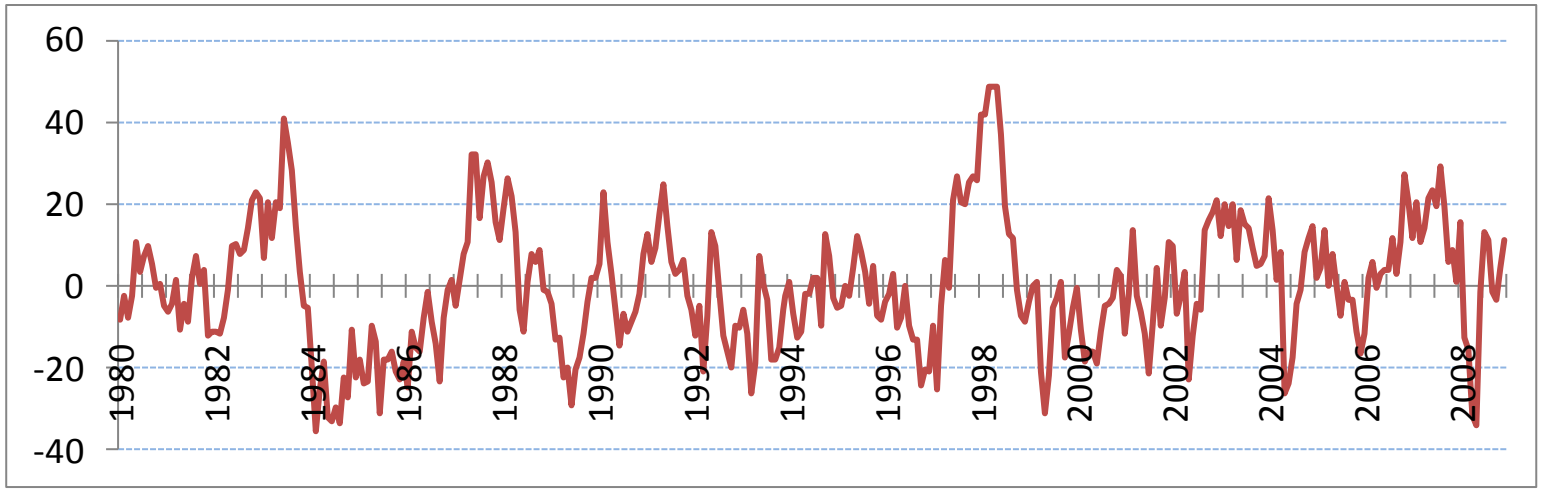

- Analysis carried out for Jan-Mar (core of spawning season) in 3 different time periods.
- During the last 50 yrs, there are 2% more 2°box-month strata with SST>26°C (threshold for tuna larvae survival)



# SST : variability pattern from principal component analysis



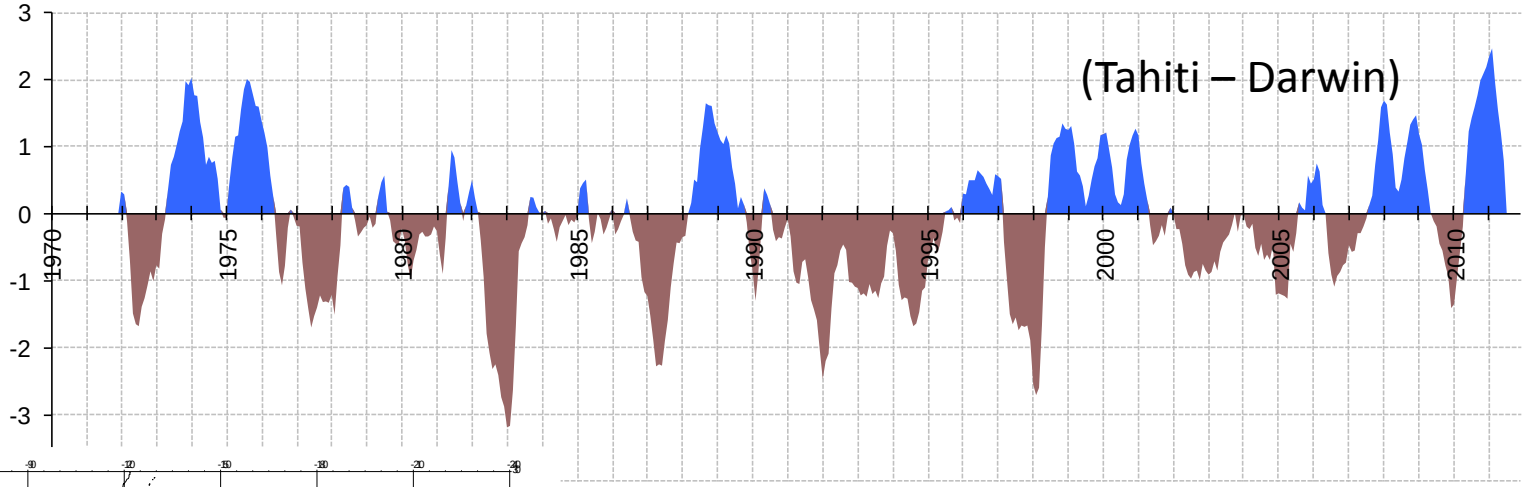

*(38% of variance captured by axis 1)*

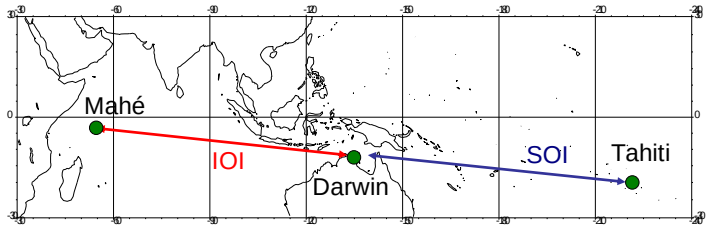


# Climate indices : SOI and IOI

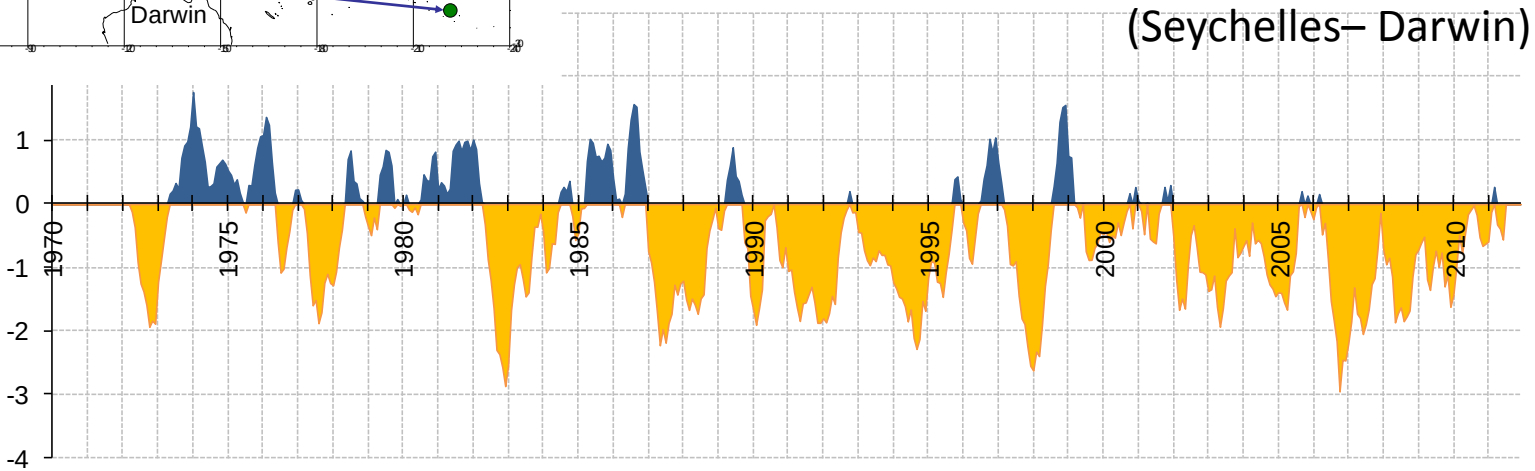
## (up to June 2011)

**Southern Oscillation Index**



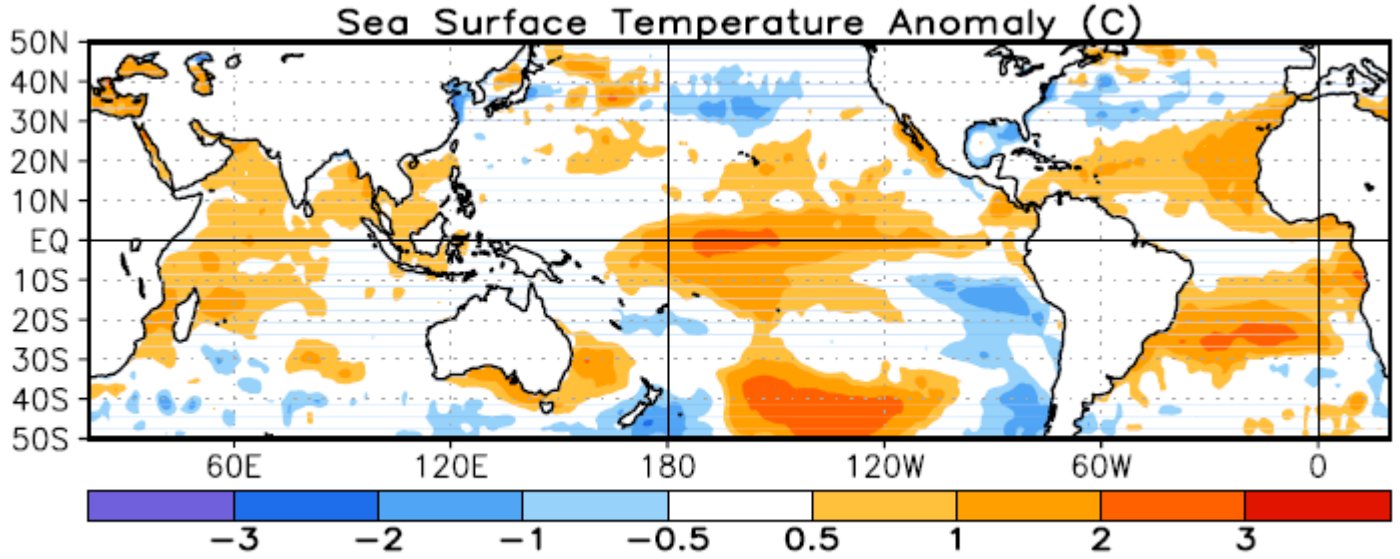

**Indian Oscillation Index**



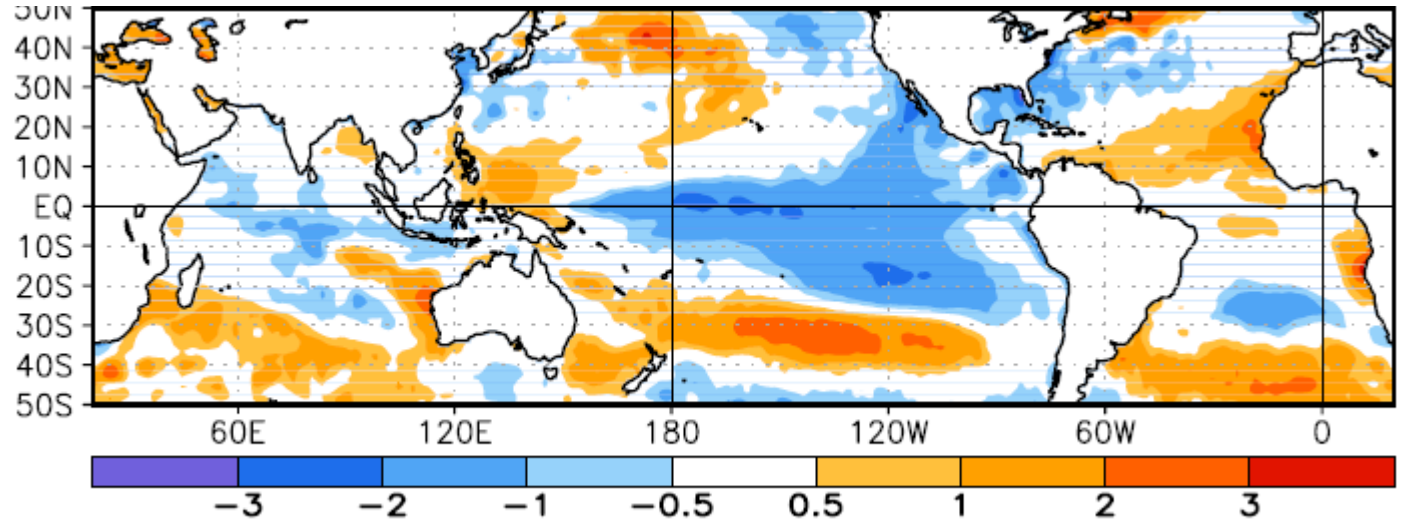
# SST anomalies, Jan 2010 and Jan 2011

## (Diagnostic Bulletin, NOAA)

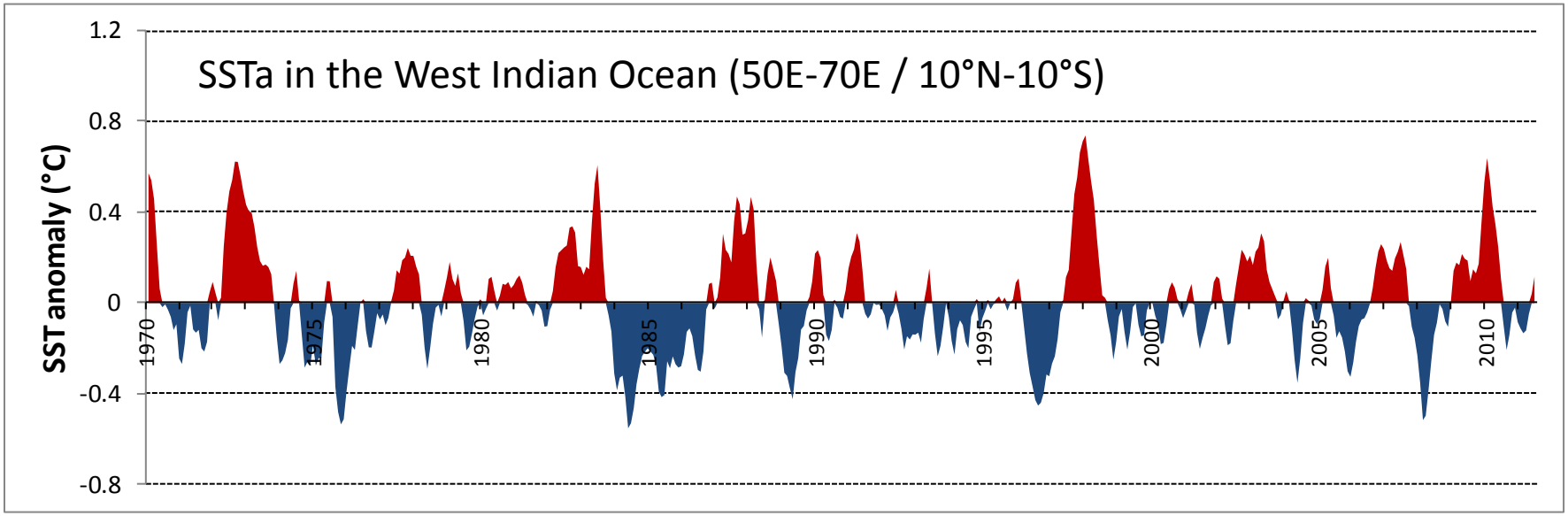
Jan 2010
Warm event

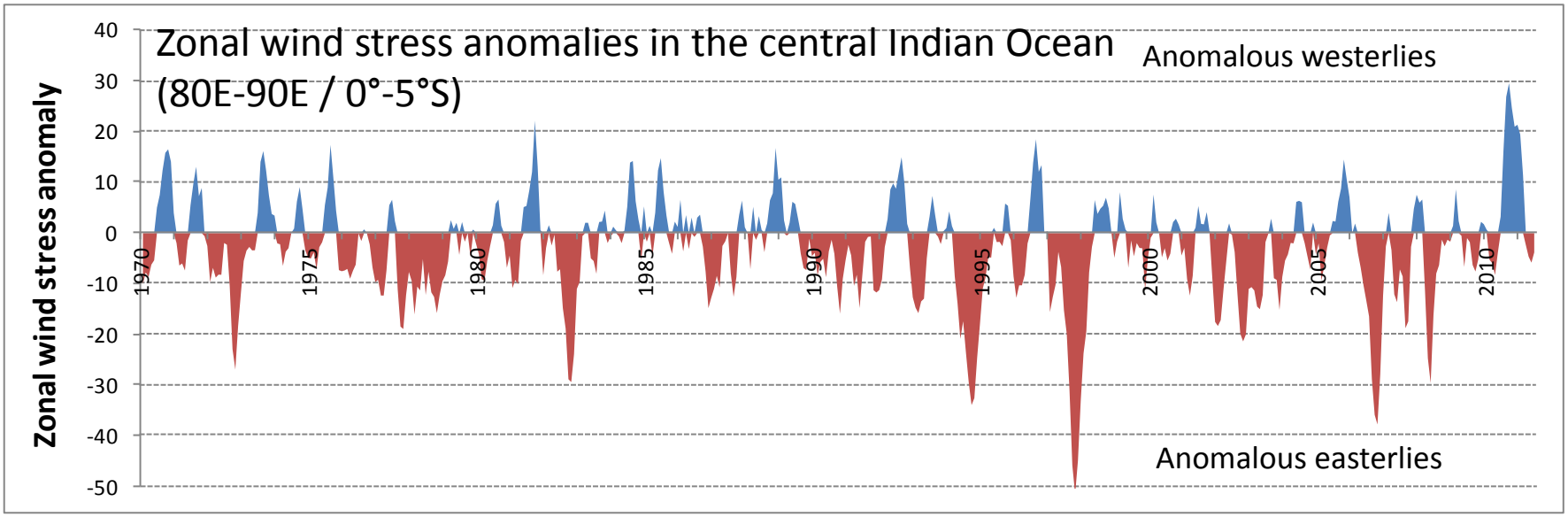



Jan 2011
Nina



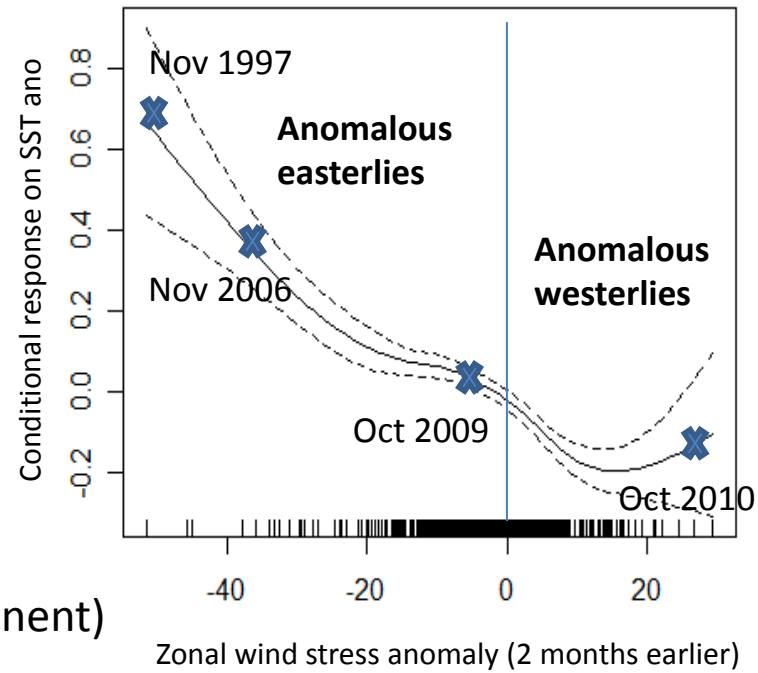
# SST (detrended) and wind stress anomalies



# Analysis of relationship Wind stress – SSTa (remote forcing)

GAM




| | edf | Est.rank | F | p-value | s(anotxlis3) |
|---|---|---|---|---|---|
| | 4.747 | 9 | 15.55 | <2e-16 | *** |

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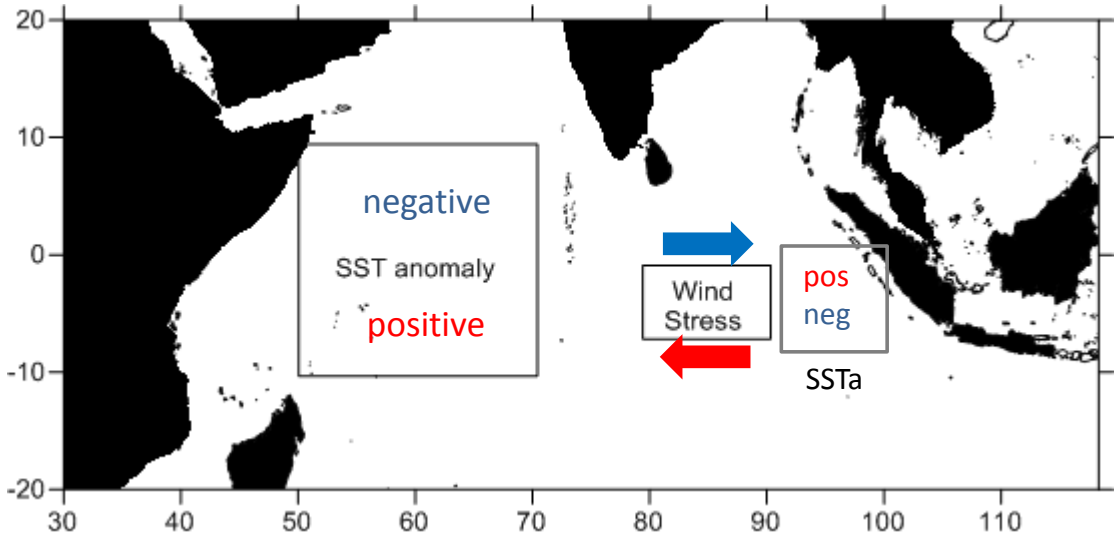
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) = 0.213 Deviance explained = 22%
GCV score = 0.039904 Scale est. = 0.03944 n = 494

Data processing : detrending SST anomalies the 3-month smoothed SSTa and Wsa (zonal component) then lagged series by 2 months lags (WS precedes SST)

The zonal component of the wind stress in the Central IO is a good predictor of SST variability in the WIO with a 2 months lag



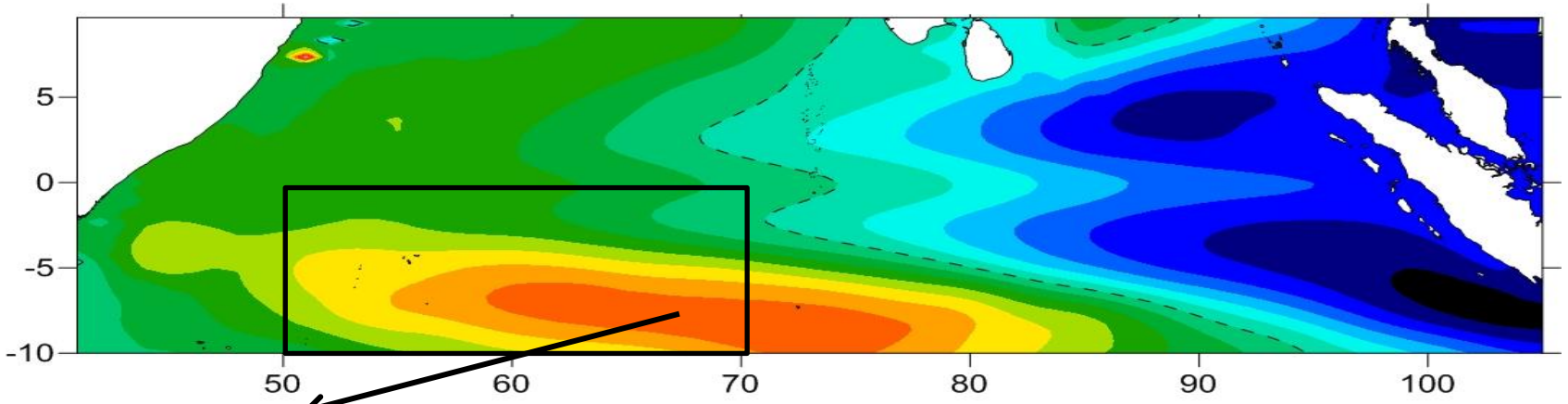
# 2 – Regional Analysis

*Variables used :*

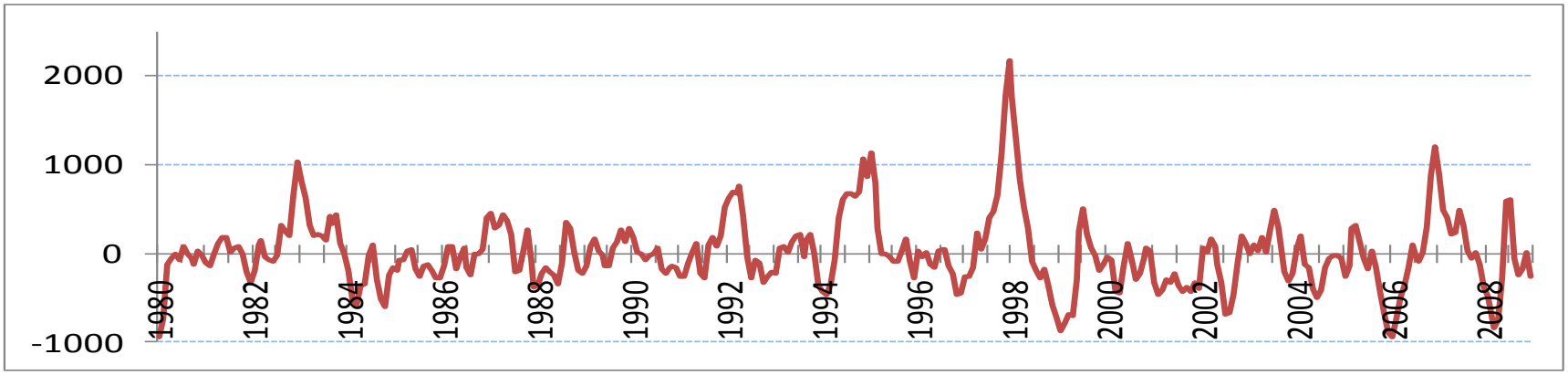
- Mixed Layer Depth and Depth of 20°C isotherm
  - NCEP-GODAS model (http://www.cpc.noaa.gov/products/GODAS/)
  - 1980-2011
  - 1° Lon x 1/3° Lat, by month
- Satellite-derived sea surface Chlorophyll-a
  - SeaWifs 1997-2009
  - Modis 2002-2011
  - 9 km level-3 data aggregated by 1°lon/0.33° lat, by month
- Wind stress
  - Same as previous section, but using the meridional (N-S) component

# Mixed Layer Depth : variability pattern from principal component analysis

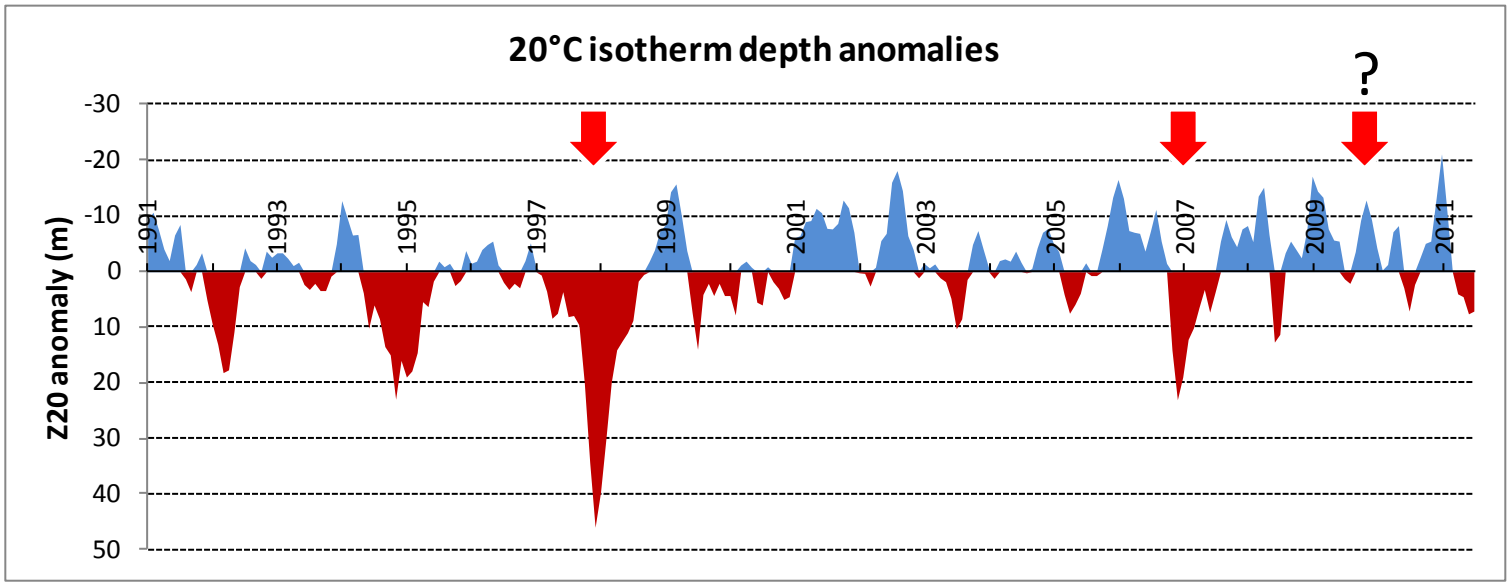
*(25 % of variance explained along axis 1)*

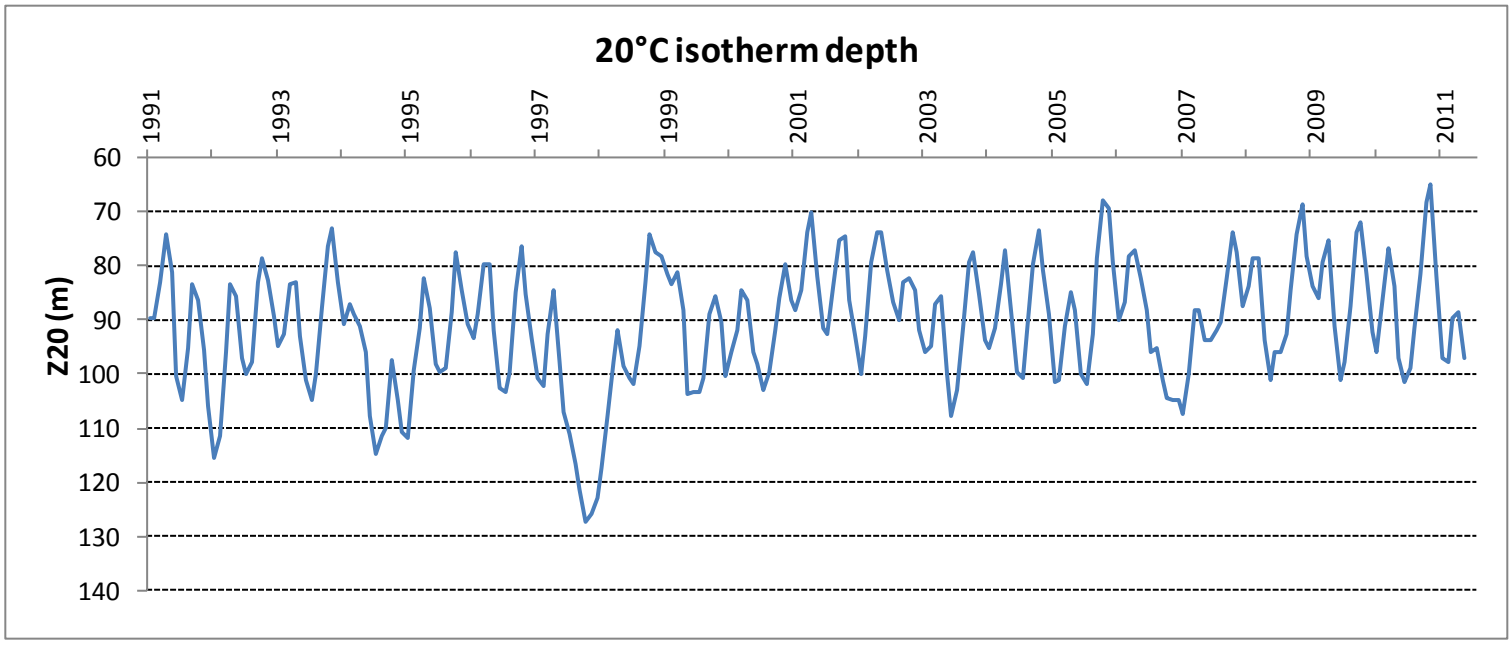



Seychelles-Chagos Thermocline Ridge

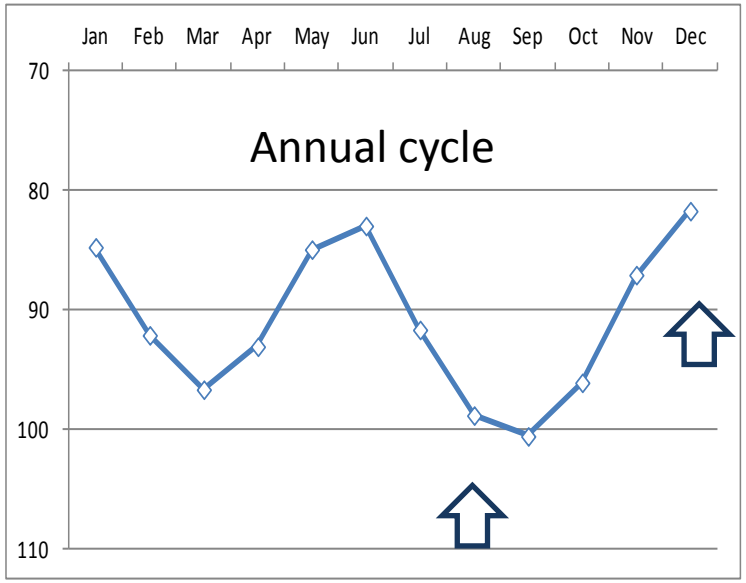


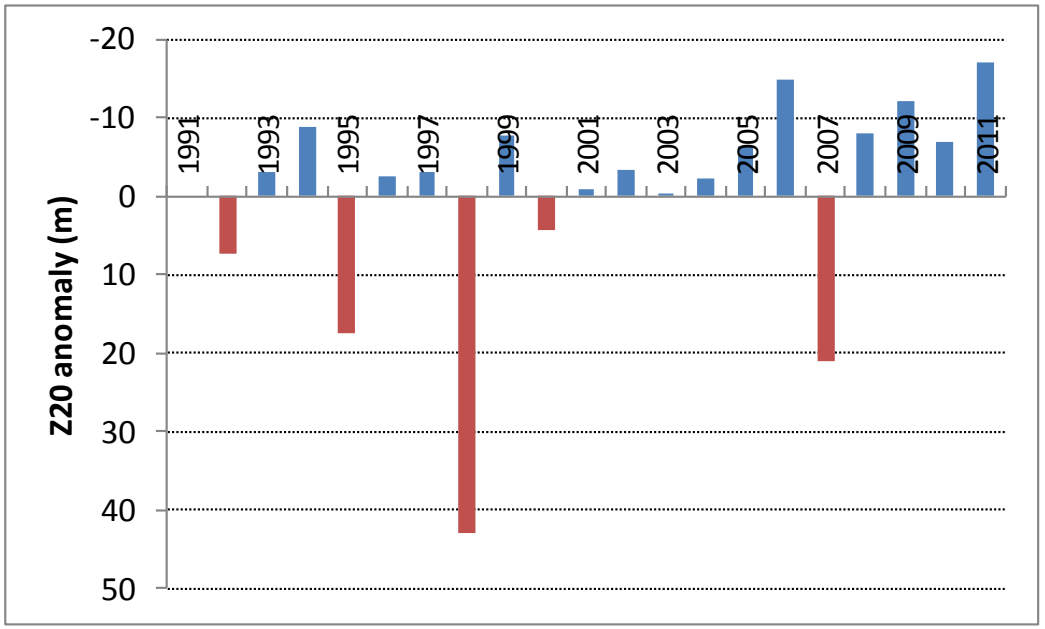

Core area of the purse seine free-swimming schools fishery

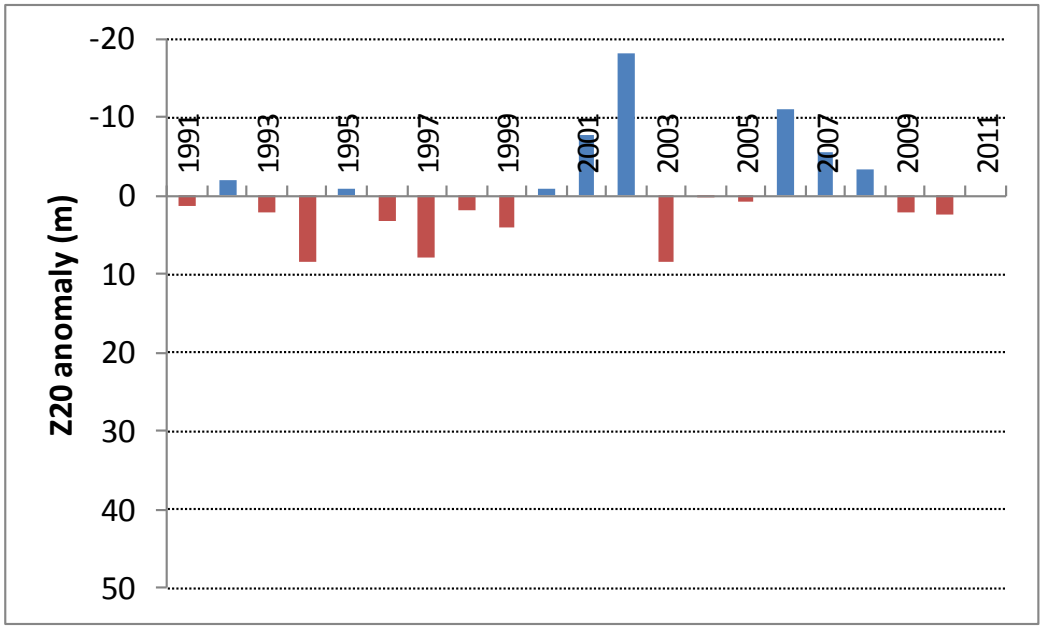

20°C isotherm depth anomalies
?
Z20 anomaly (m)
-30
-20
-10
0
10
20
30
40
50
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011


20°C isotherm depth
Z20 (m)
60
70
80
90
100
110
120
130
140
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011

20°C Isotherm depth anomalies – Dec-Jan




20°C Isotherm depth anomalies – August

Anomalies are more pronounced at the turn of the year compared to the south-east monsoon

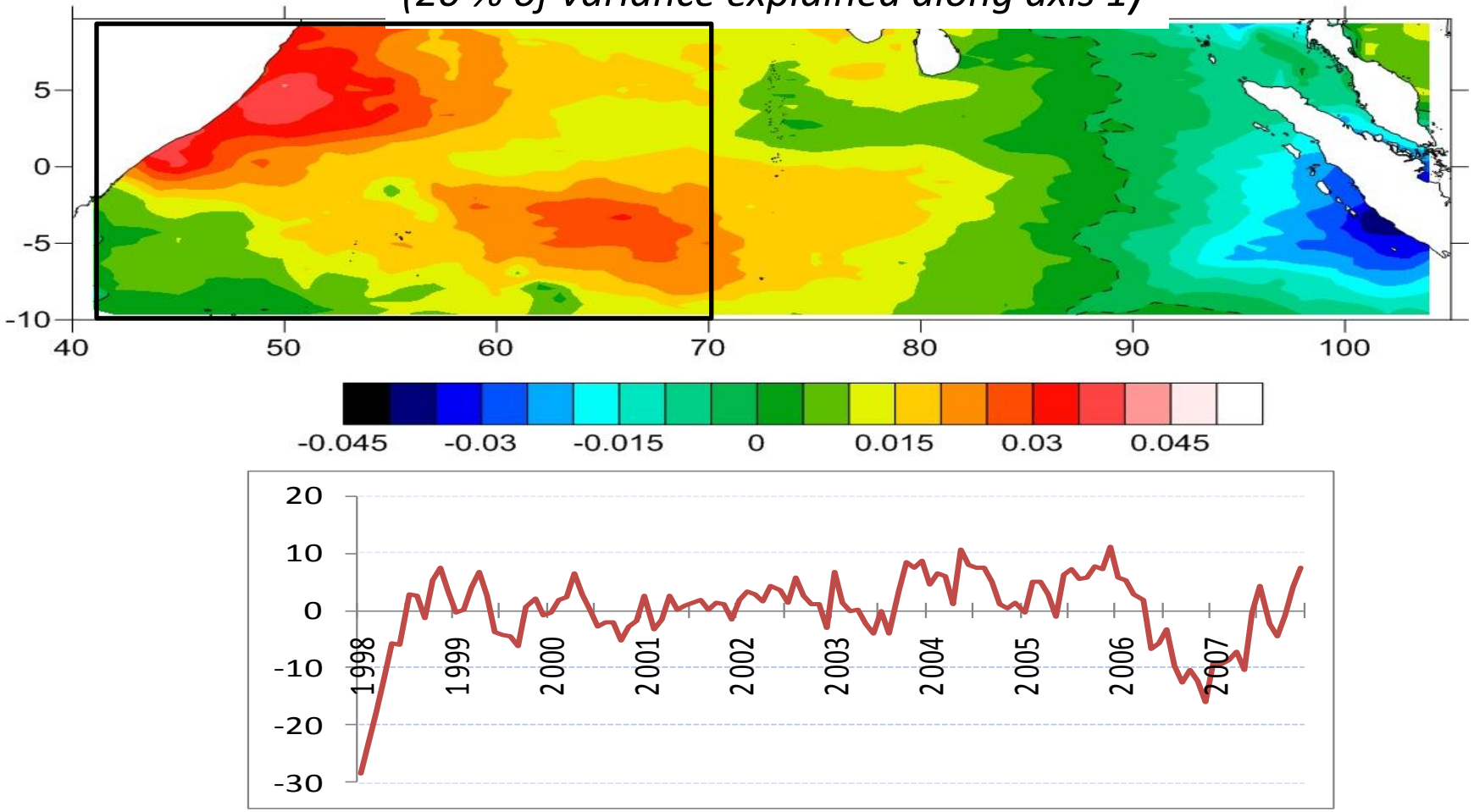
# Mixed Layer Depth Summary

## South Equatorial region, WIO

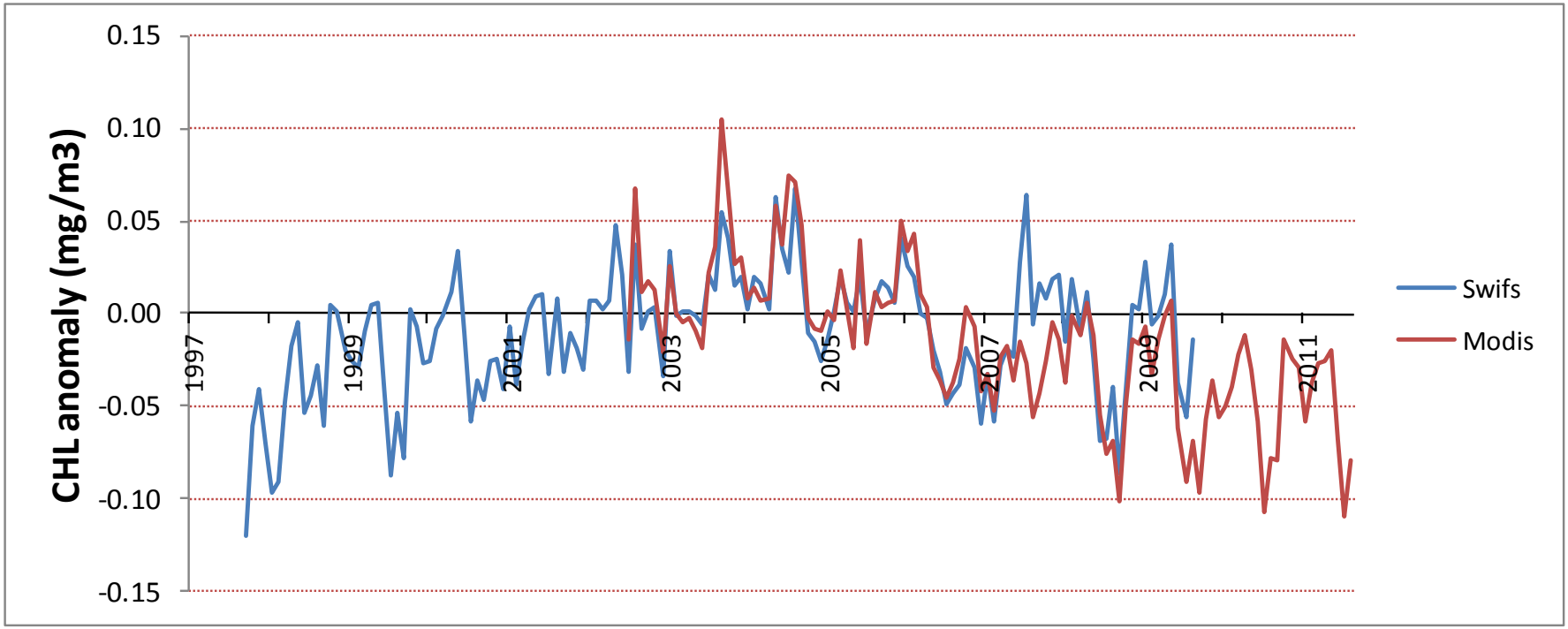
- Deeper thermocline is associated with El Nino and positive Dipole in the WIO, which is mostly visible at the turn of the year
  - Deepest anomalies for Isotherm 20°C are > 40 m in Jan 1998 and 20 m in Jan 2007
- Shallow thermocline have prevailed since the 2007 Nino
- No anomalous deepening of the mixed layer in the Seychelles-Chagos Thermocline Ridge associated to the 2010 warm event

# Sea Surface Chlorophyll: variability pattern from principal component analysis

*(20 % of variance explained along axis 1)*



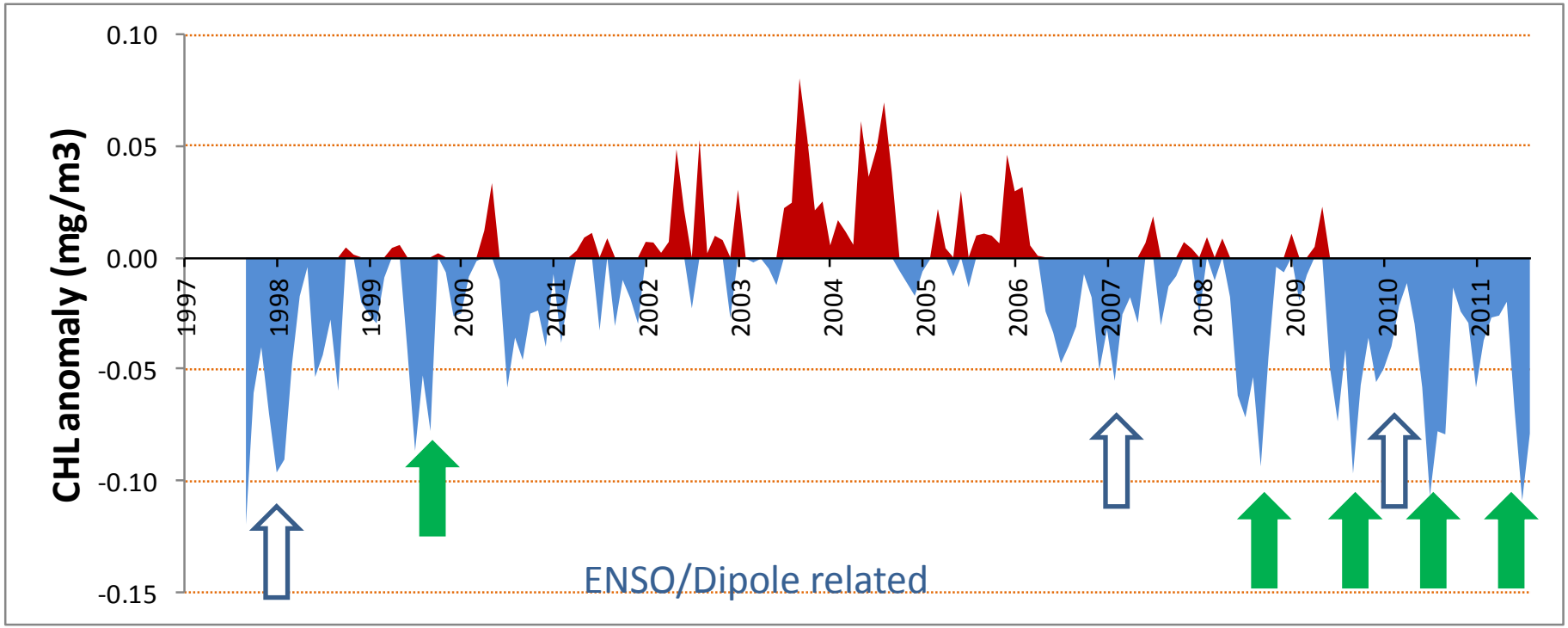
# Surface CHL-a anomalies in the whole WIO : monthly series 1997-2011




Satellite-boarded sensors :

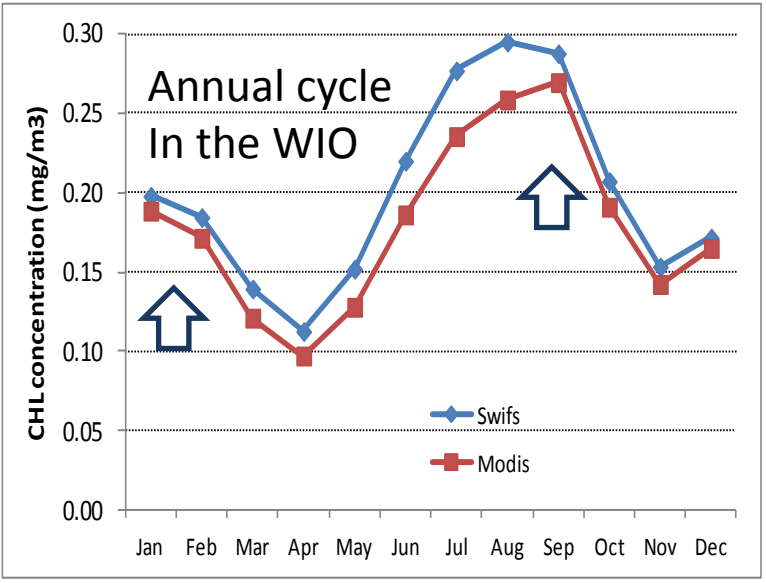
- SEAWIFS series : Sept 1997 – Aug 2009
- MODIS series : July 2002 – Aug2011
- Note some discrepancies between SEAWIFS and MODIS values during the common period (especially in 2008)

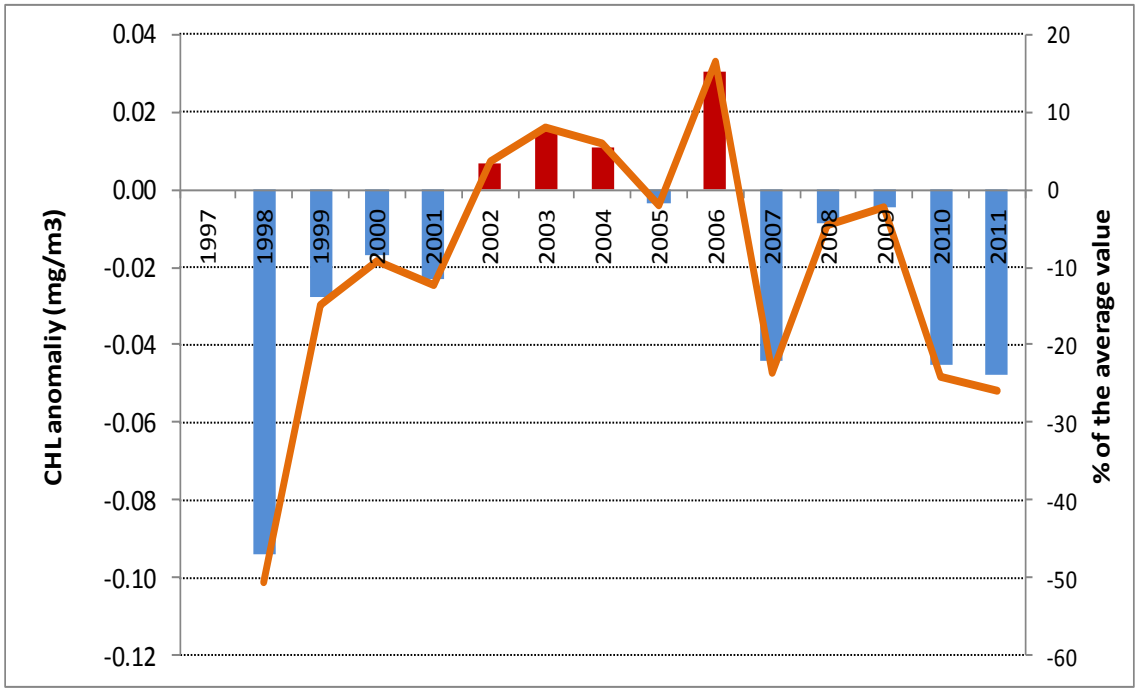
# Surface CHL-a anomalies in the whole WIO : a composite series



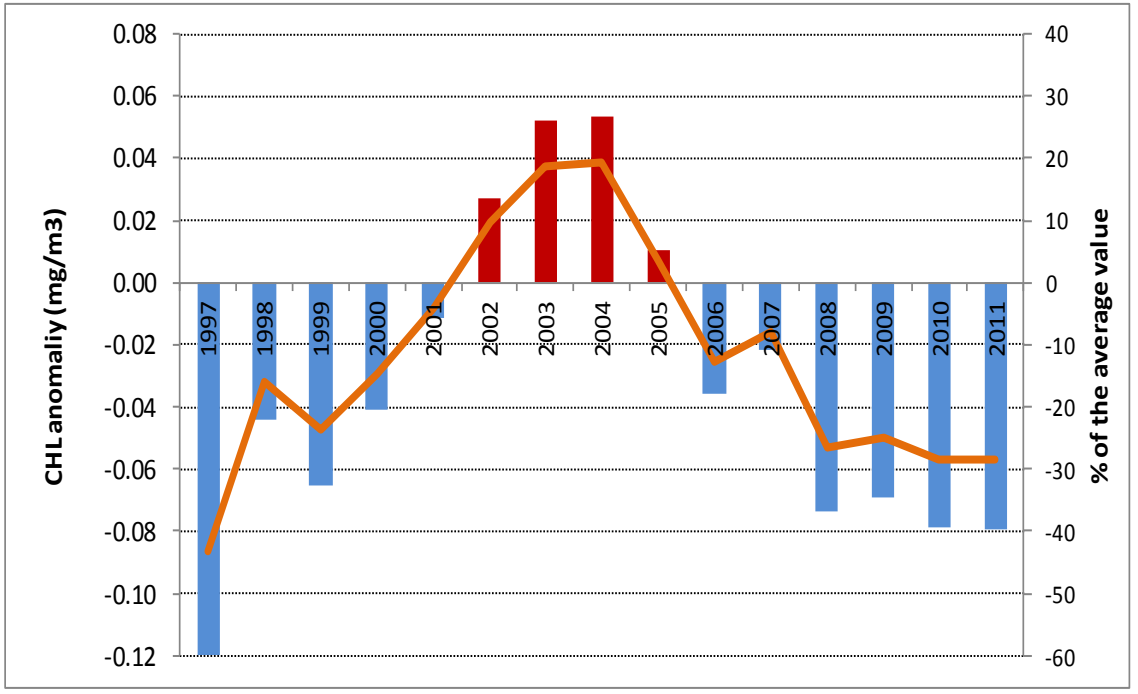

- Negative anomalies occurring in Dec-Feb are generally related to ENSO-Dipole
- Negative anomalies occurring during the South west monsoon would reflect a weaker than normal Somali upwelling, this being observed every single year since 2008

Chlorophyll-a anomalies
January – February



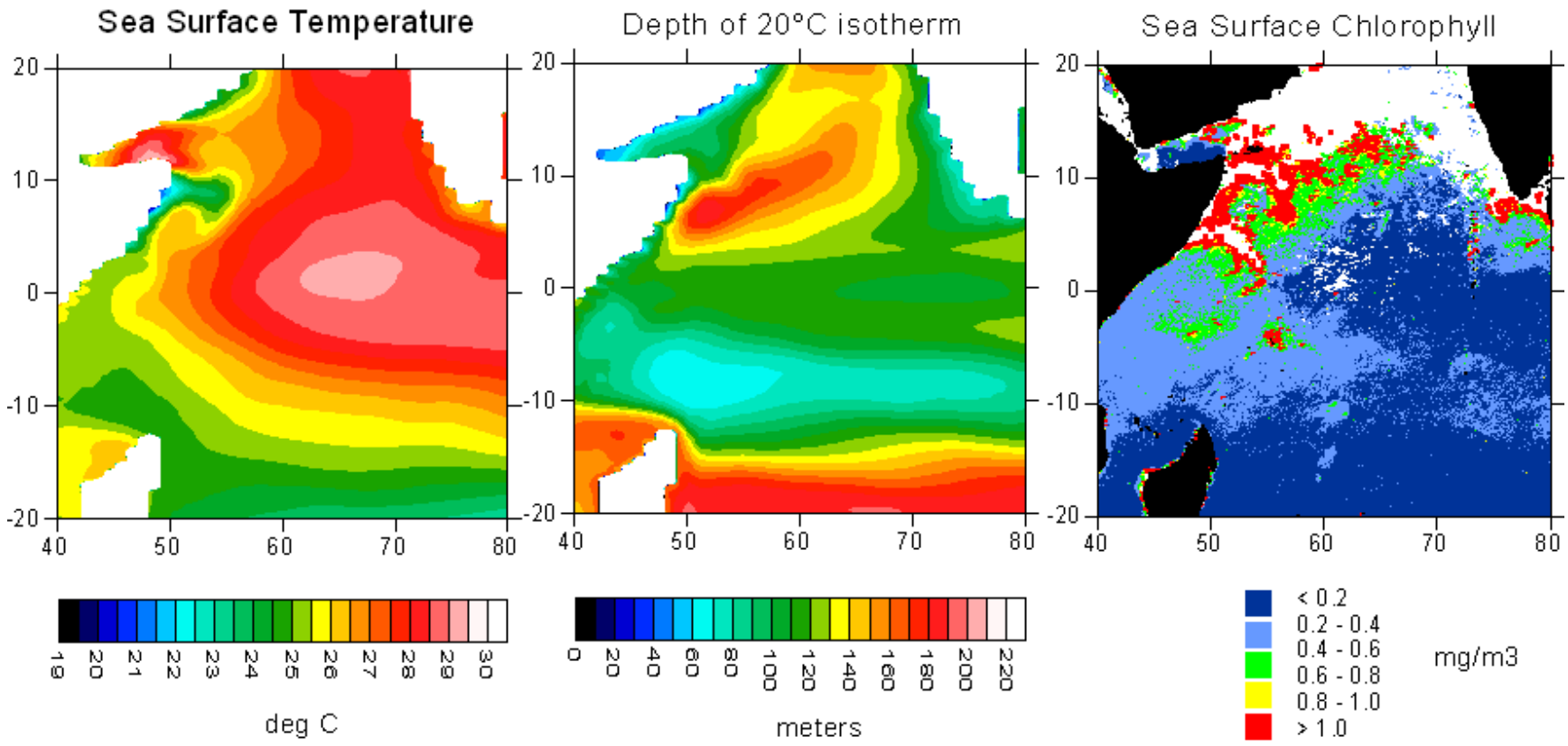




Chlorophyll-a anomalies
August - Sept



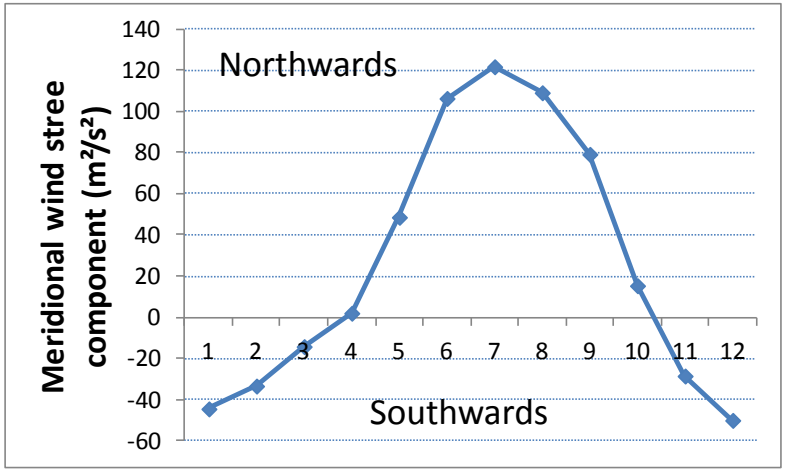

Decline of 20-40% of primary productivity in the recent years

# A focus on the Somali upwelling

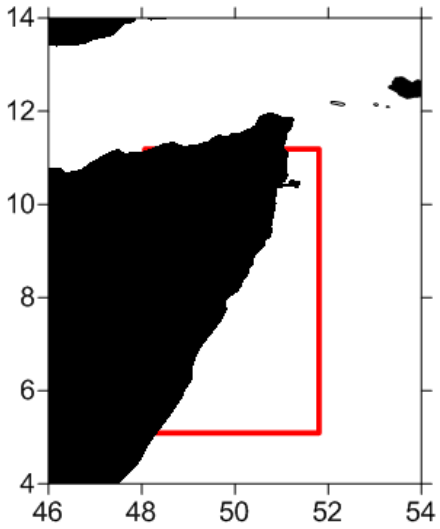


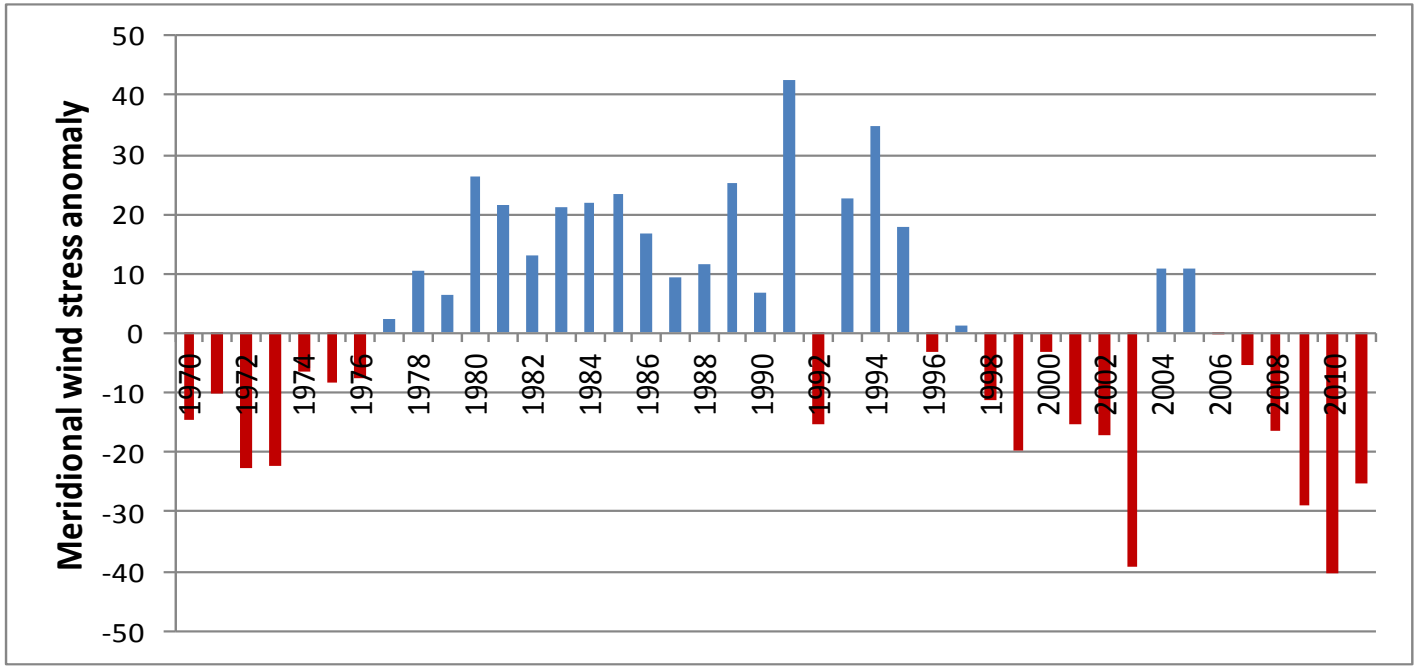

Average for July

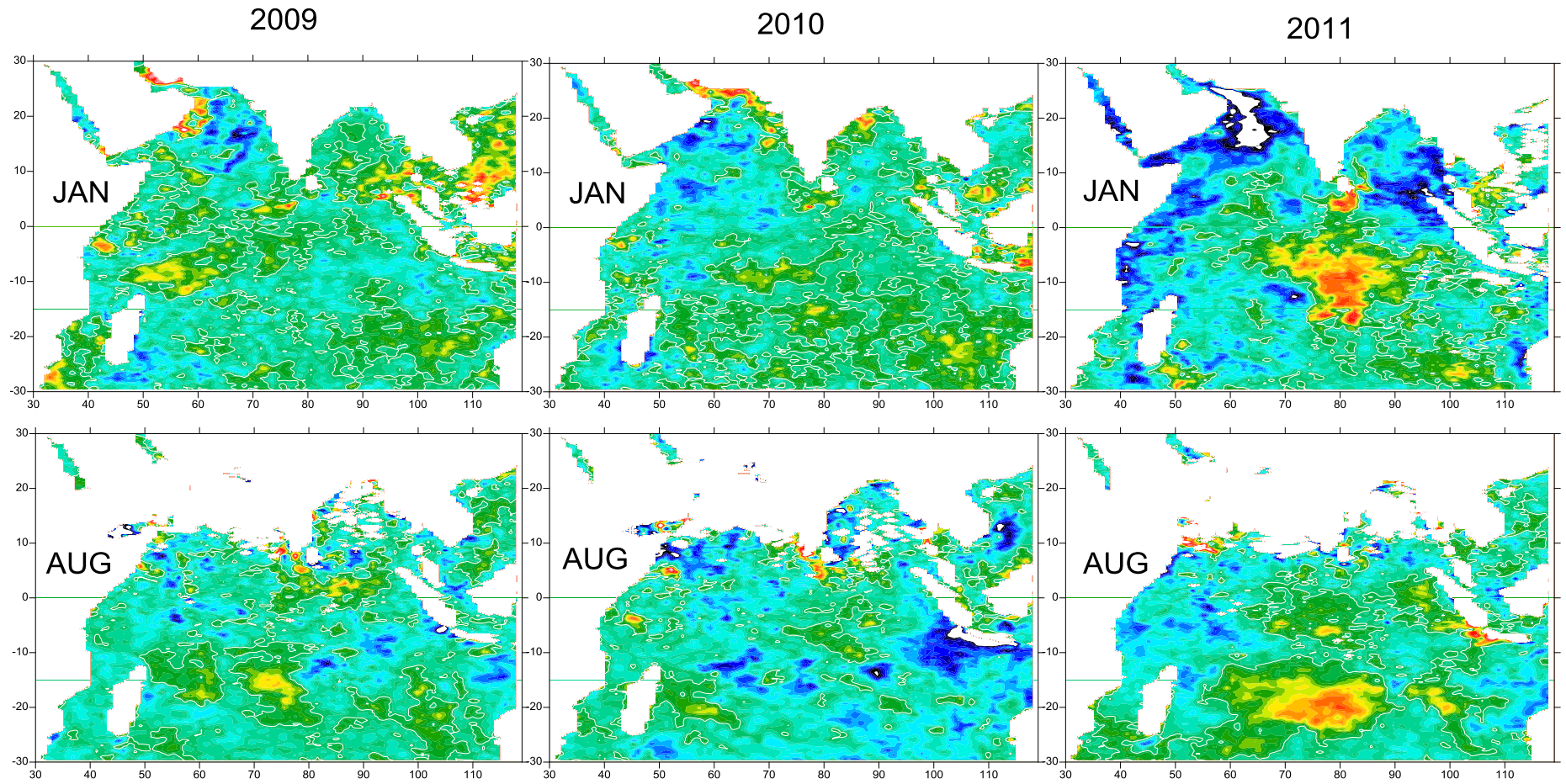
# Wind trend in the Somali upwelling




- We use the meridional component of the wind stress and calculate the average for Jun-Aug
- The result points out alternating phases (decadal variability ?)
- Since 1998, **greater occurrence of weak winds** off Somali, with only 2 years having above normal wind stress (2004-2005)



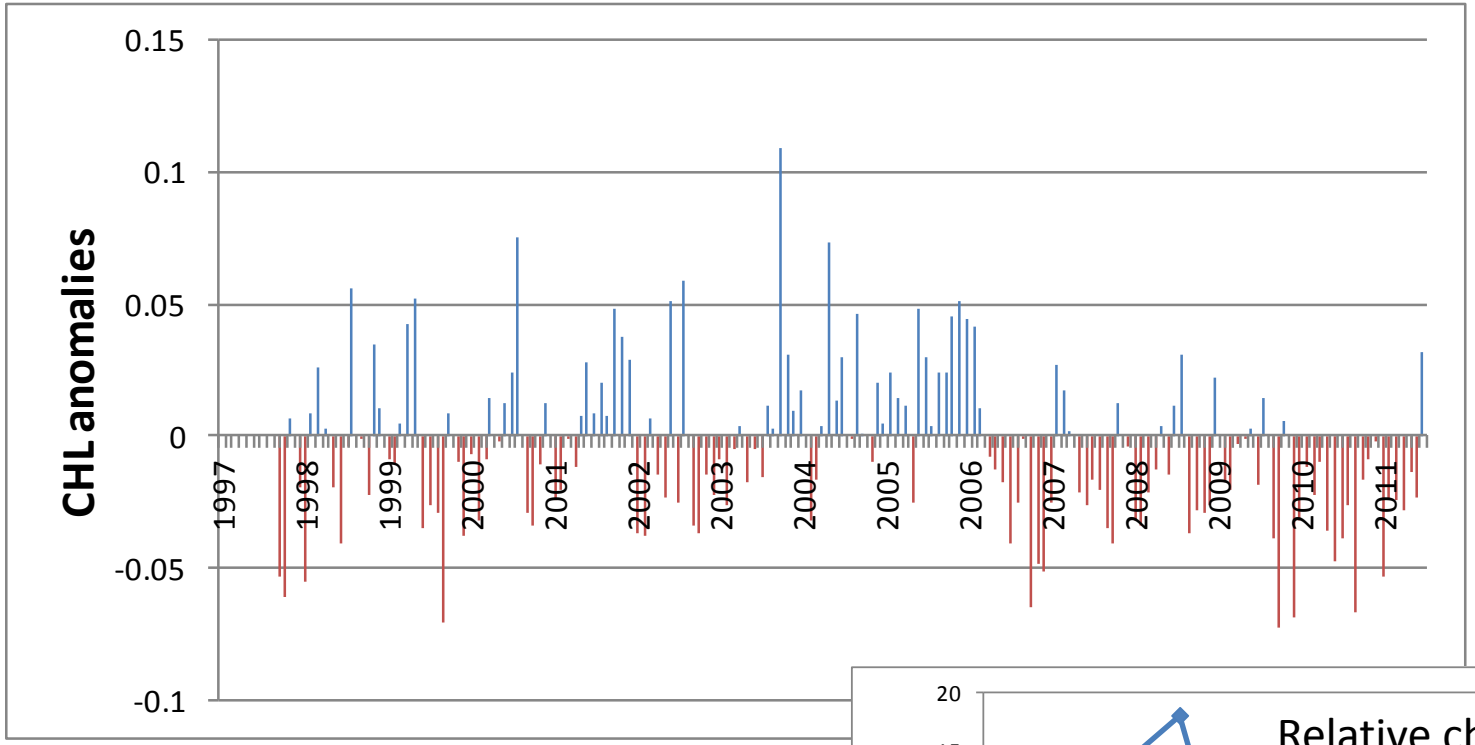






Chlorophyll a (MODIS), January and August 2009 to 2011

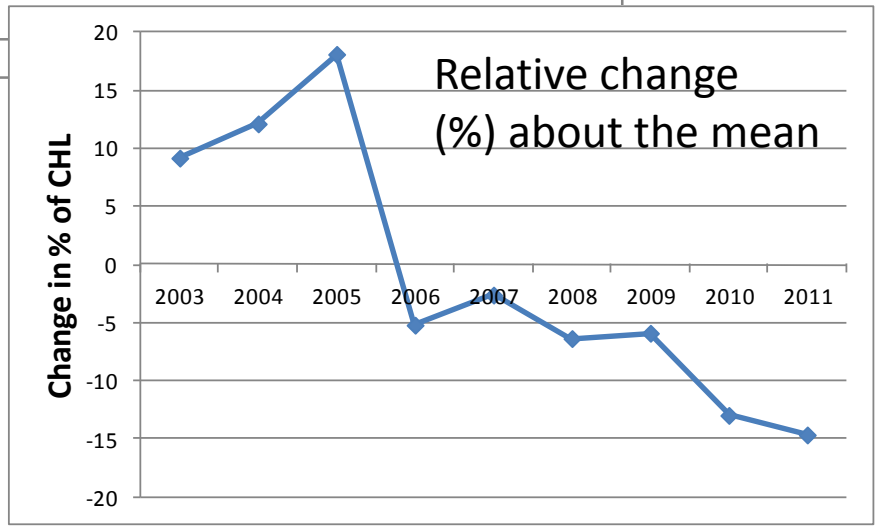
This sequence shows the decreasing trend in primary productivity of the westernmost region of the equatorial Indian Ocean, especially during the boreal winter

# Surface chlorophyll trend in Maldives




Each bar represents a monthly CHL anomaly

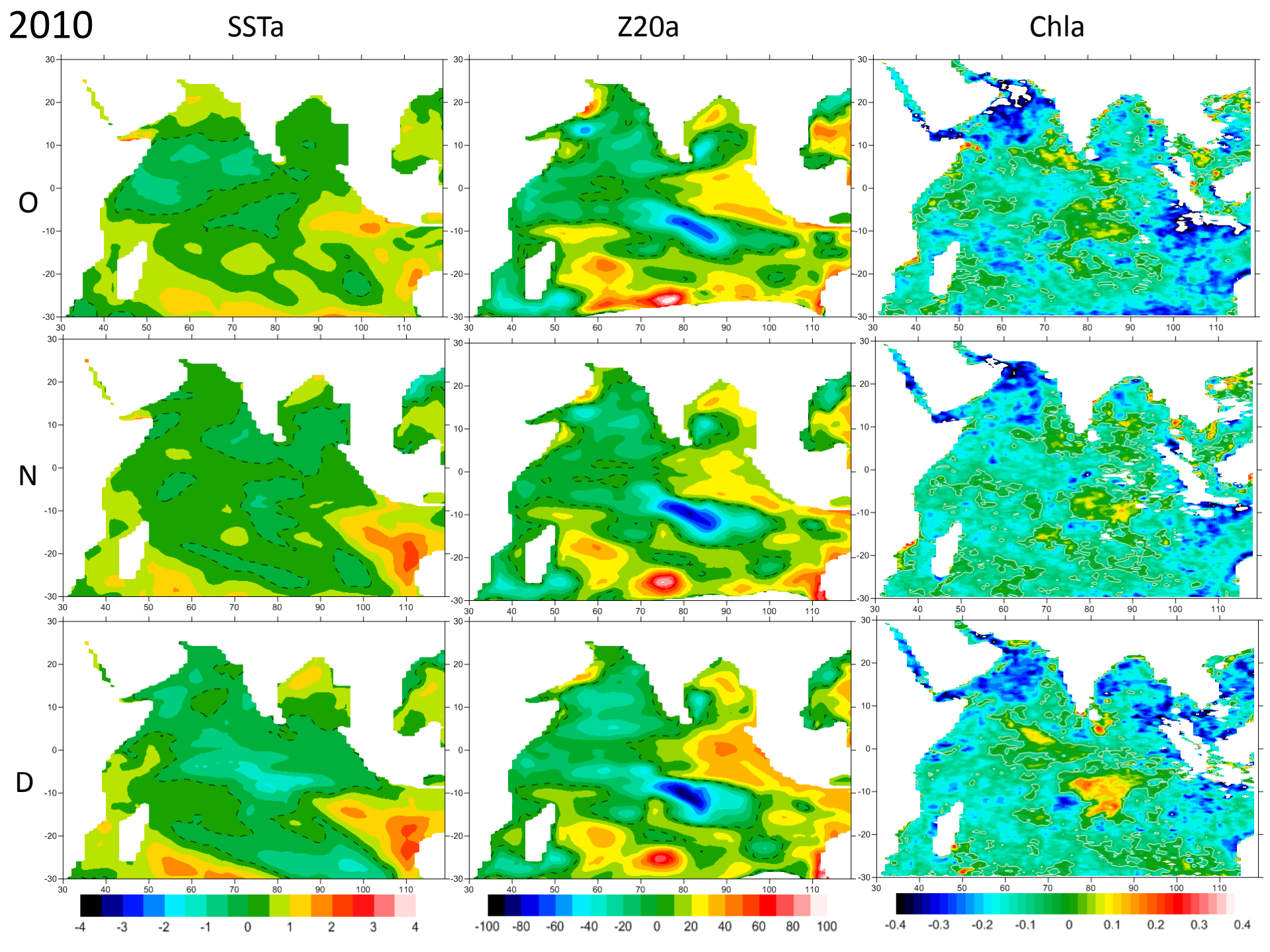
Since 2006, the average productivity is less than the 1998-2002 values and the relative change (in %) about the mean is around -15% in 2011

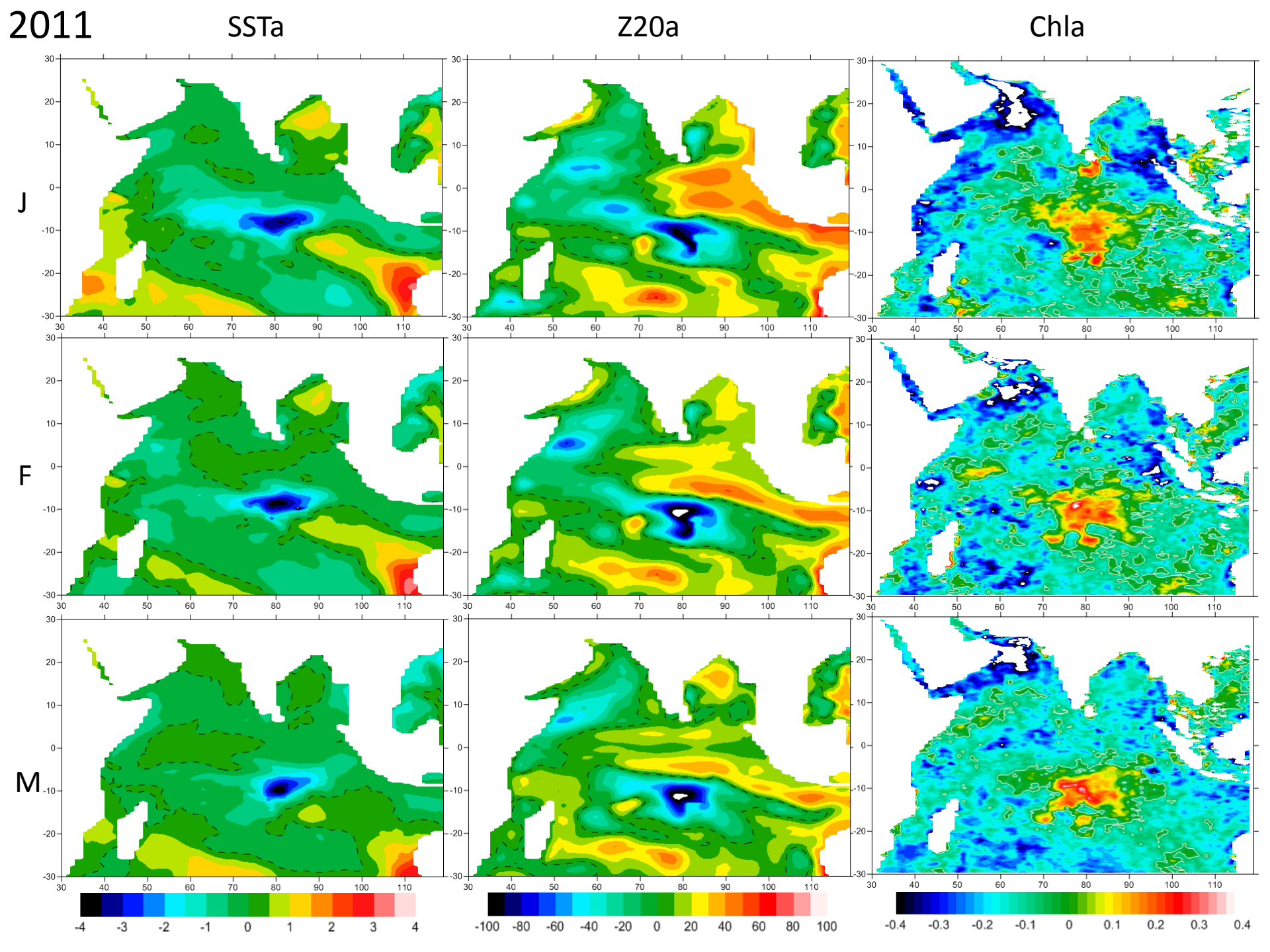


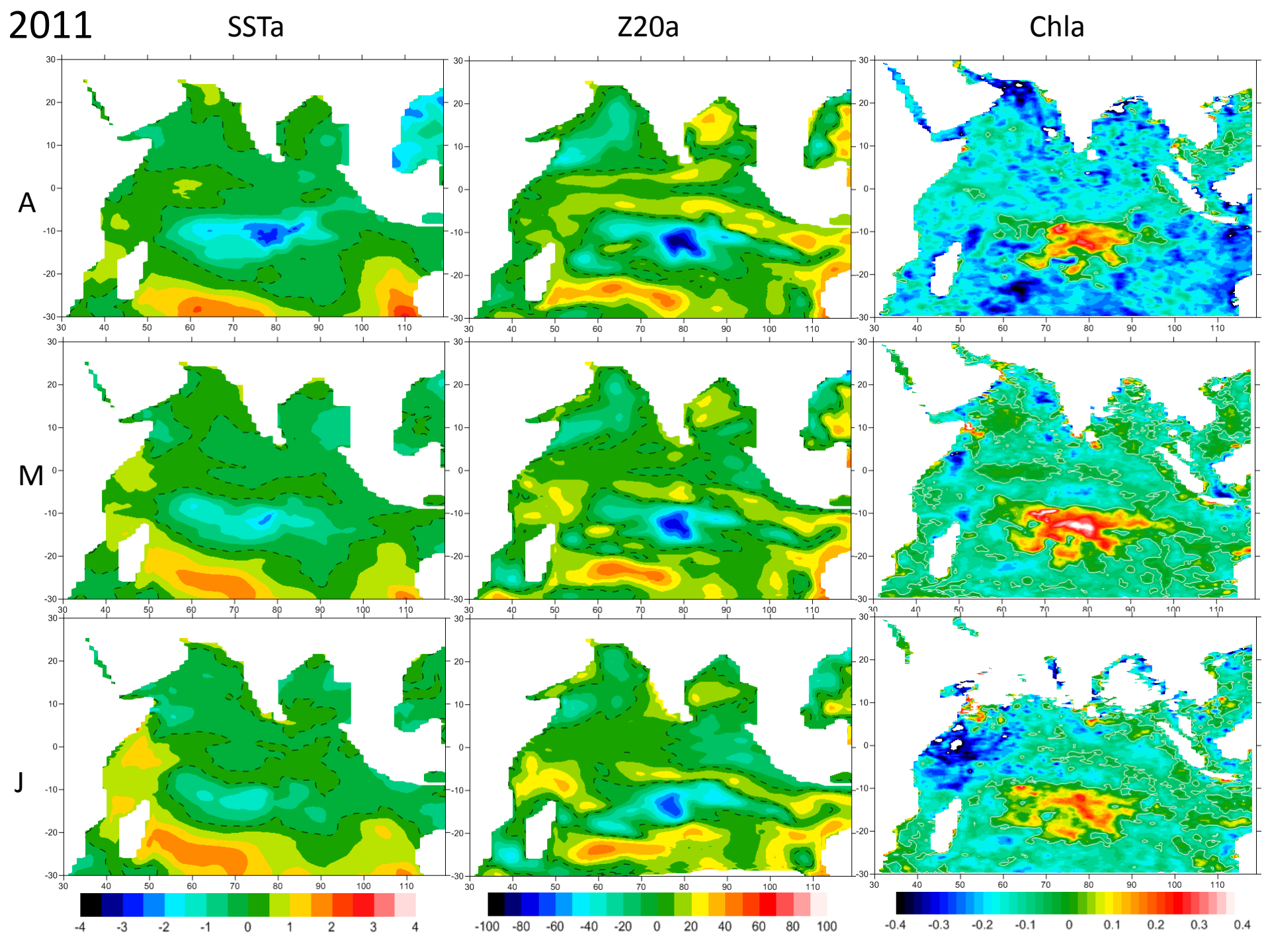
# An anomalous and lasting event in the Central Indian Ocean

- From October 2010 to August 2011 (possibly beyond, data not available yet), an anomalously high productivity was detected in the Central Indian Ocean, between 5°S-15°S/75°E-90°E. The high productivity was triggered by a very shallow thermocline which led to a general cooling of the mixed layer, with a visible trace at the surface.
- The sequence of this anomalous event is represented in the following slides

*Anomalies on SST (SSTa), depth of 20°C isotherm (Z20a) and Surface Chlorophyll (Chla)*


2010
SSTa
Z20a
Chla
O
N
D
-4 -3 -2 -1 0 1 2 3 4
-100 -80 -60 -40 -20 0 20 40 60 80 100
-0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4

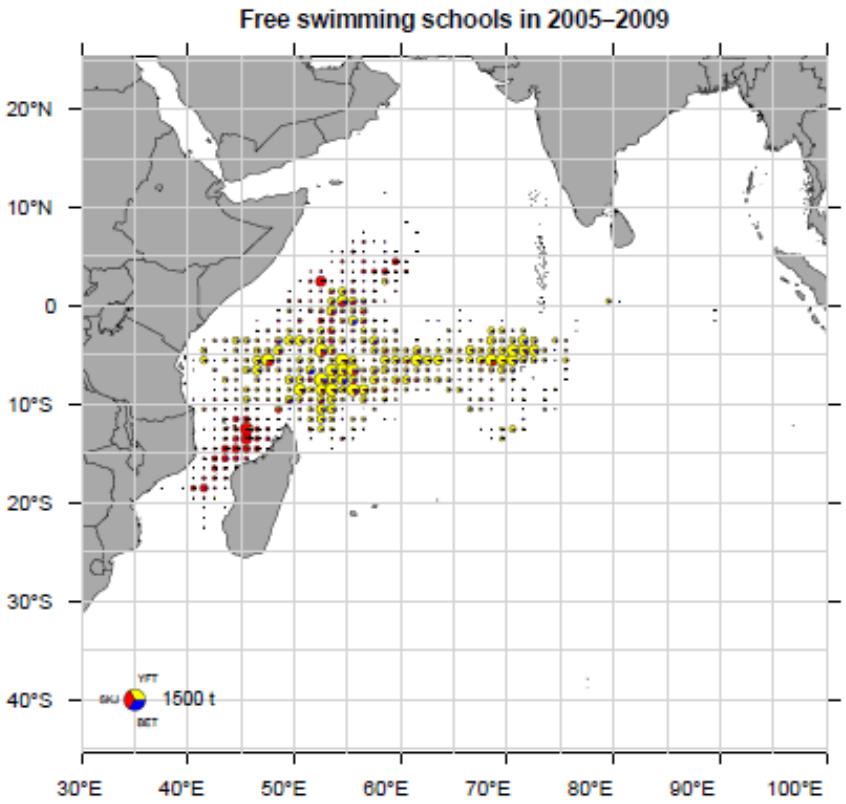

2011
SSTa
Z20a
Chla
J
F
M
-4 -3 -2 -1 0 1 2 3 4
-100 -80 -60 -40 -20 0 20 40 60 80 100
-0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4

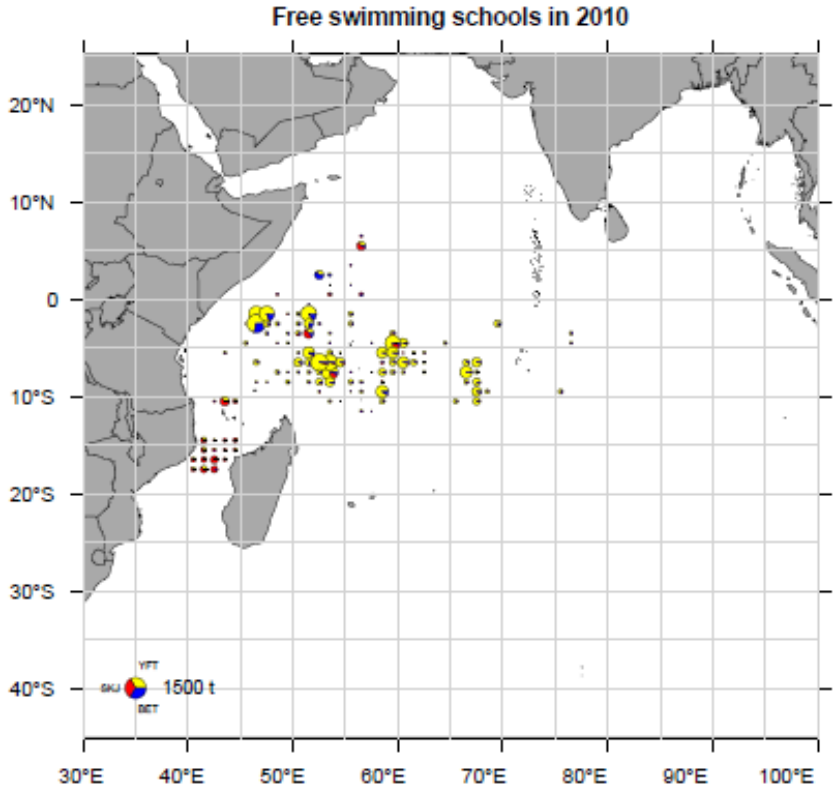

2011
SSTa
Z20a
Chla
A
M
J
-4 -3 -2 -1 0 1 2 3 4
-100 -80 -60 -40 -20 0 20 40 60 80 100
-0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4

# CHL Summary

- Overall decreasing trend of productivity in the WIO. Levels in 2010 and 2011 are 25% and 30% below the average for respectively Jan-Feb and Aug-Sept
- Aug-Sept low figures would suggest a less active Somali upwelling, as shown by the weaker wind stress nearshore. However, this should be further investigated using other variables.
- An anomalous high productive event developed in the Central Indian Ocean and remained active for at least 7 months. A substantial secondary and tertiary production (which can reach top predators) can be expected for such a lasting event.

# 3 – Link with PS CPUE

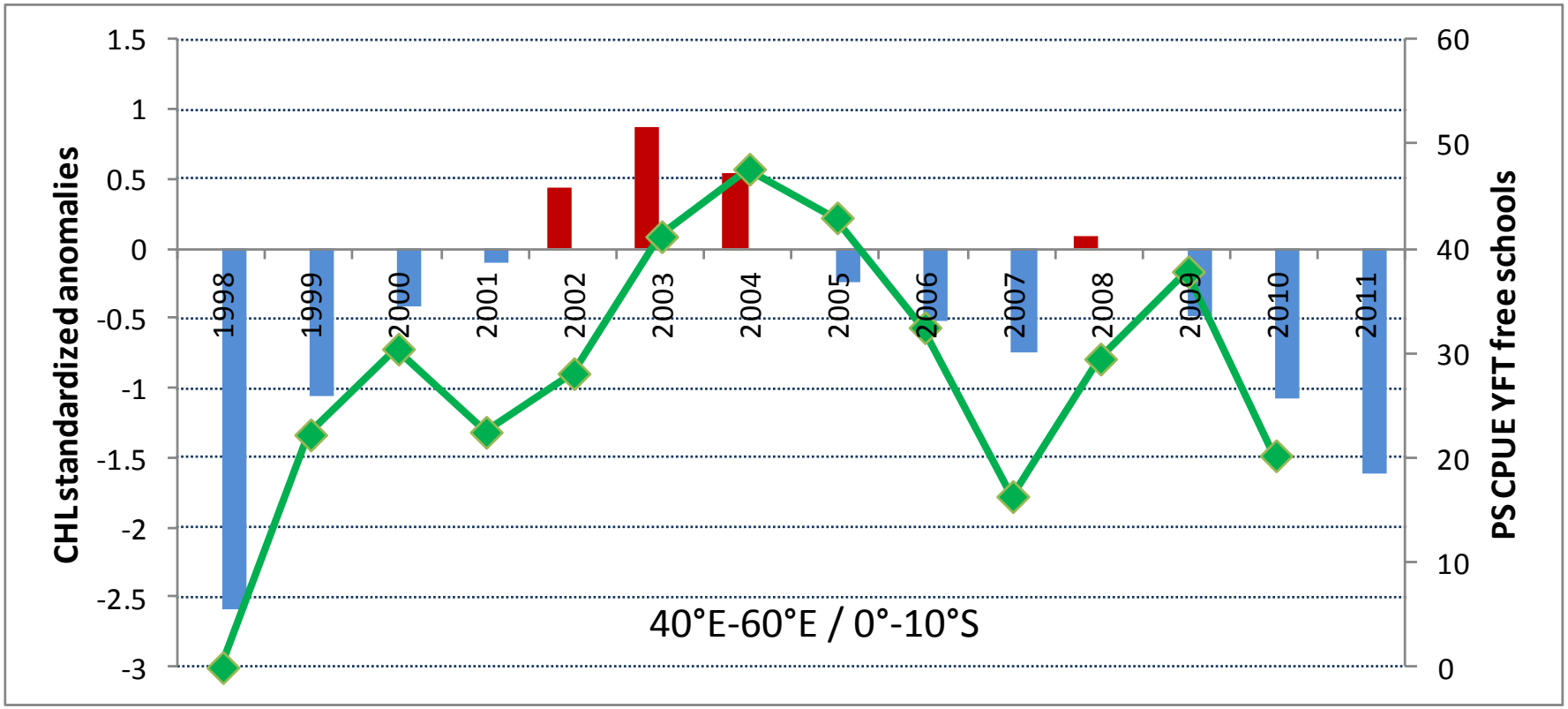


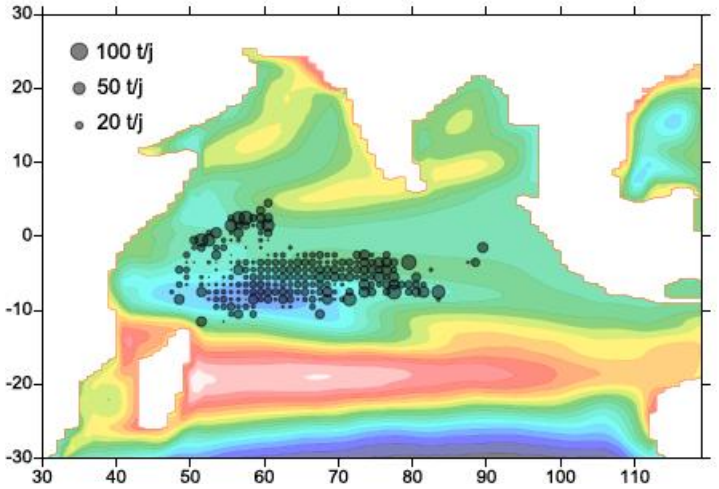

*Source IOTC-2011-WPTT13-20*

Dramatic reduction of PS free-schools catches in 2010 with a very patchy distribution

# CHL-a anomalies and Yellowfin PS CPUE on free schools in the core of the FS area, Jan-Feb

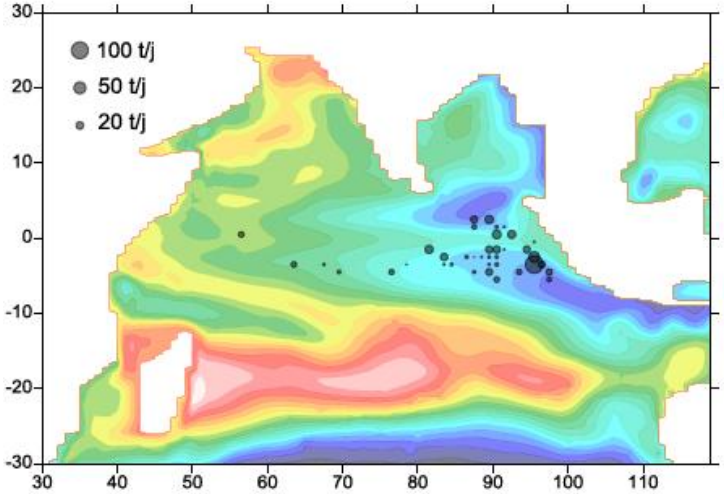


# A reminder : Spatial effects of Nino-related events on PS FS CPUE

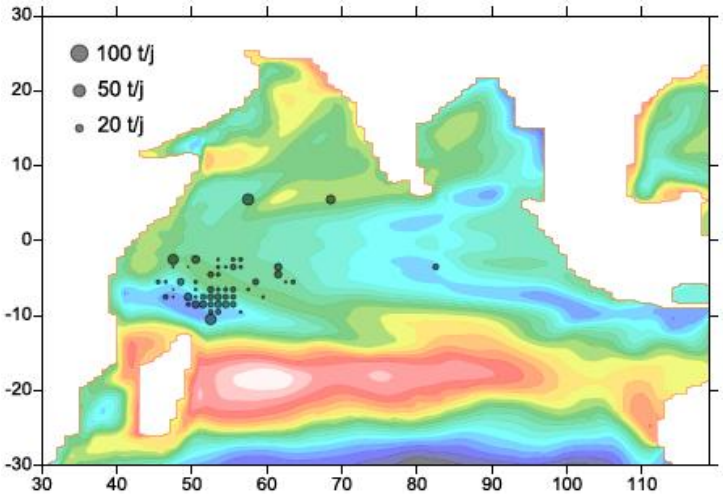



Jan 1991-2002
CPUE = 8.5 t/day

- We overlay the PS CPUE on the depth of the 20°C isotherm
- Dramatic change/contraction in the FS area




Jan 1998 / CPUE = 2.0 t/day

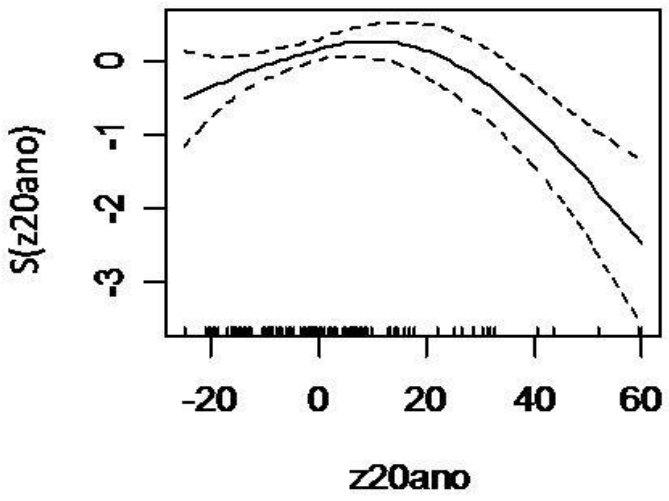


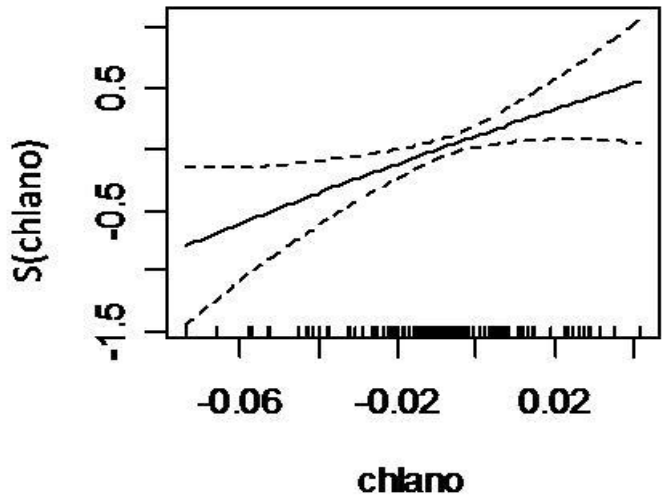

Jan 2007 / CPUE = 2.8 t/day

# GAM analysis PS CPUE YFT FS vs Env

| *Predictor* | *Edf* | *F* | *P value* |
|---|---|---|---|
| s(Z20ano) | 2.657 | 5.02 | 0.000116 *** |
| s(chlano) | 1.080 | 3.984 | 0.009387 ** |

$R^2$ (adjusted) = 0.257 **Explained deviance = 27.7%** GCV score = 1.049 n=136




Period
1983-2008

PS CPUEs show a dramatic decline for 20°C isotherm depth anomaly greater than 30 m (left panel), whereas the CPUEs exhibit a quasi positive linear trend against surface chlorophyll (right panel)

# Summary on PS fishery trend versus the environment

- The variable PS CPUEs (on free schools -FS) are driven by the interannual ocean climate signal, especially in the WIO yellowfin spawning ground (free swimming schools)
- The CPUE series exhibits two record lows related to obvious El Nino-associated events (1998 & 2007).
- CPUE figures for 2010 are also substantially below-normal, and preliminary information for 2011 suggest that low FS CPUEs are prevailing
- The recent decline of primary productivity in the WIO might lead to a reduced carrying capacity of the ecosystem, with adverse effects on tuna concentration and biological processes.
- Other reasons might also explain the declining trend of FS CPUE (change in fishing strategy due to piracy) . Need to deconvoluate those signals