The Abdus Salam
International Centre for Theoretical Physics

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1968-43

Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

Role of the Indian ocean in the monsoon-ENSO system

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Role of the Indian Ocean in the monsoon-ENSO system
A new perspective

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GOALS AND QUESTIONS

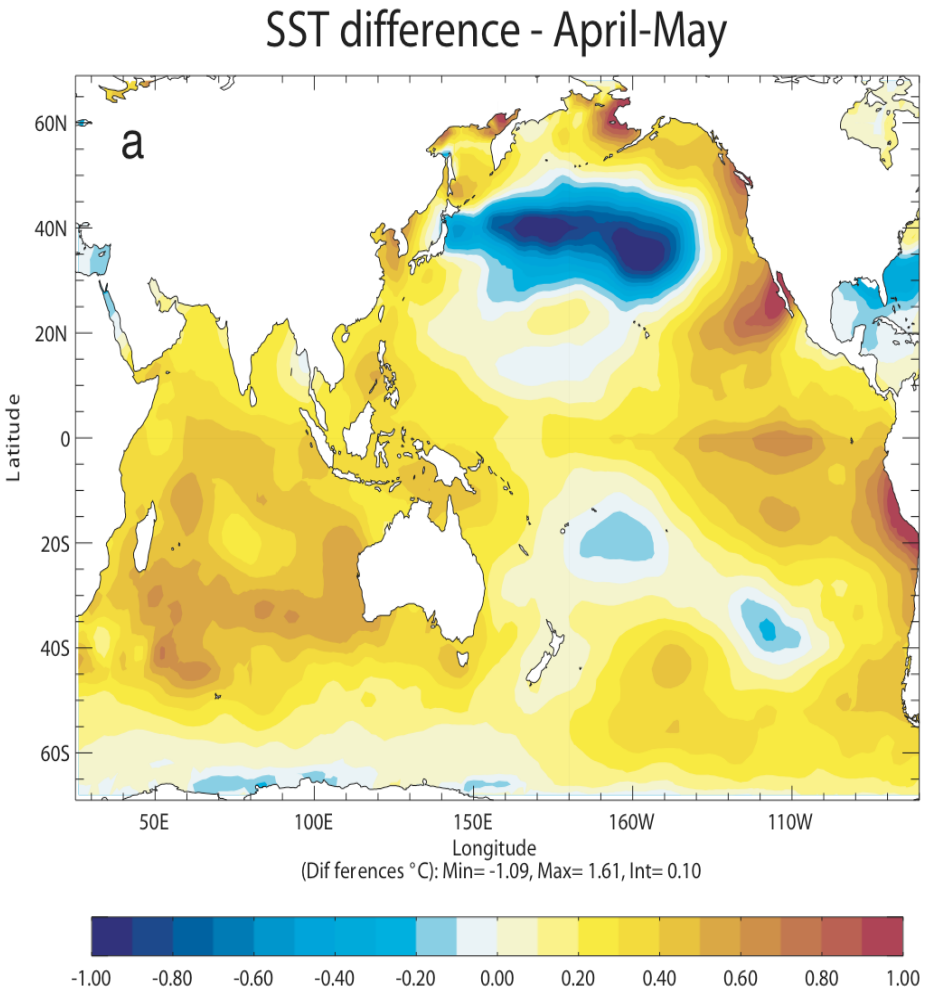
The Indian Ocean experienced a sudden warming around 1976-1977 (Nitta and Yamada, 1989; Terray, 1994; Aoki et al., 2003).

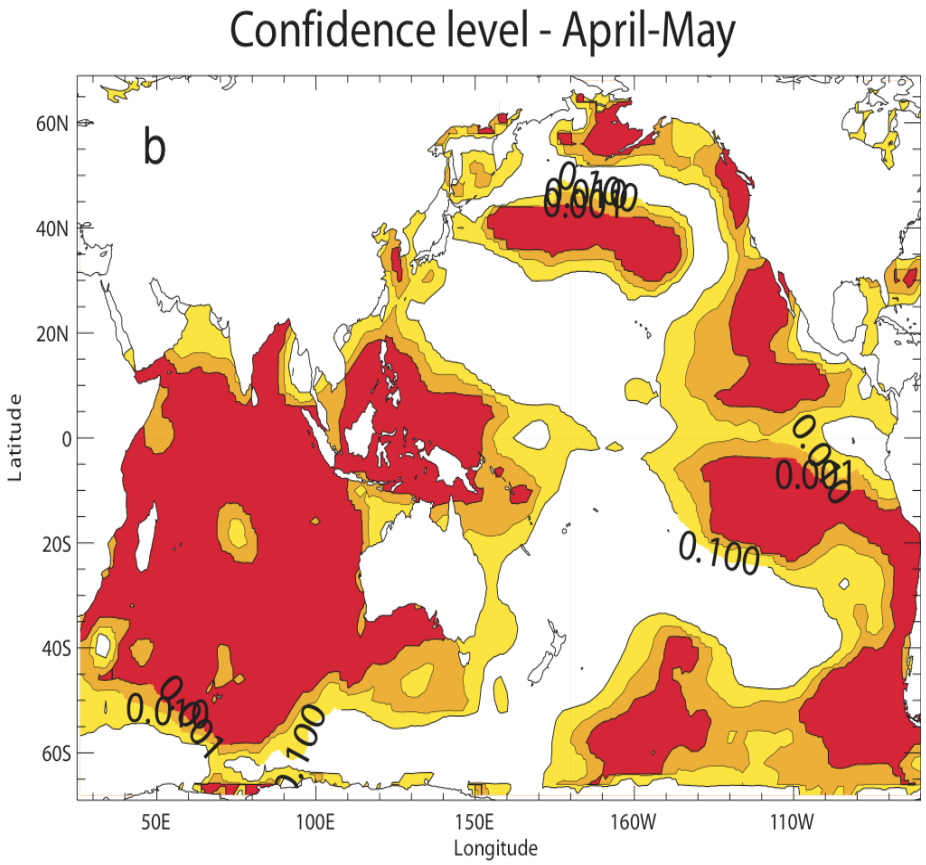
- **How this Indian Ocean warming may influence the teleconnection patterns between the Indian and Pacific Oceans ?**

- **What about the role of the Indian Ocean in ENSO dynamics after the 1976-1977 regime shift and in a global warming context ?**

The Indian Ocean experienced a sudden warming around 1976-1977

Differences between the April-May mean SST
before and after the 1976-1977 climate regime shift





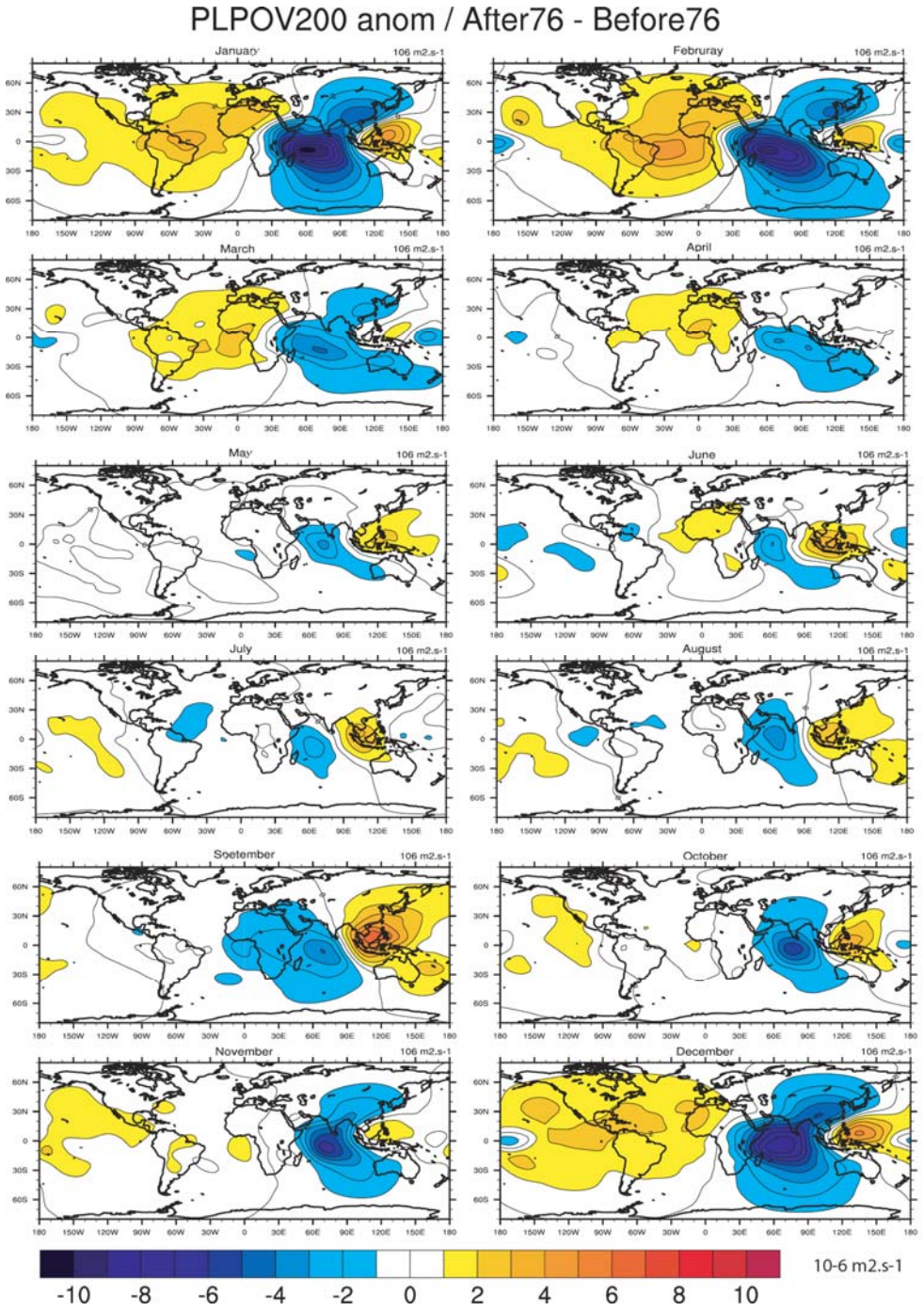
Critical probabilities: 0.001(99.9%), 0.01(99%), 0.1(90%)

Physical significance of the shift

Differences between post- and pre-1976-77 Indian Ocean climatologies of velocity potential at 200 hPa computed from 50-year seasonal cycle experiments (ARPEGE-climat).

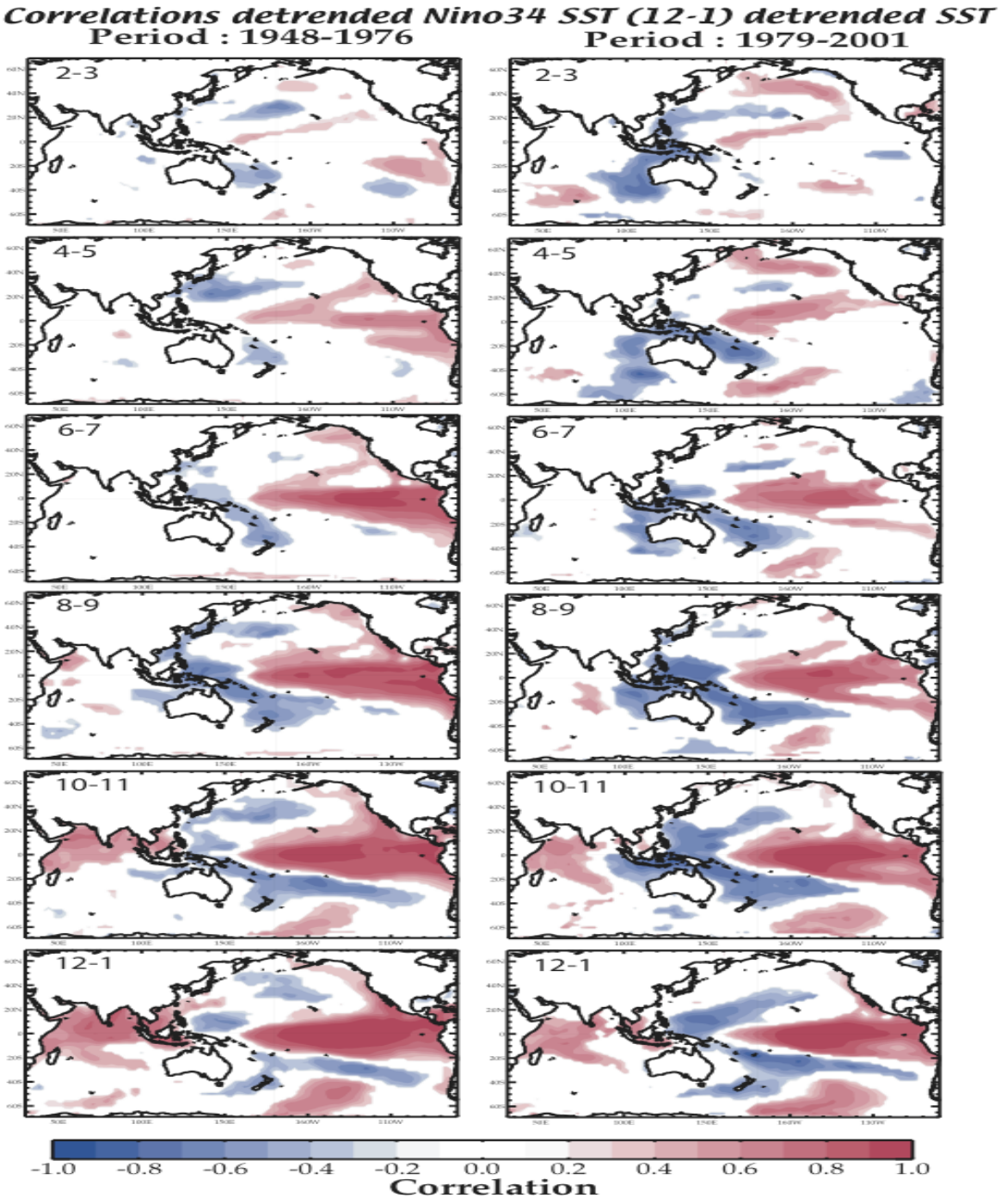
The warming of the Indian Ocean after 1976-77 is associated with shifts of the Walker circulation in the three oceans (Atlantic, Indian and Pacific) !

(Collab. C. Cassou)

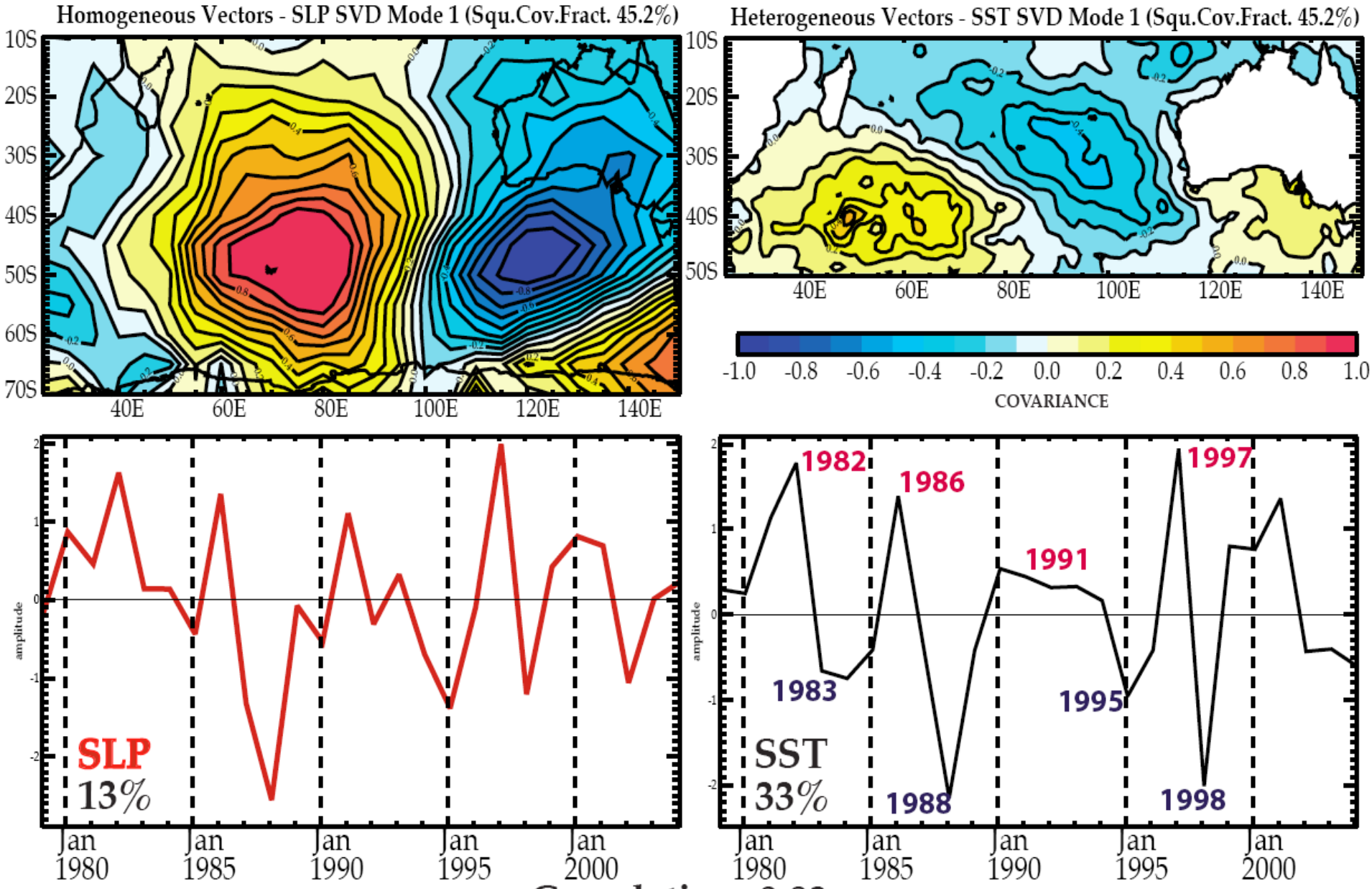


Background

- the 1976-1977 climate regime shift was accompanied by a remarkable change in the lead-lag relationships between Indian Ocean SSTs and El Niño evolution.



SVD (cov.) analysis (SST with SLP) - 1979-2004 - HadISST1 and HadSLP2

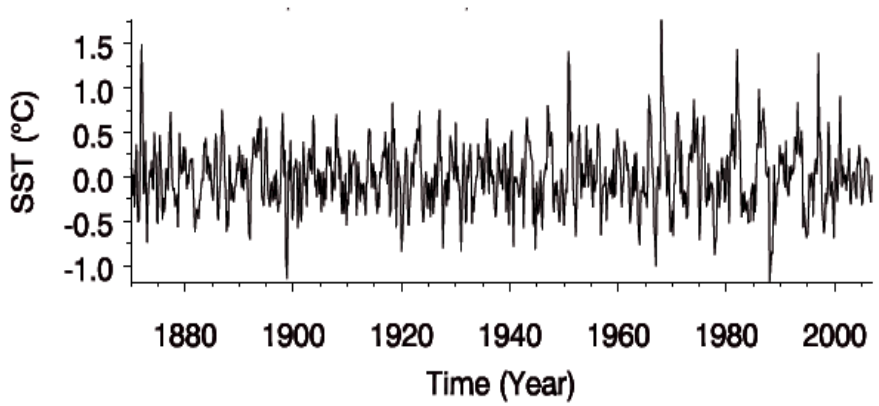


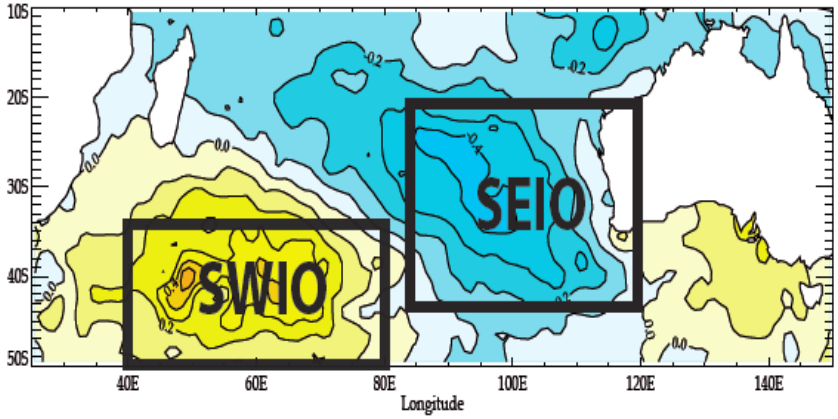
Correlation: 0.83

SLP (red) and SST (black) SVD Mode 1 Standardized Singular Variables

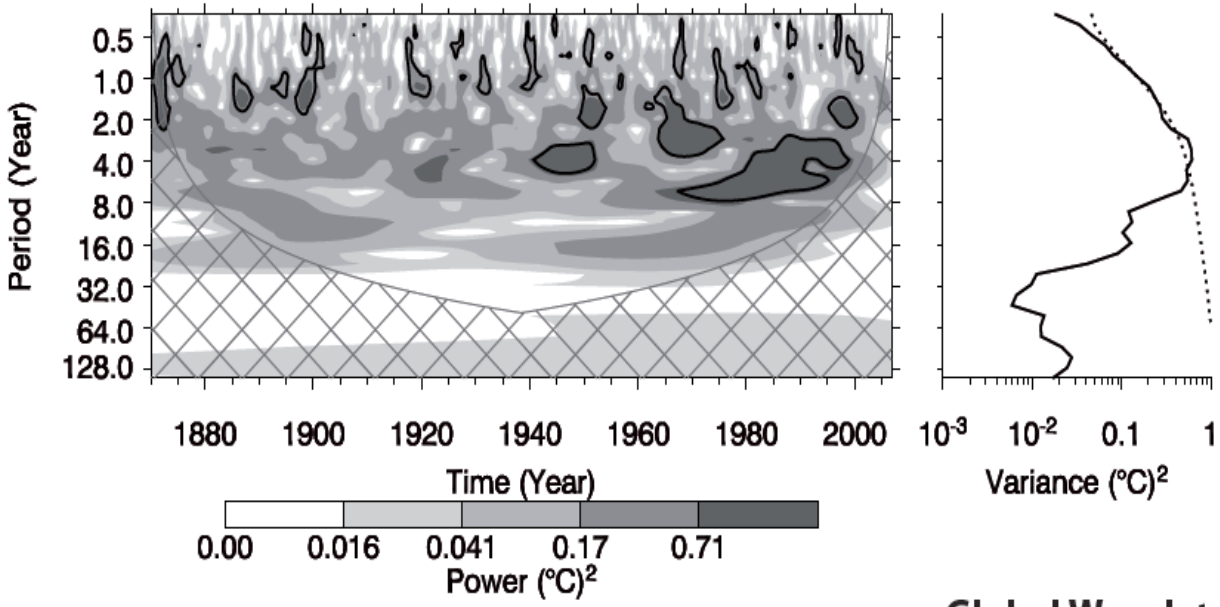
Subtropical Dipole Index

SDI = SWIO - SEIO





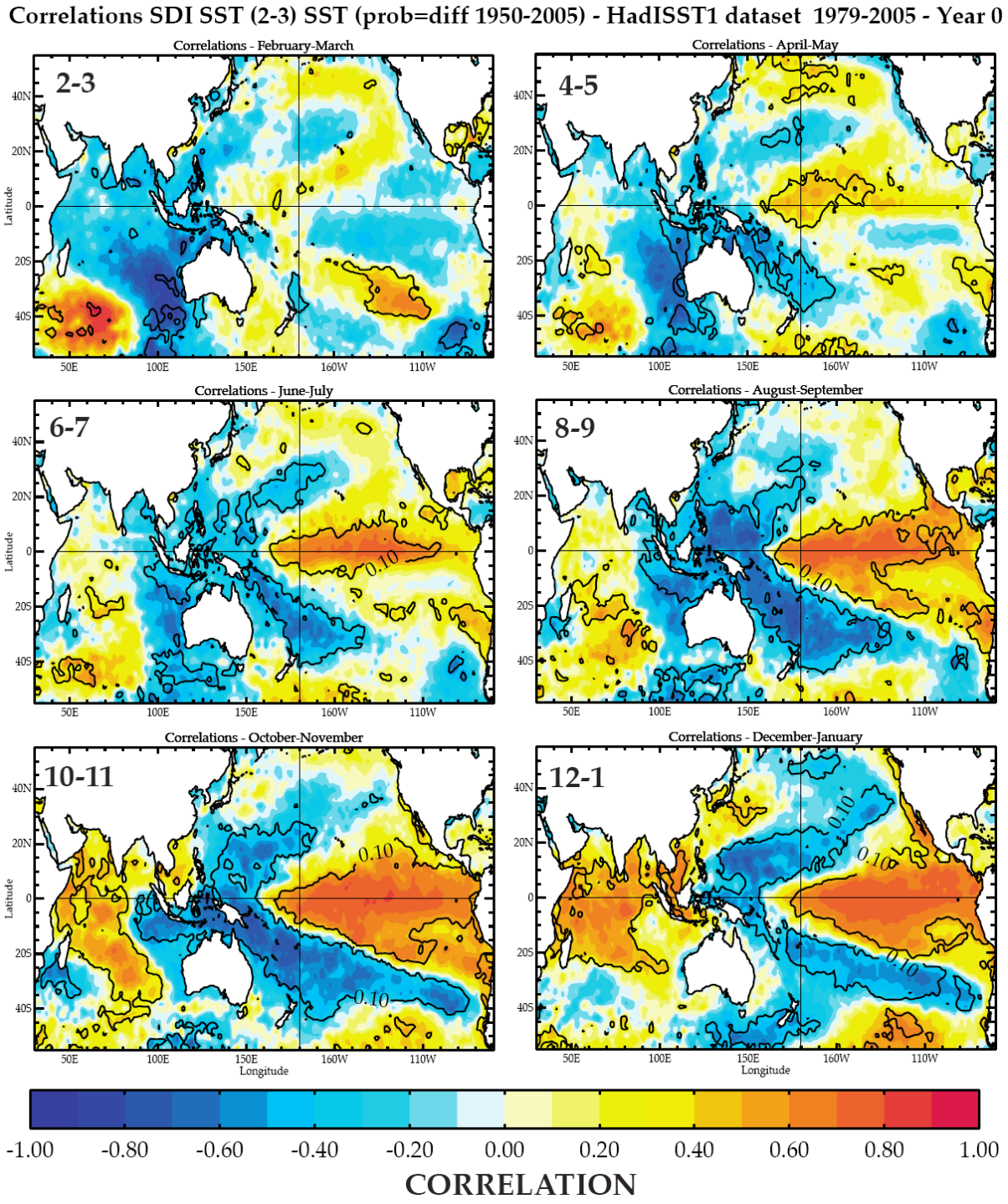
Heterogeneous Vector
SST SVD Mode 1



Wavelet Power spectrum

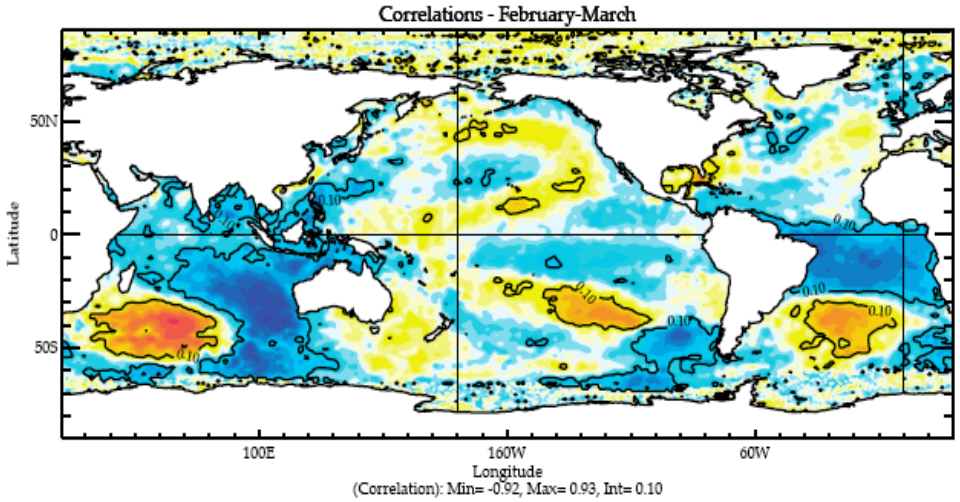
Global Wavelet

- In the figure, the 1979-2005 correlations are plotted and the black line indicates where these correlations are significantly higher (90% confidence level) during the 1979-2005 period compared to the 1950-1977 period.

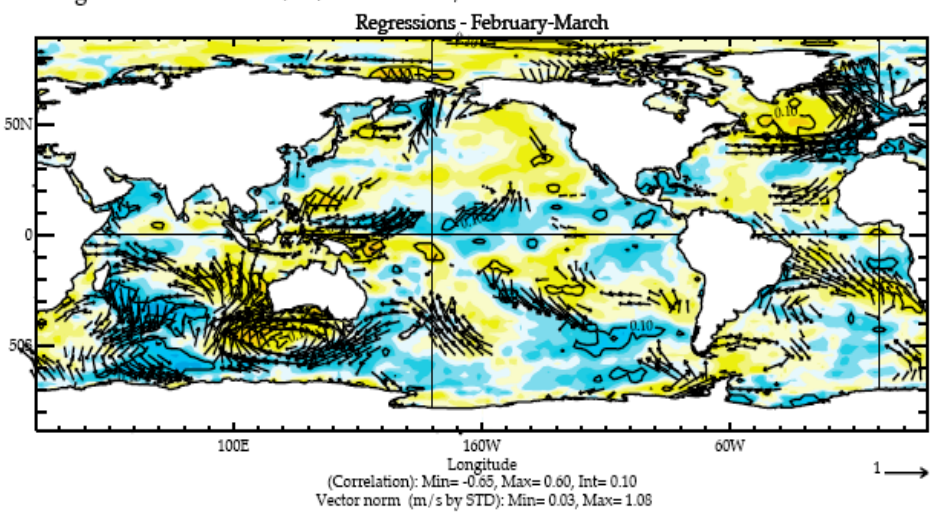


February-March - Year 0

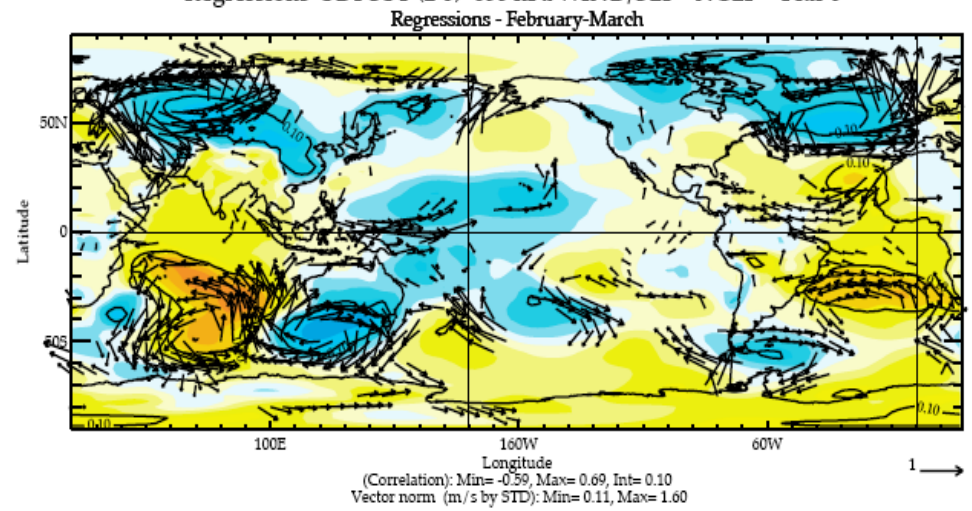
Correlations SDI SST (2-3) detrended SST - HadISST1 dataset 1979-2005 - Year 0



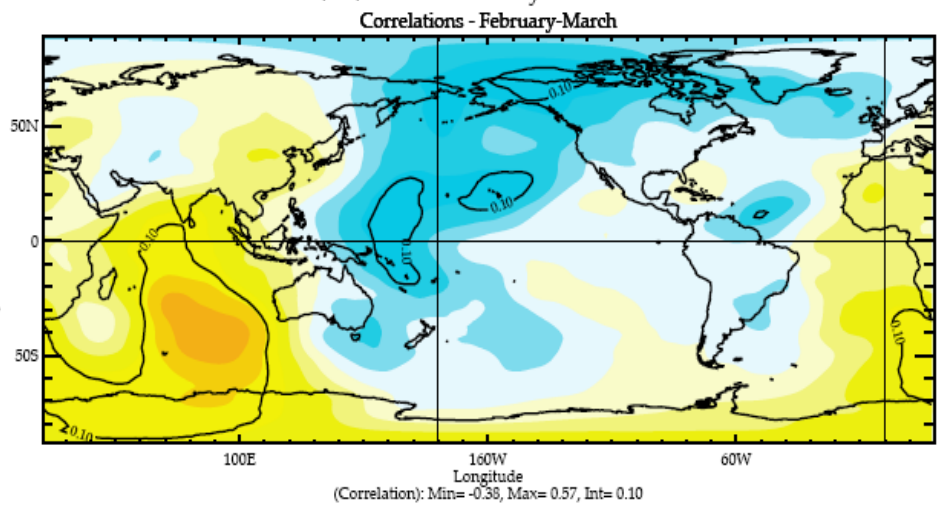
Regressions SDI SST (2-3) 10m WIND/LATENT HEAT FLUX - NCEP - Year 0



Regressions SDI SST (2-3) 850 hPa WIND/SLP - NCEP - Year 0

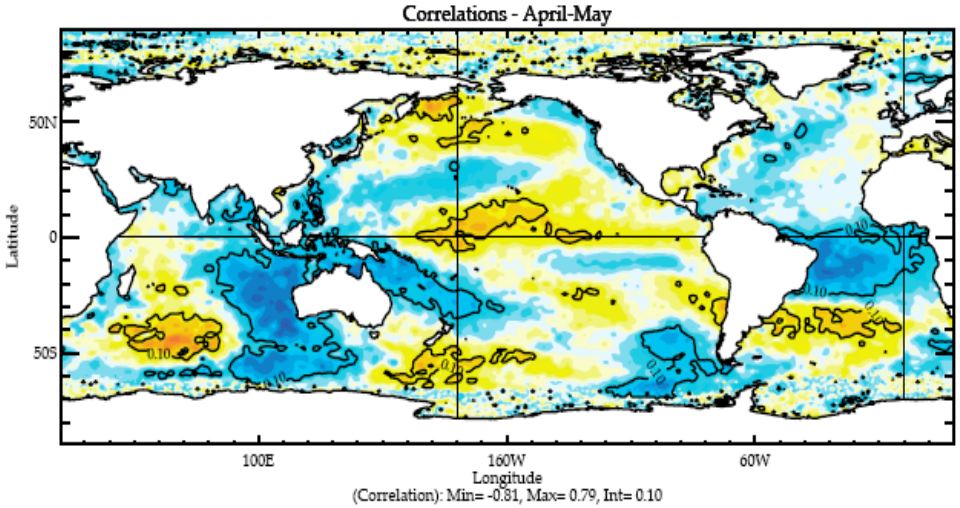


Correlations SDI SST (2-3) 200 hPa Velocity Potential - NCEP 1979-2005 - Year 0

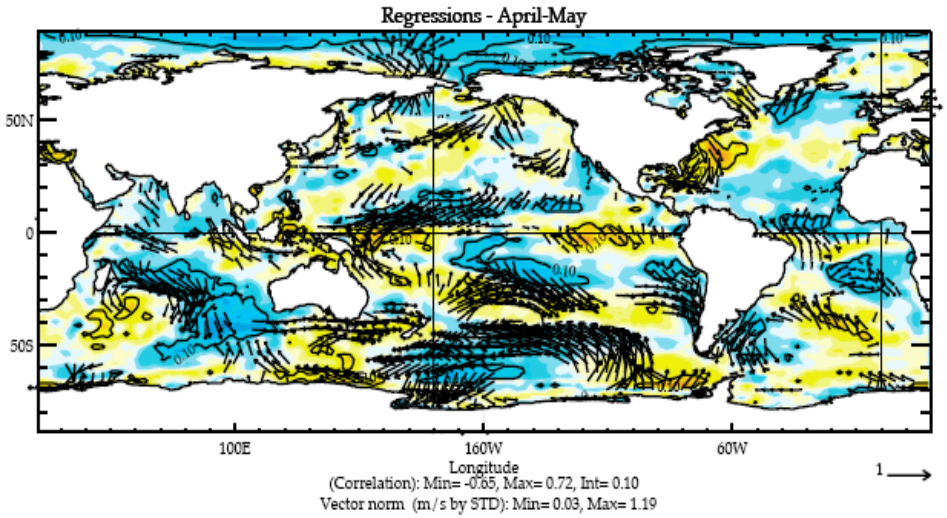


April-May - Year 0

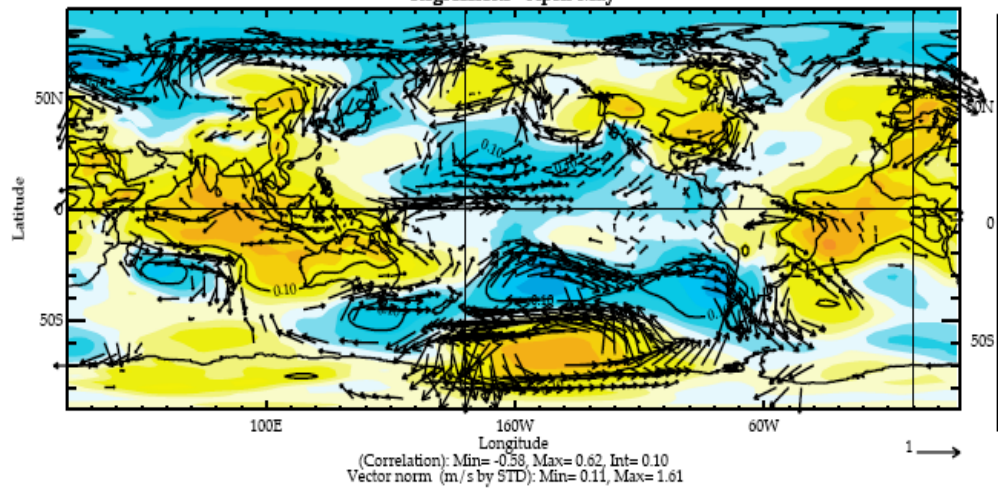
Correlations SDI SST (2-3) detrended SST - HadISST1 dataset 1979-2005 - Year 0



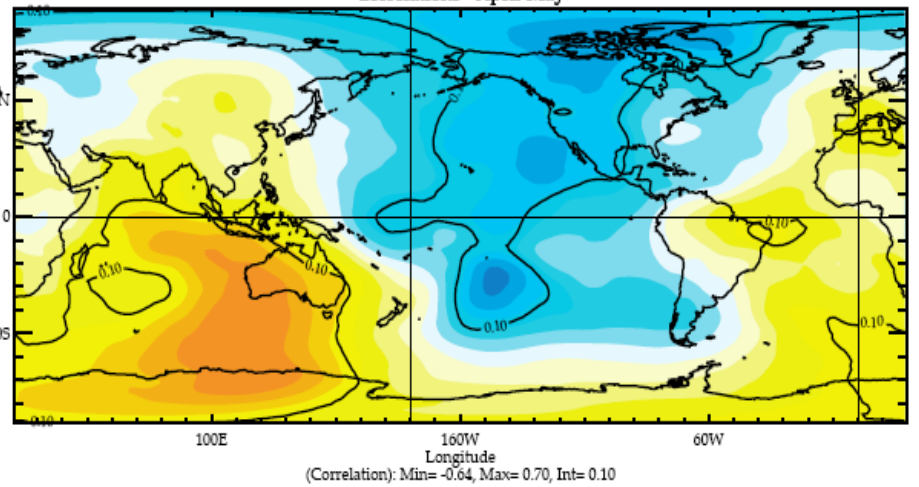
Regressions SDI SST (2-3) 10m WIND/LATENT HEAT FLUX - NCEP - Year 0

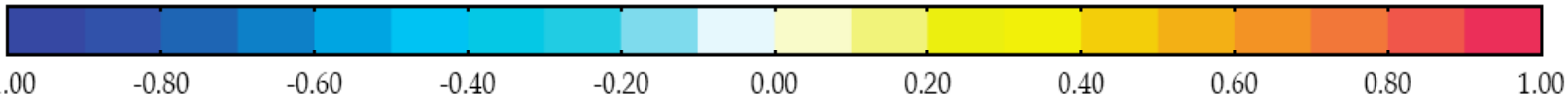


Regressions SDI SST (2-3) 850 hPa WIND/SLP - NCEP - Year 0



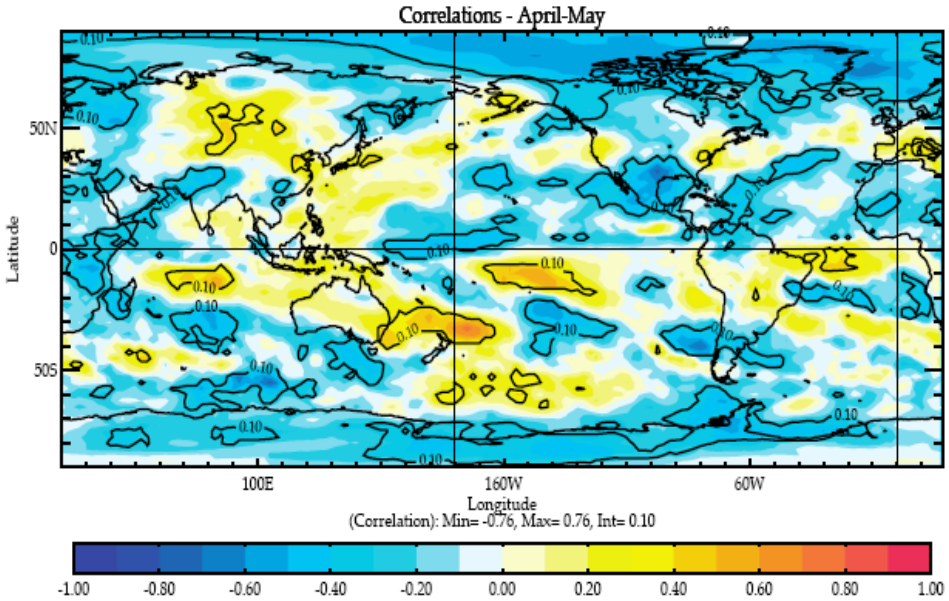
Correlations SDI SST (2-3) 200 hPa Velocity Potential - NCEP 1979-2005 - Year 0



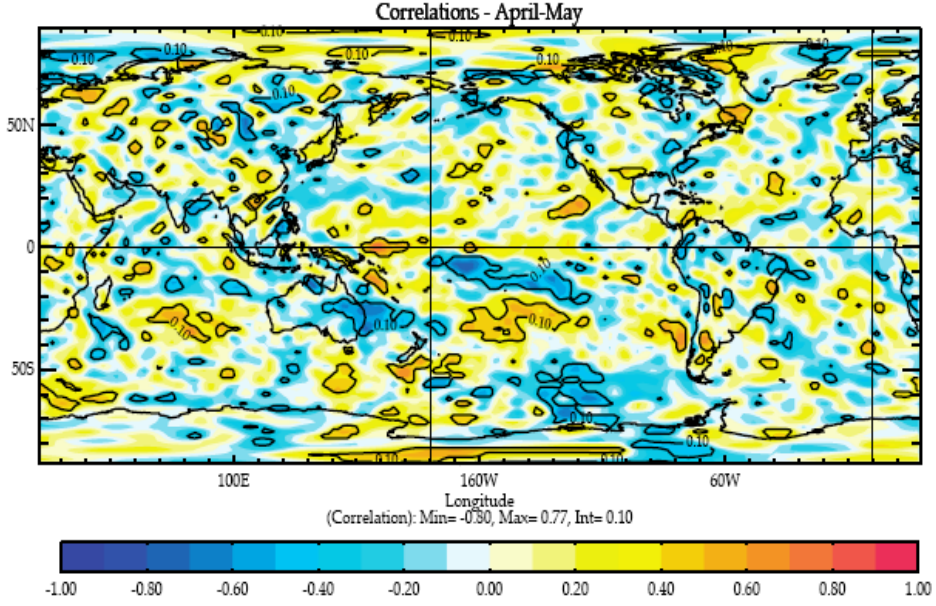


CORRELATION

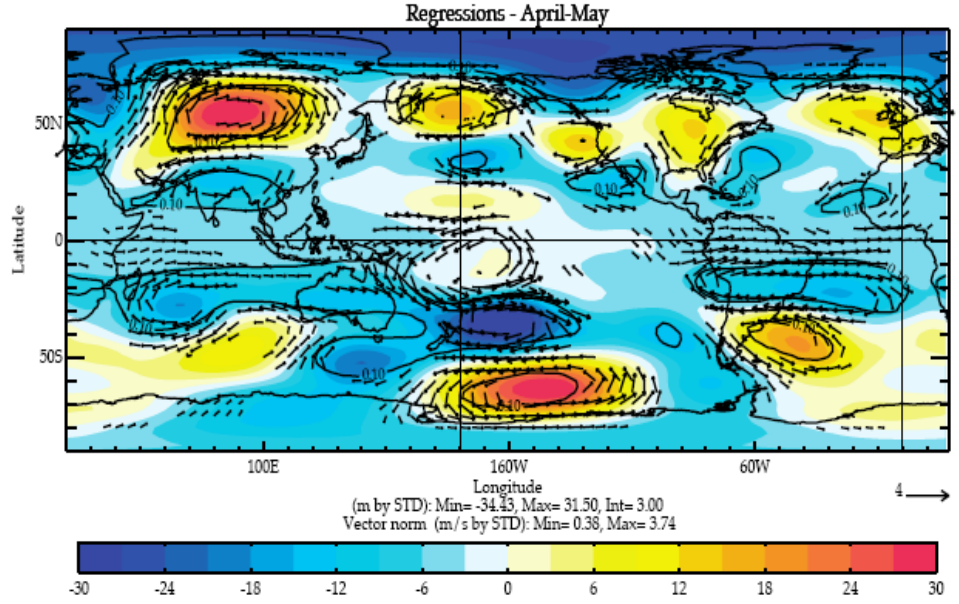
Correlations SDI SST (2-3) OLR - NOAA dataset 1979-2005 - Year 0



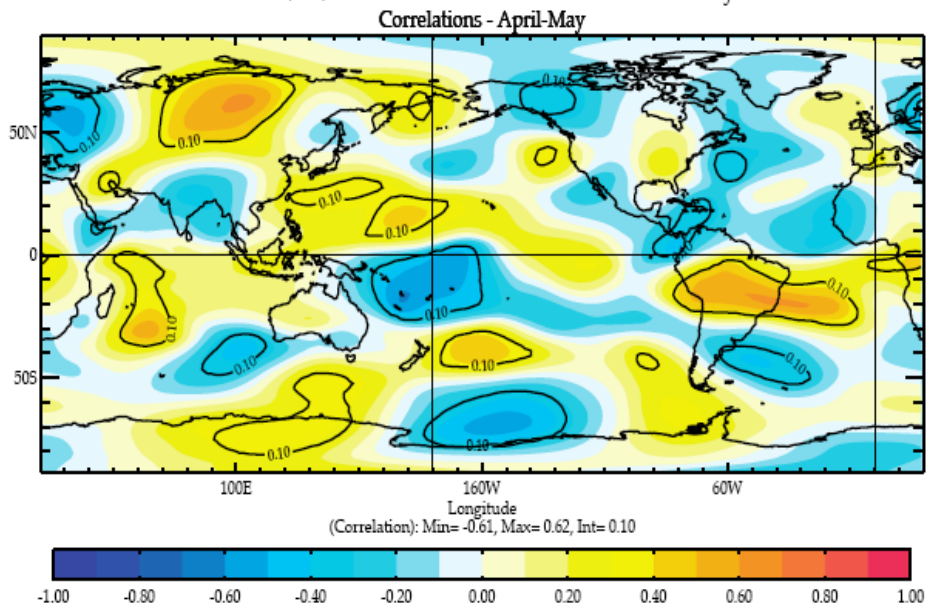
Correlations SDI SST (2-3) 200 hPa Divergence - NCEP - Year 0



Regressions SDI SST (2-3) 200 hPa WIND/Geopotential height - NCEP - Year 0

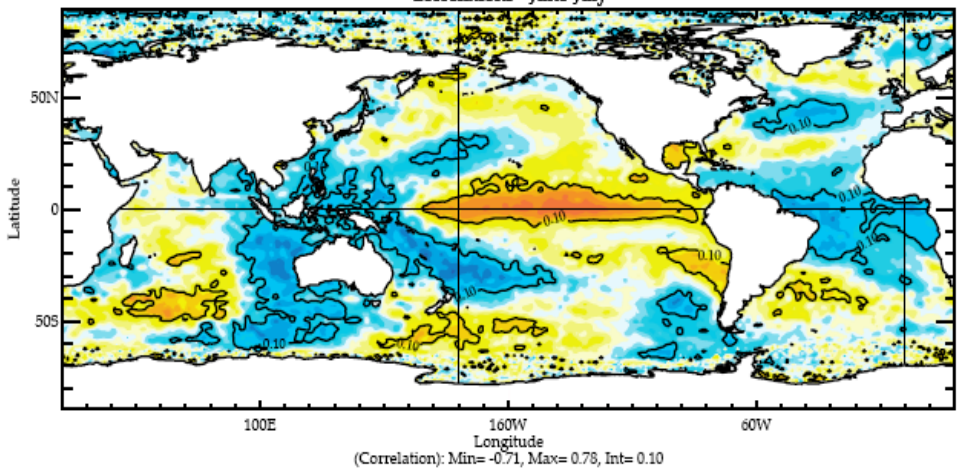


Correlations SDI SST (2-3) 200 hPa Streamfunction zonal anomaly - NCEP - Year 0

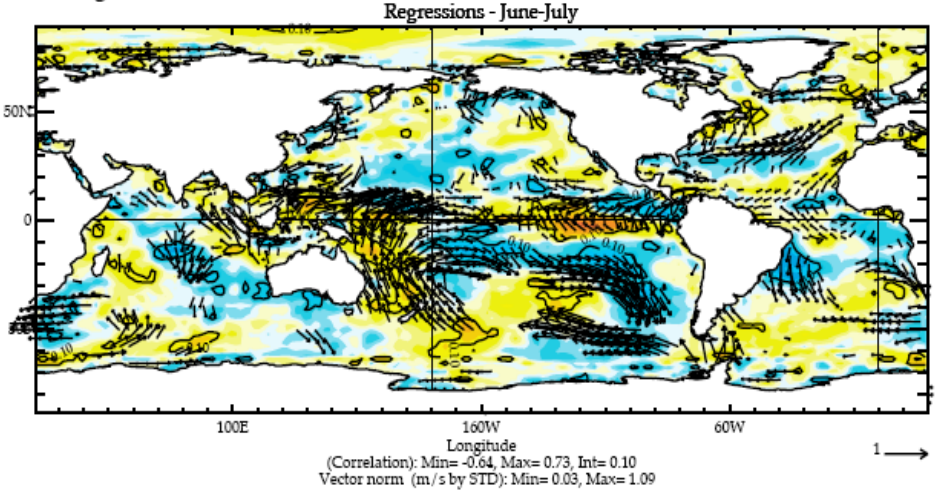


June-July - Year 0

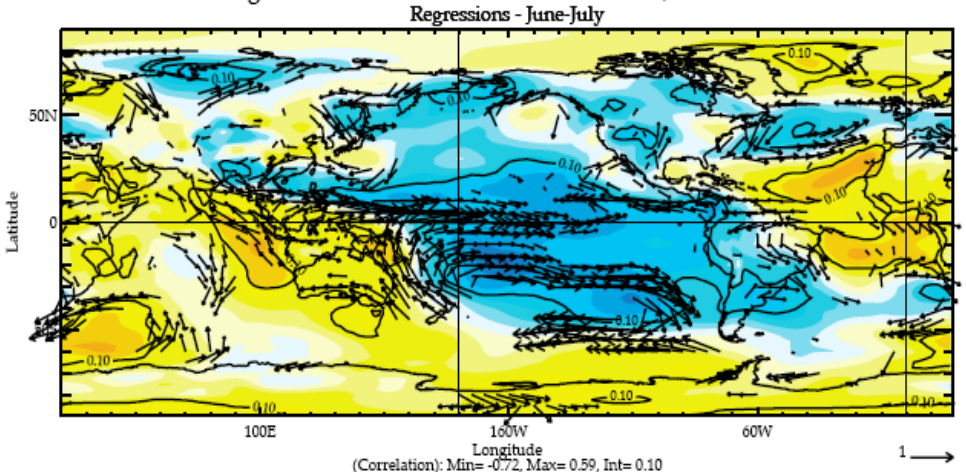
Correlations SDI SST (2-3) detrended SST - HadISST1 dataset 1979-2005 - Year 0



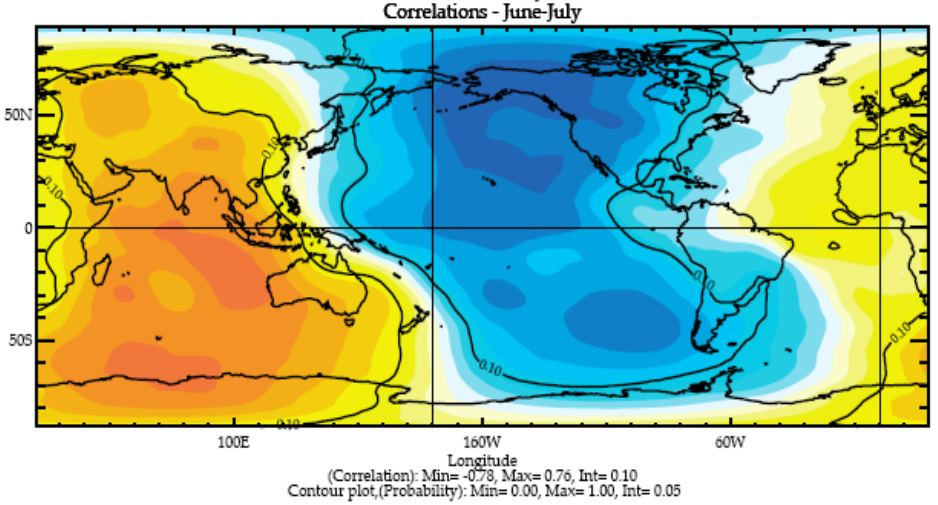
Regressions SDI SST (2-3) 10m WIND/LATENT HEAT FLUX - NCEP - Year 0



Regressions SDI SST (2-3) 850 hPa WIND/SLP - NCEP - Year 0

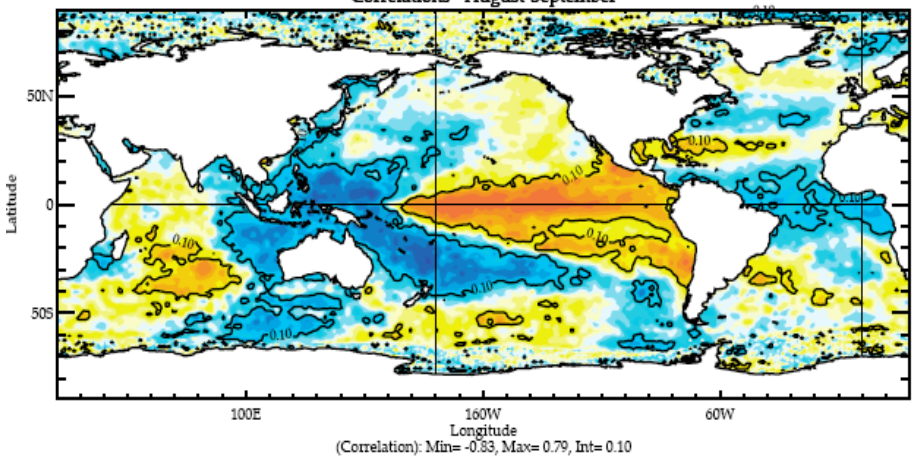


Correlations SDI SST (2-3) 200 hPa Velocity Potential - NCEP 1979-2005 - Year 0

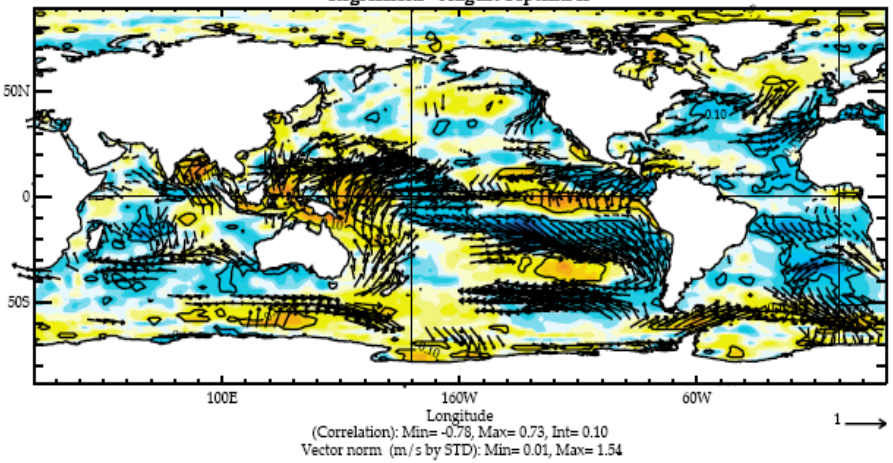


August-September - Year 0

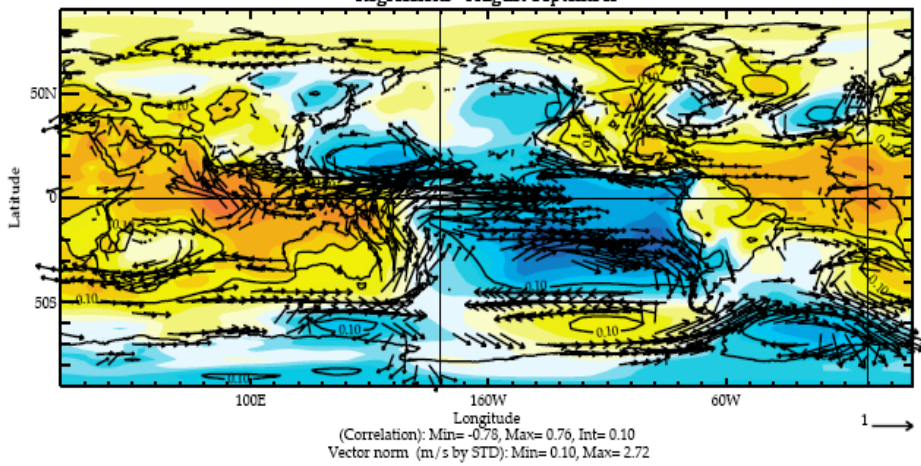
Correlations SDI SST (2-3) detrended SST - HadISST1 dataset 1979-2005 - Year 0



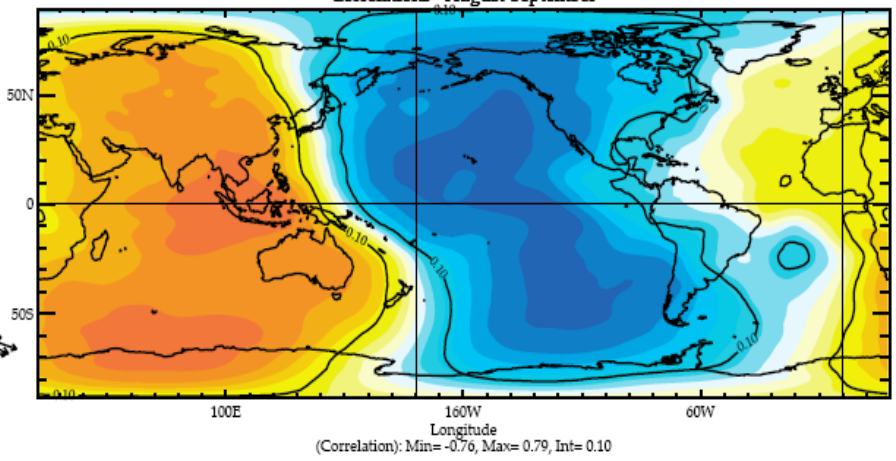
Regressions SDI SST (2-3) 10m WIND/LATENT HEAT FLUX - NCEP - Year 0

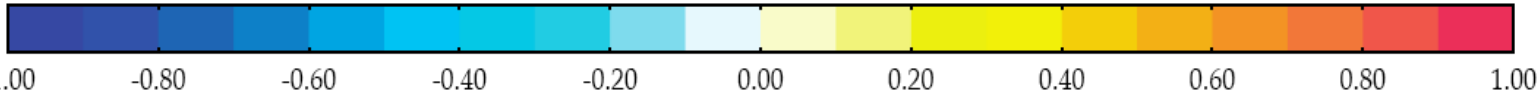


Regressions SDI SST (2-3) 850 hPa WIND/SLP - NCEP - Year 0



Correlations SDI SST (2-3) 200 hPa Velocity Potential - NCEP 1979-2005 - Year 0

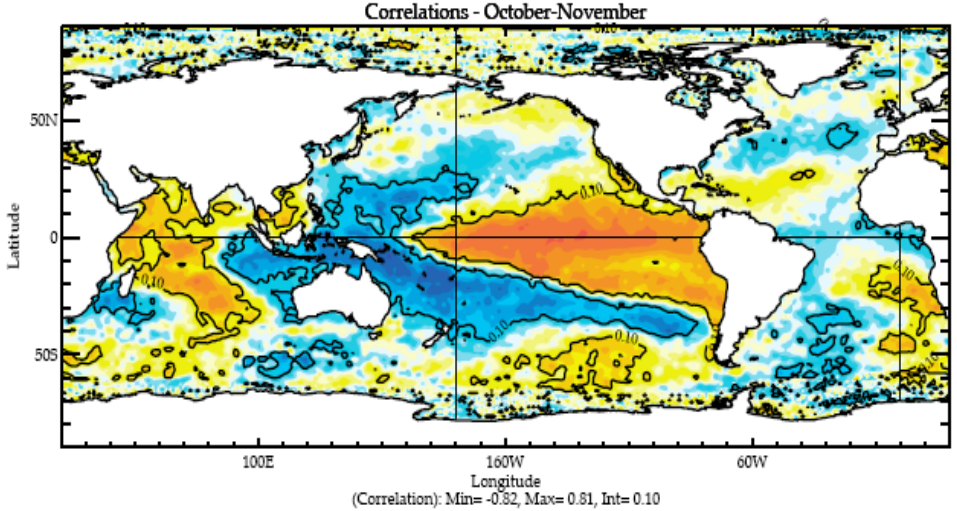




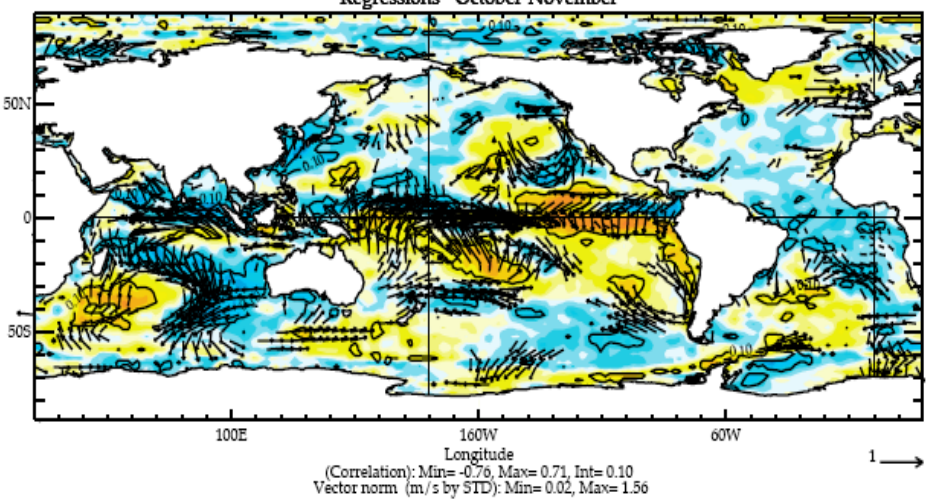
CORRELATION

October-November - Year 0

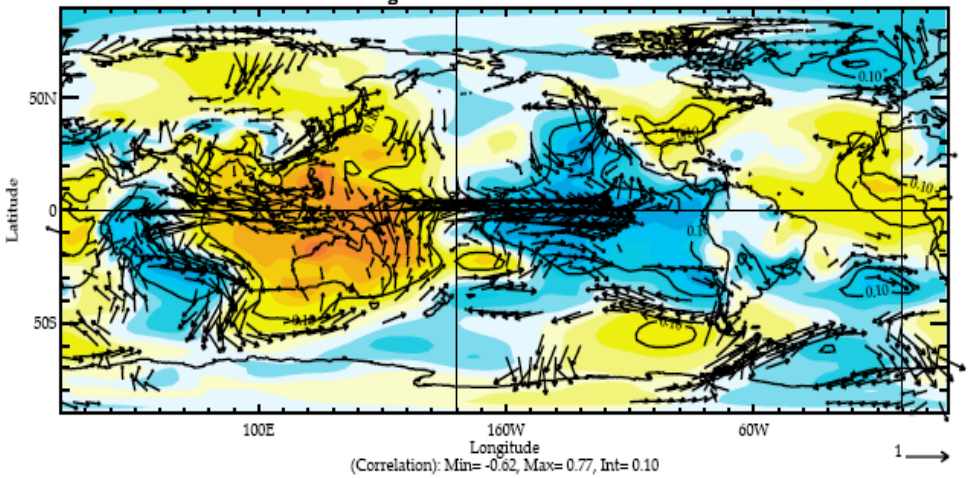
Correlations SDI SST (2-3) detrended SST - HadISST1 dataset 1979-2005 - Year 0



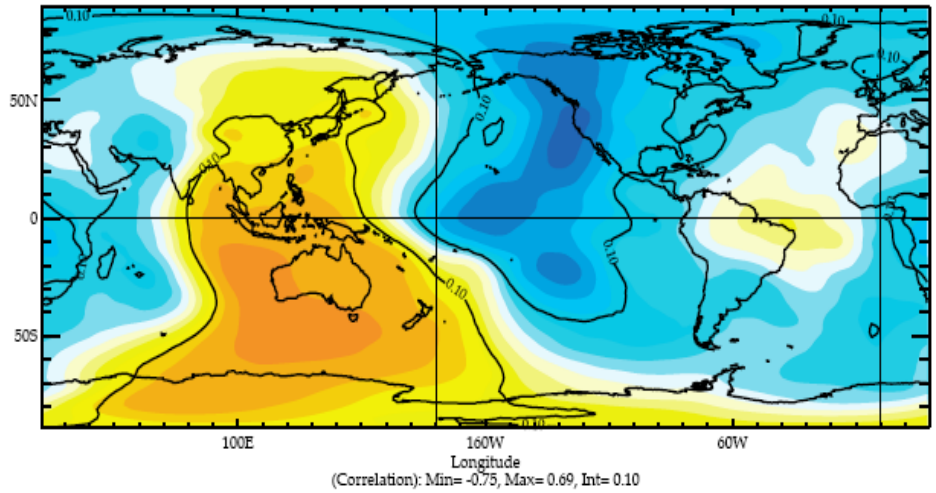
Regressions SDI SST (2-3) 10m WIND/LATENT HEAT FLUX - NCEP - Year 0



Regressions SDI SST (2-3) 850 hPa WIND/SLP - NCEP - Year 0

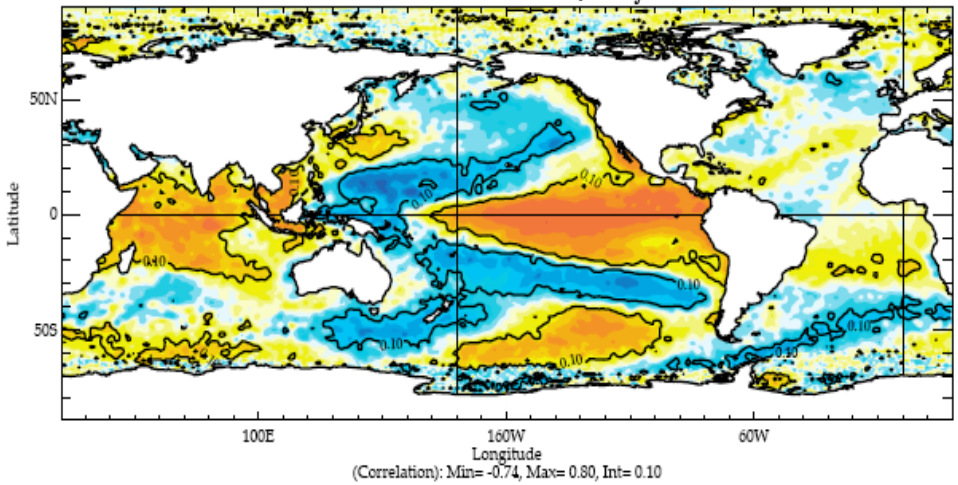


Correlations SDI SST (2-3) 200 hPa Velocity Potential - NCEP 1979-2005 - Year 0

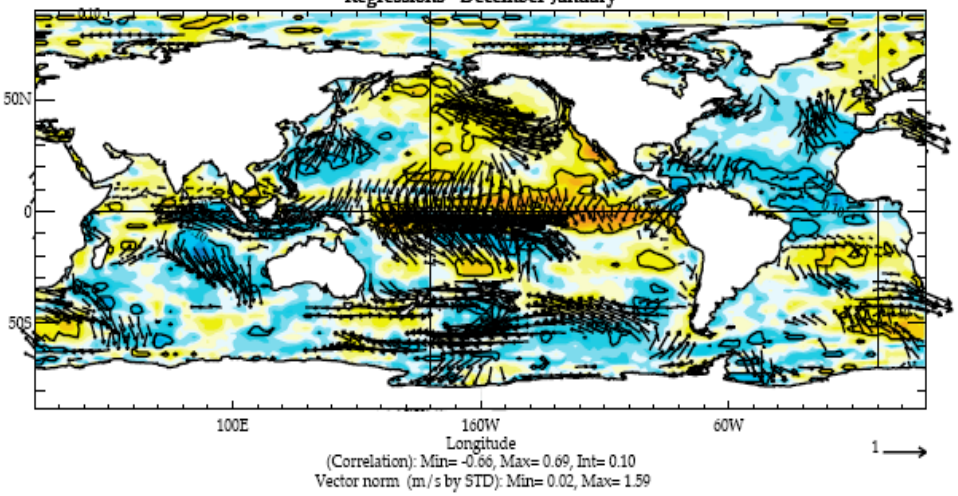


December-January - Year 0

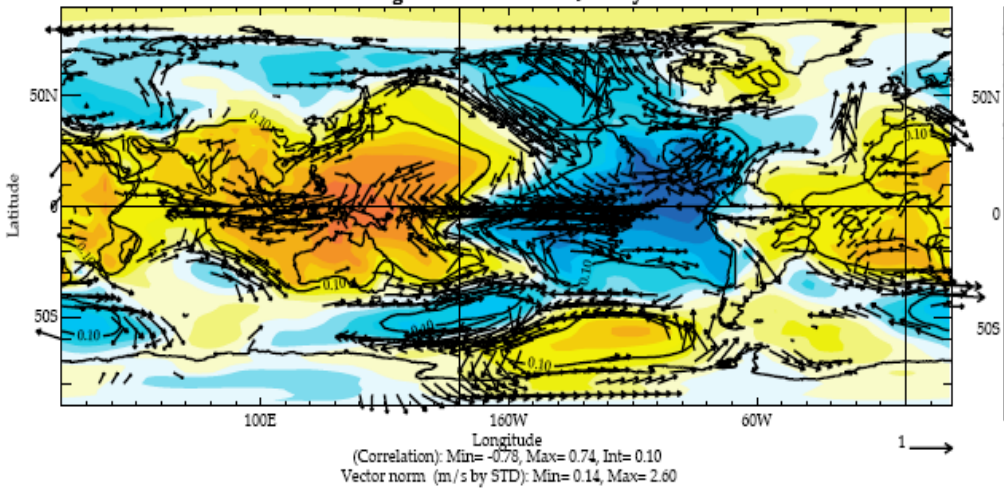
Correlations SDI SST (2-3) detrended SST - HadISST1 dataset 1979-2005 - Year 0



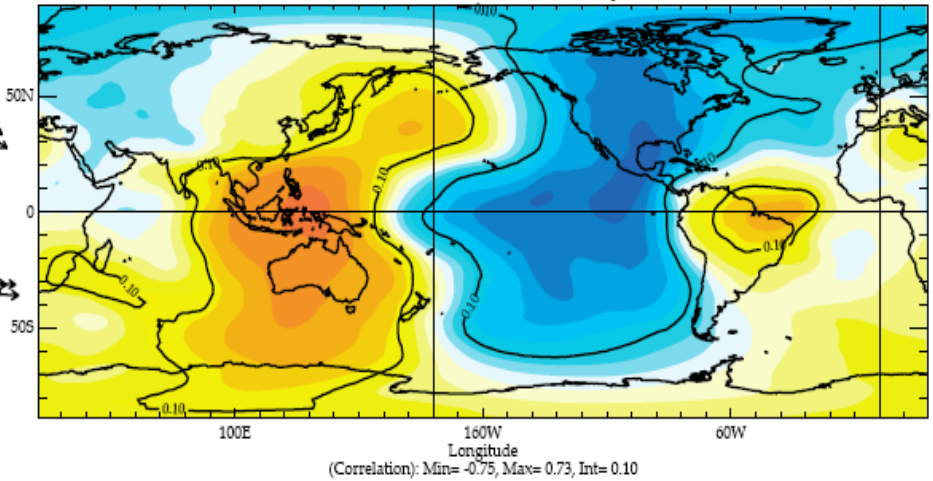
Regressions SDI SST (2-3) 10m WIND/LATENT HEAT FLUX - NCEP - Year 0

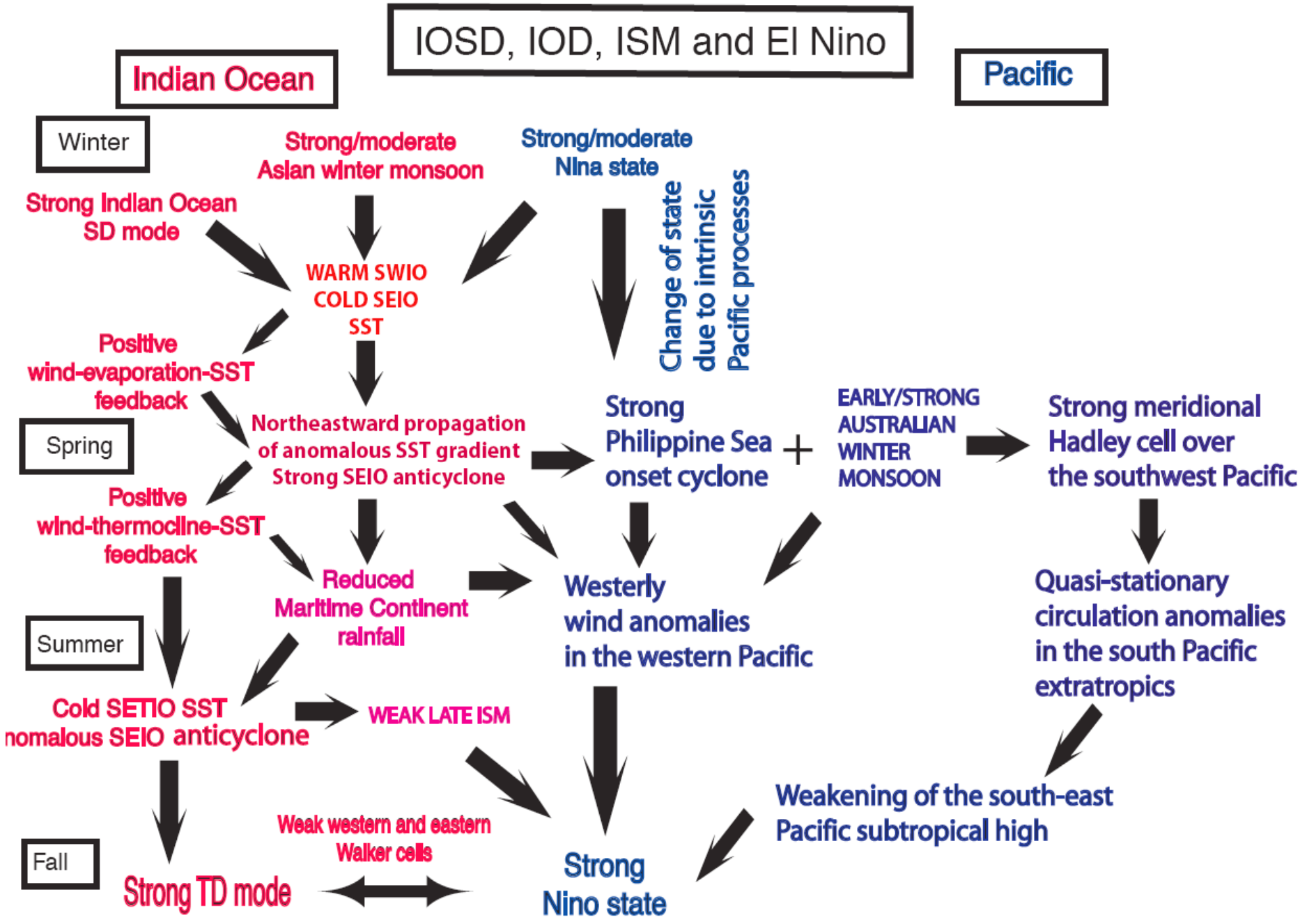


Regressions SDI SST (2-3) 850 hPa WIND/SLP - NCEP - Year 0



Correlations SDI SST (2-3) 200 hPa Velocity Potential - NCEP 1979-2005 - Year 0




IOSD, IOD, ISM and El Nino
Indian Ocean
Pacific
Winter
Strong/moderate
Asian winter monsoon
Strong/moderate
Nina state
Strong Indian Ocean
SD mode
WARM SWIO
COLD SEIO
SST
Change of state
due to intrinsic
Pacific processes
Positive
wind-evaporation-SST
feedback
Spring
Northeastward propagation
of anomalous SST gradient
Strong SEIO anticyclone
Strong
Philippine Sea
onset cyclone
+
EARLY/STRONG
AUSTRALIAN
WINTER
MONSOON
Strong meridional
Hadley cell over
the southwest Pacific
Positive
wind-thermocline-SST
feedback
Reduced
Maritime Continent
rainfall
Westerly
wind anomalies
in the western Pacific
Quasi-stationary
circulation anomalies
in the south Pacific
extratropics
Summer
Cold SETIO SST
nomalous SEIO anticyclone
WEAK LATE ISM
Weakening of the south-east
Pacific subtropical high
Fall
Weak western and eastern
Walker cells
Strong TD mode
Strong
Nino state

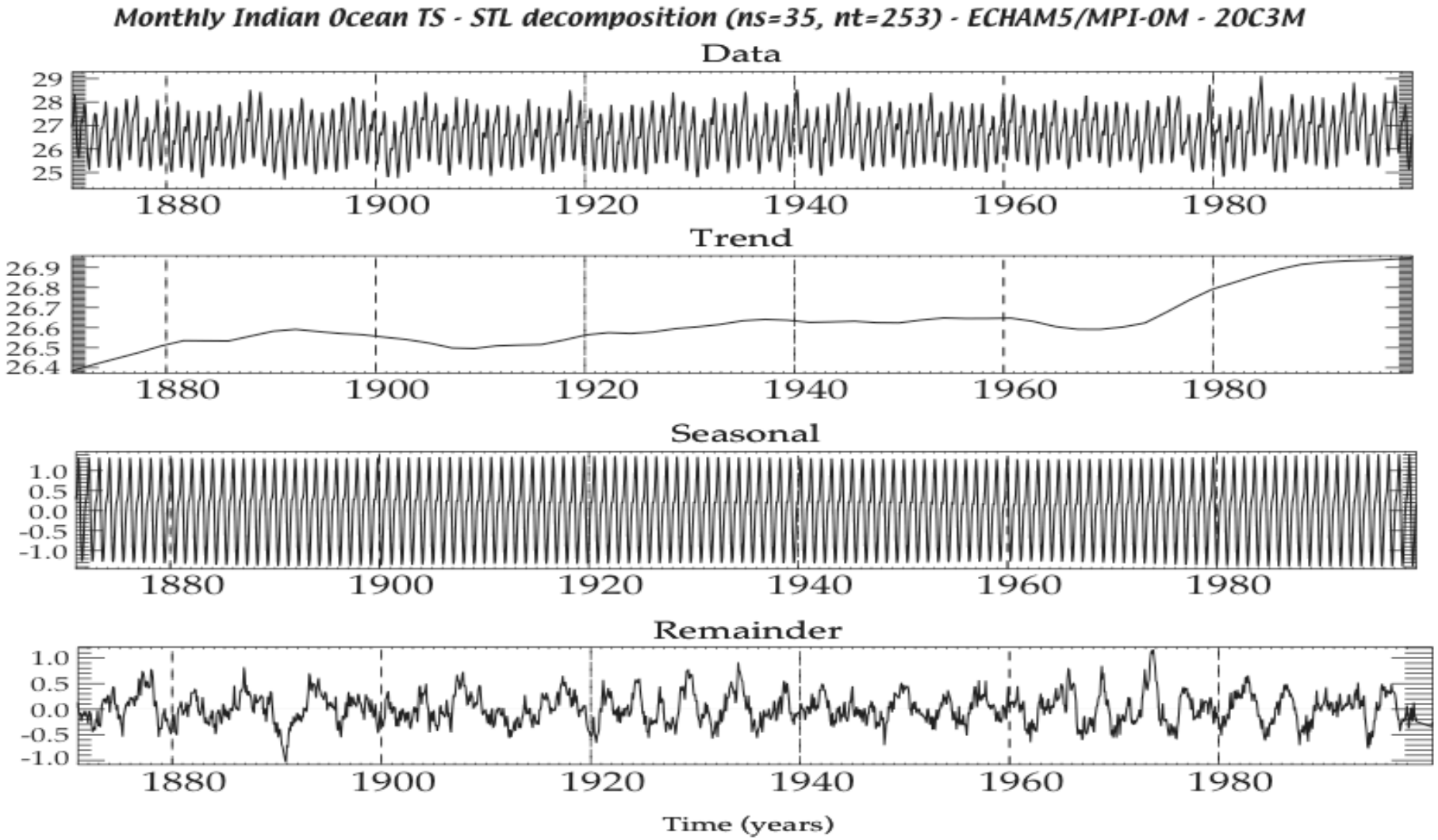
Questions

- **Are these climate changes due to the global warming ?**

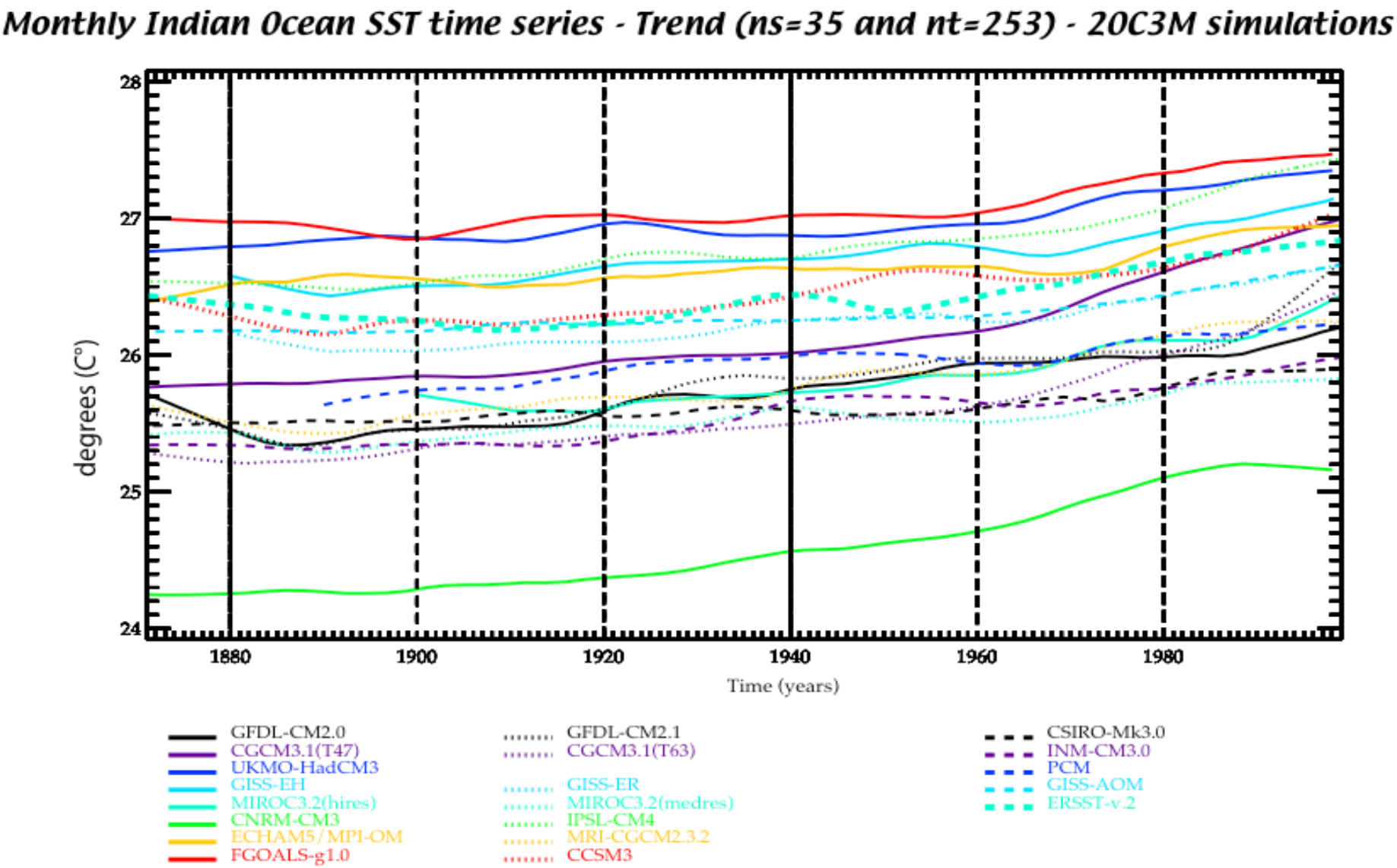
- **What about the future of the monsoon-ENSO system in a global warming context?**

➢ **Analysis of the IPCC AR4 simulations (20C3M, 1pctto2x, 1pctto4x)**

Seasonal-Trend decomposition procedure based on Loess (locally -weighted regression)



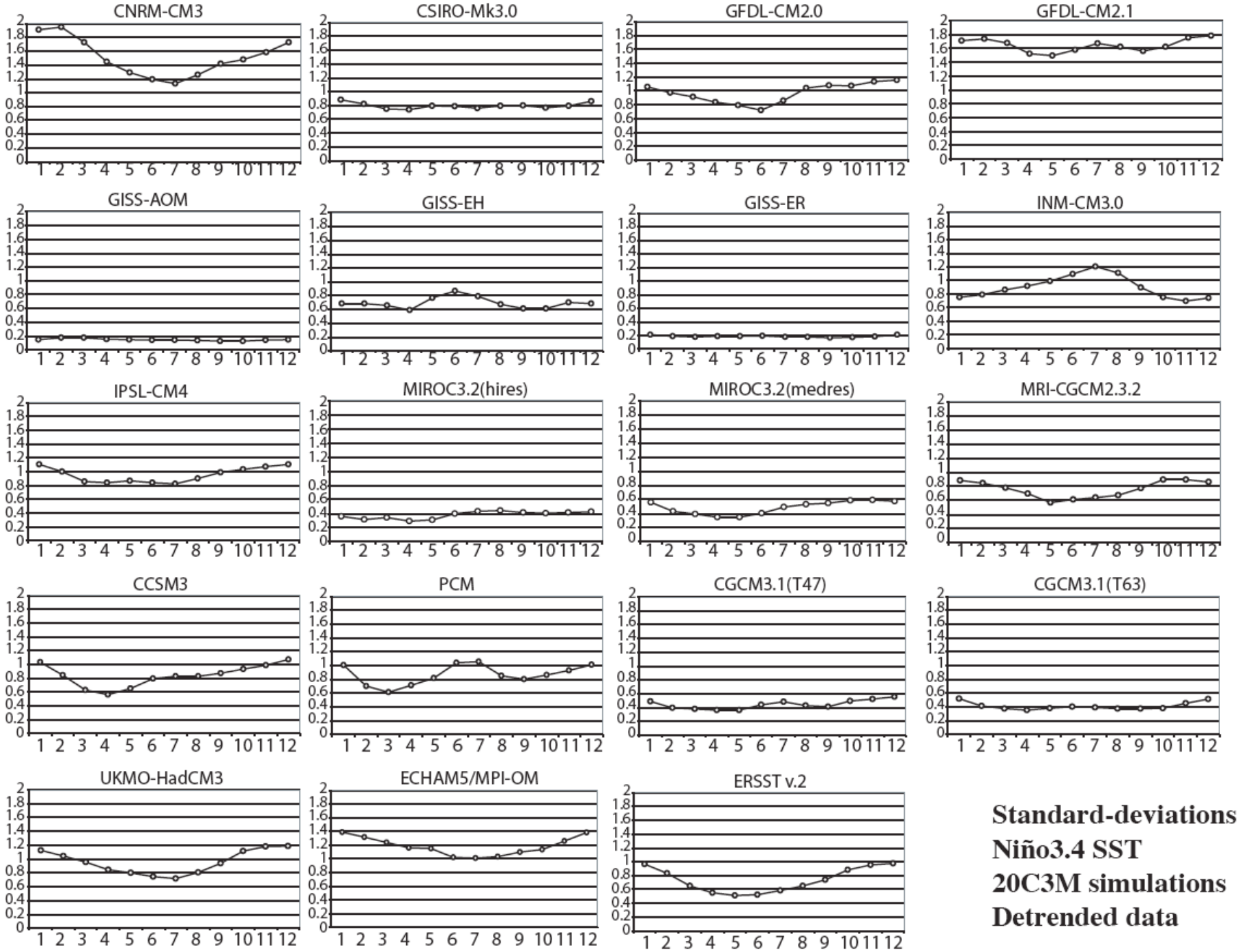
Is the recent Indian Ocean warming trend an anthropogenically forced climate change ?

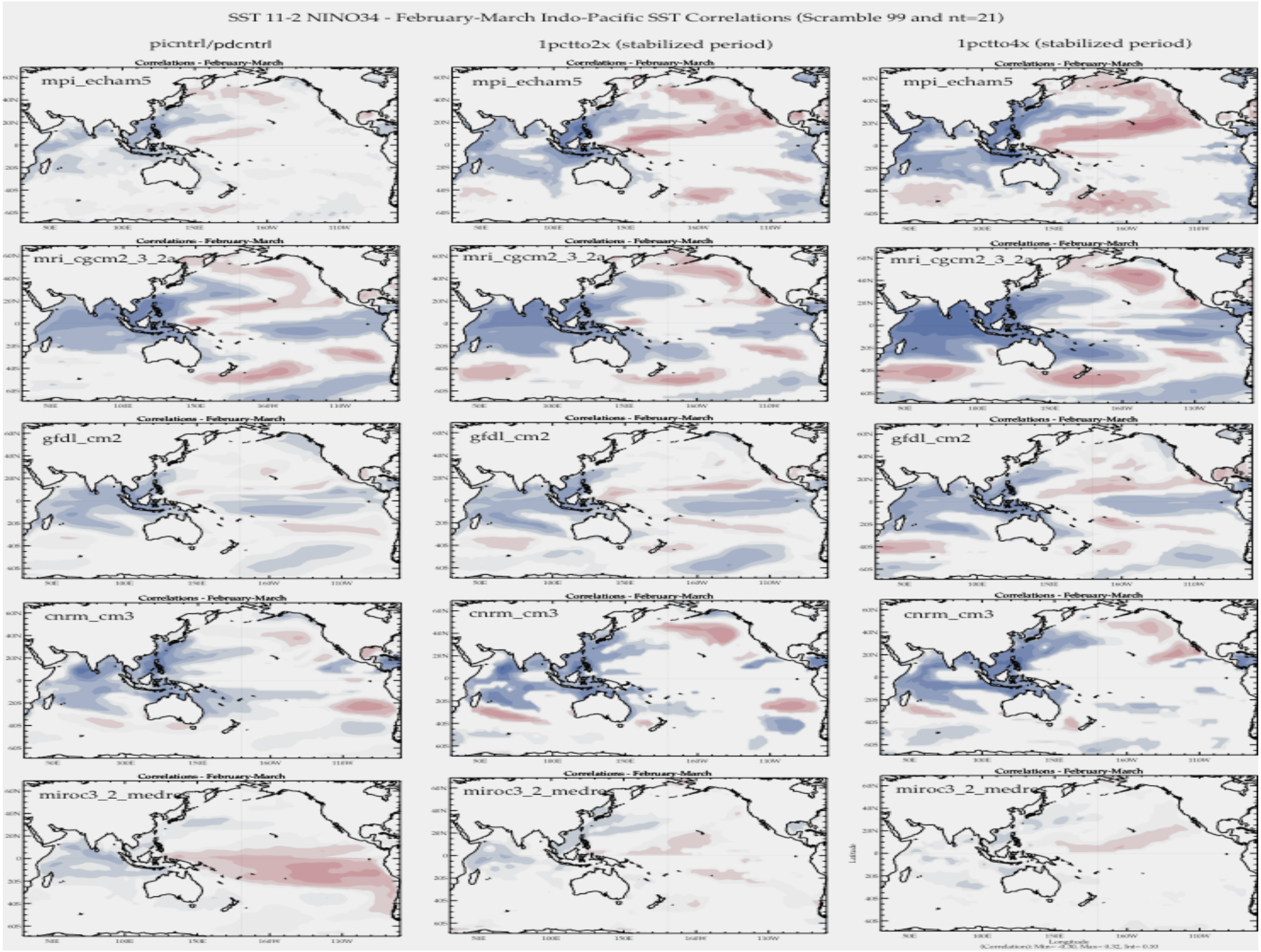


Is the recent Indian Ocean warming an anthropogenically forced climate change ?

Correlations 20C3M simulations-observations

	Monthly global SSTs		Monthly Indian Ocean SSTs		Monthly Nino 3.4 SSTs	
	nt=133	nt=253	nt=133	nt=253	nt=133	nt=253
CNRM-CM3	0,77	0,80	0,89	0,92	0,45	0,54
CSIRO-Mk3.0	0,38	0,43	0,82	0,89	0,14	0,45
GFDL-CM2.0	0,78	0,83	0,79	0,84	0,15	0,41
GFDL-CM2.1	0,79	0,82	0,89	0,91	0,33	0,54
GISS-AOM	0,79	0,82	0,89	0,91	0,33	0,54
GISS-EH	0,49	0,56	0,74	0,79	0,04	0,36
GISS-ER	0,66	0,73	0,88	0,91	0,53	0,63
FGOALS-g1.0	0,50	0,53	0,89	0,94	0,31	0,52
INM-CM3.0	0,80	0,83	0,84	0,87	-0,11	0,17
IPSL-CM4	0,78	0,82	0,85	0,90	0,21	0,41
MIROC3.2(hires)	0,39	0,42	0,57	0,65	0,03	0,06
MIROC3.2(medres)	0,82	0,85	0,86	0,89	0,23	0,51
ECHAM5/MPI-OM	0,81	0,84	0,78	0,86	0,14	0,17
MRI-CGCM2.3.2	0,76	0,79	0,85	0,88	0,31	0,45
CCSM3	0,86	0,91	0,83	0,88	0,32	0,56
PCM	0,34	0,38	0,42	0,47	0,26	0,25
CGCM3.1(T47)	0,79	0,81	0,91	0,93	0,30	0,52
CGCM3.1(T63)	0,78	0,80	0,89	0,92	0,30	0,52
UKMO-HadCM3	0,74	0,77	0,82	0,87	0,26	0,33
UKMO-HadGEM1	-	-	-	-	-	-

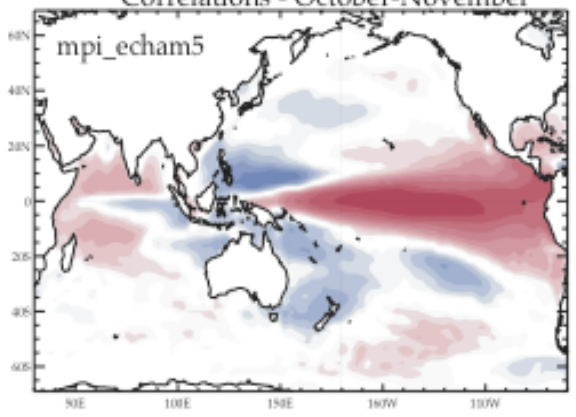

CNRM-CM3
CSIRO-Mk3.0
GFDL-CM2.0
GFDL-CM2.1
GISS-AOM
GISS-EH
GISS-ER
INM-CM3.0
IPSL-CM4
MIROC3.2(hires)
MIROC3.2(medres)
MRI-CGCM2.3.2
CCSM3
PCM
CGCM3.1(T47)
CGCM3.1(T63)
UKMO-HadCM3
ECHAM5/MPI-OM
ERSST v.2
Standard-deviations
Niño3.4 SST
20C3M simulations
Detrended data

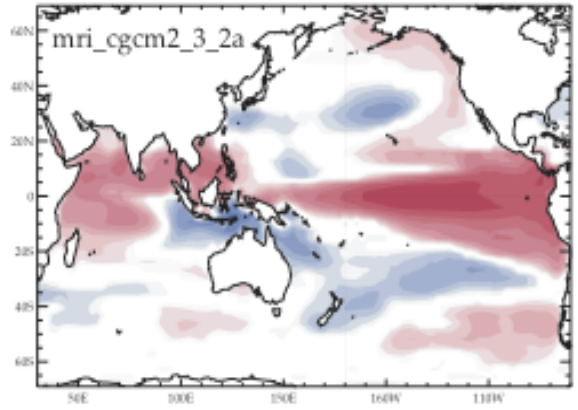

SST 11-2 NINO34 - February-March Indo-Pacific SST Correlations (Scramble 99 and nt=21)
picntrl/pdcntrl
1pctto2x (stabilized period)
1pctto4x (stabilized period)
Correlations - February-March
mpi_echam5
mri_cgcm2_3_2a
gfdl_cm2
cnrm_cm3
miroc3_2_medre
Latitude
Longitude

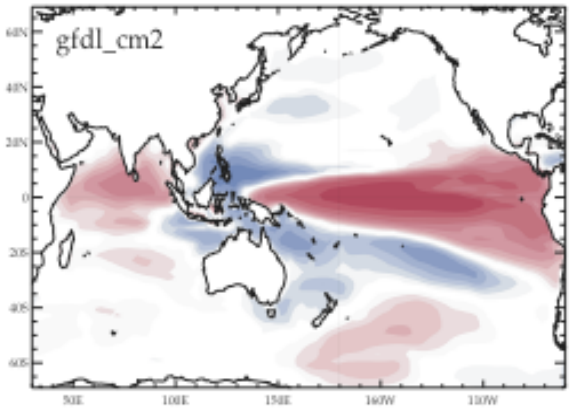
SST 11-2 NINO34 - October-November Indo-Pacific SST Correlations (Scramble 99 and nt=21)

picntrl/pdcntrl

Correlations - October-November

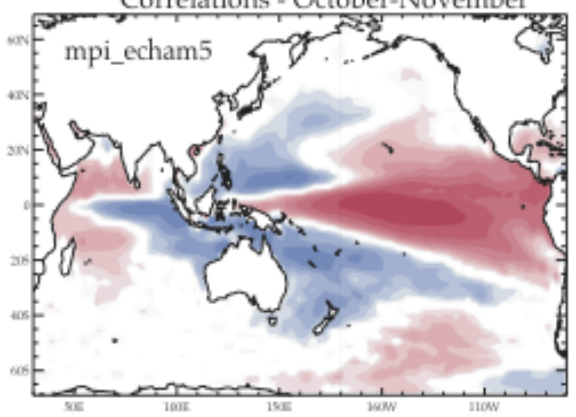


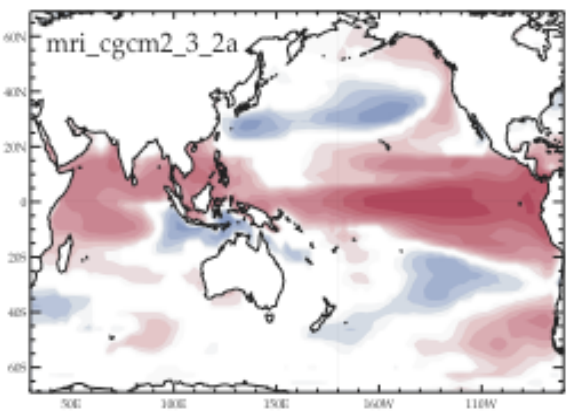


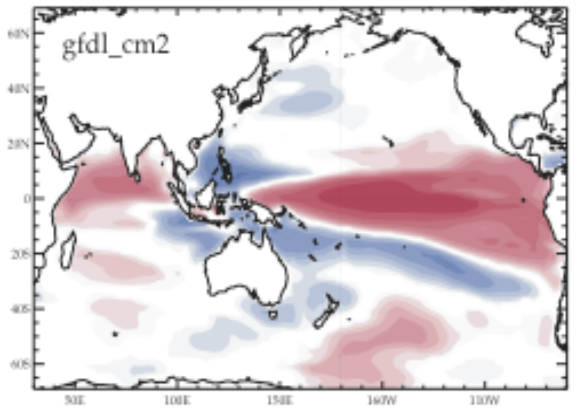


1pctto2x (stabilized period)

Correlations - October-November

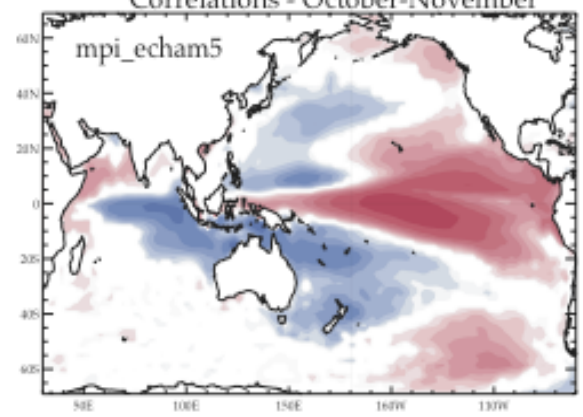


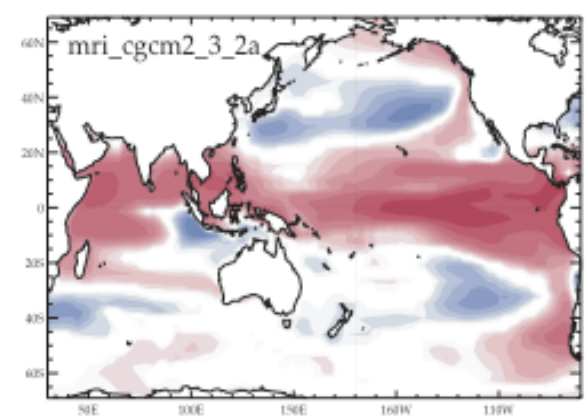


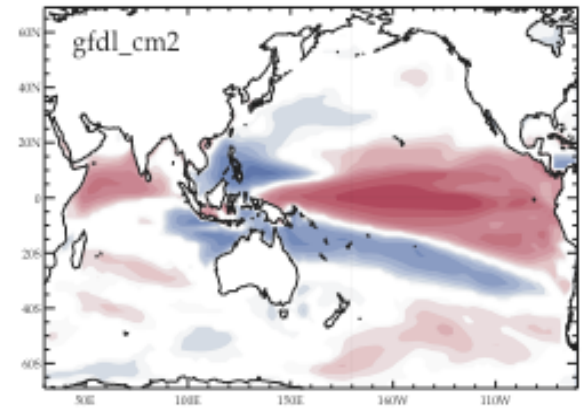


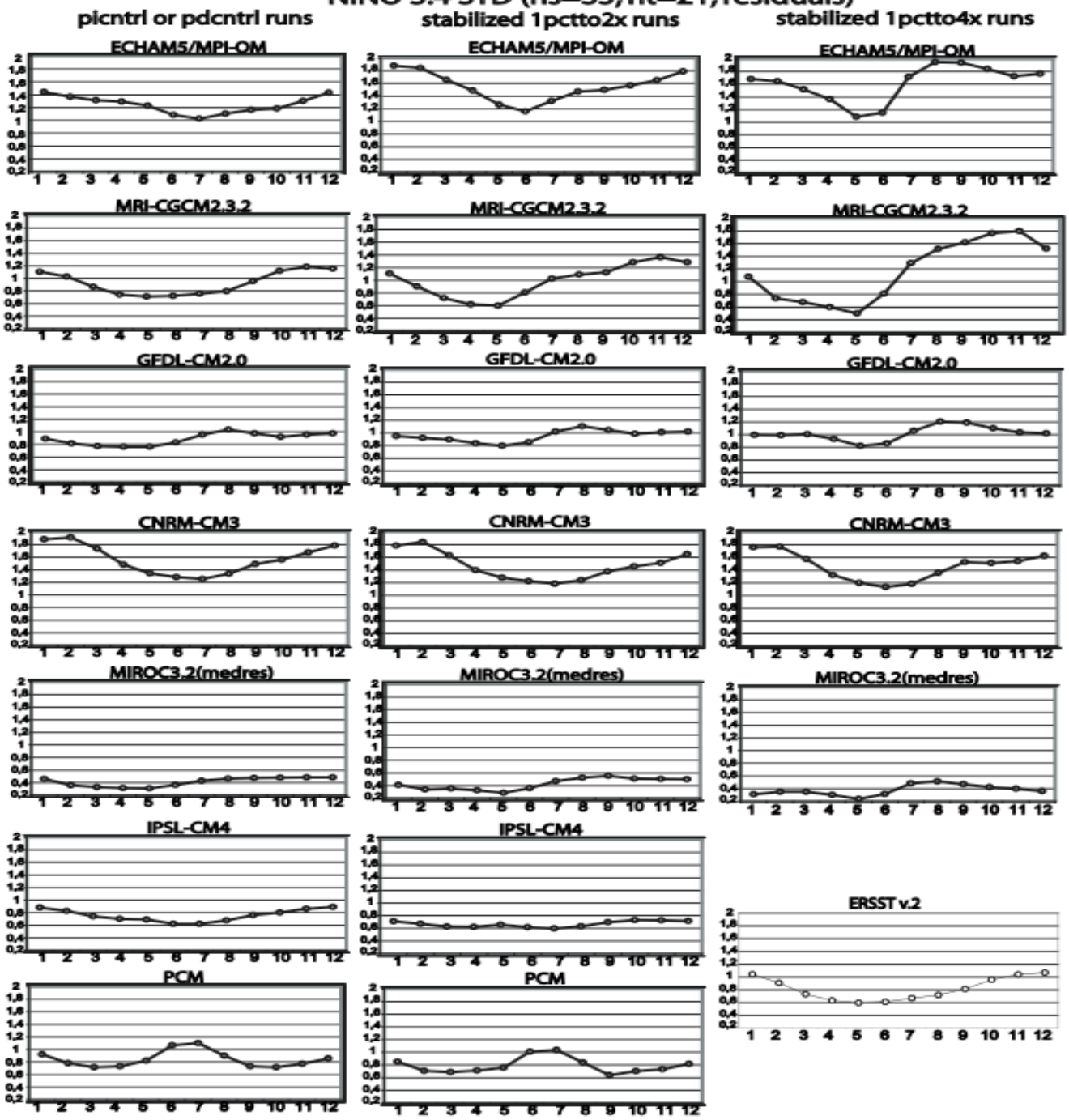
1pctto4x (stabilized period)

Correlations - October-November








NINO 3.4 STD (ns=35, nt=21, residuals)
picntrl or pdcntrl runs
stabilized 1pctto2x runs
stabilized 1pctto4x runs
ECHAM5/MPI-OM
ECHAM5/MPI-OM
ECHAM5/MPI-OM
MRI-CGCM2.3.2
MRI-CGCM2.3.2
MRI-CGCM2.3.2
GFDL-CM2.0
GFDL-CM2.0
GFDL-CM2.0
CNRM-CM3
CNRM-CM3
CNRM-CM3
MIROC3.2(medres)
MIROC3.2(medres)
MIROC3.2(medres)
IPSL-CM4
IPSL-CM4
ERSST v.2
PCM
PCM

CONCLUSIONS

- Southern Indian Ocean SSTs during late boreal winter is a highly significant precursor of the ENSO evolution after the 1976-1977 regime shift.

- These SSTs anomalies are mainly generated by Mascarene High pulses during the boreal winter.

- These SST anomalies trigger coupled air-sea processes in the tropical eastern Indian Ocean and produce a persistent remote forcing on the whole monsoon-ENSO climate system during the following seasons.

- These climate changes may be due to the global warming.