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ENSO
Monsoon interactions under different ENSO states

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ENSO – Monsoon interactions under different ENSO states

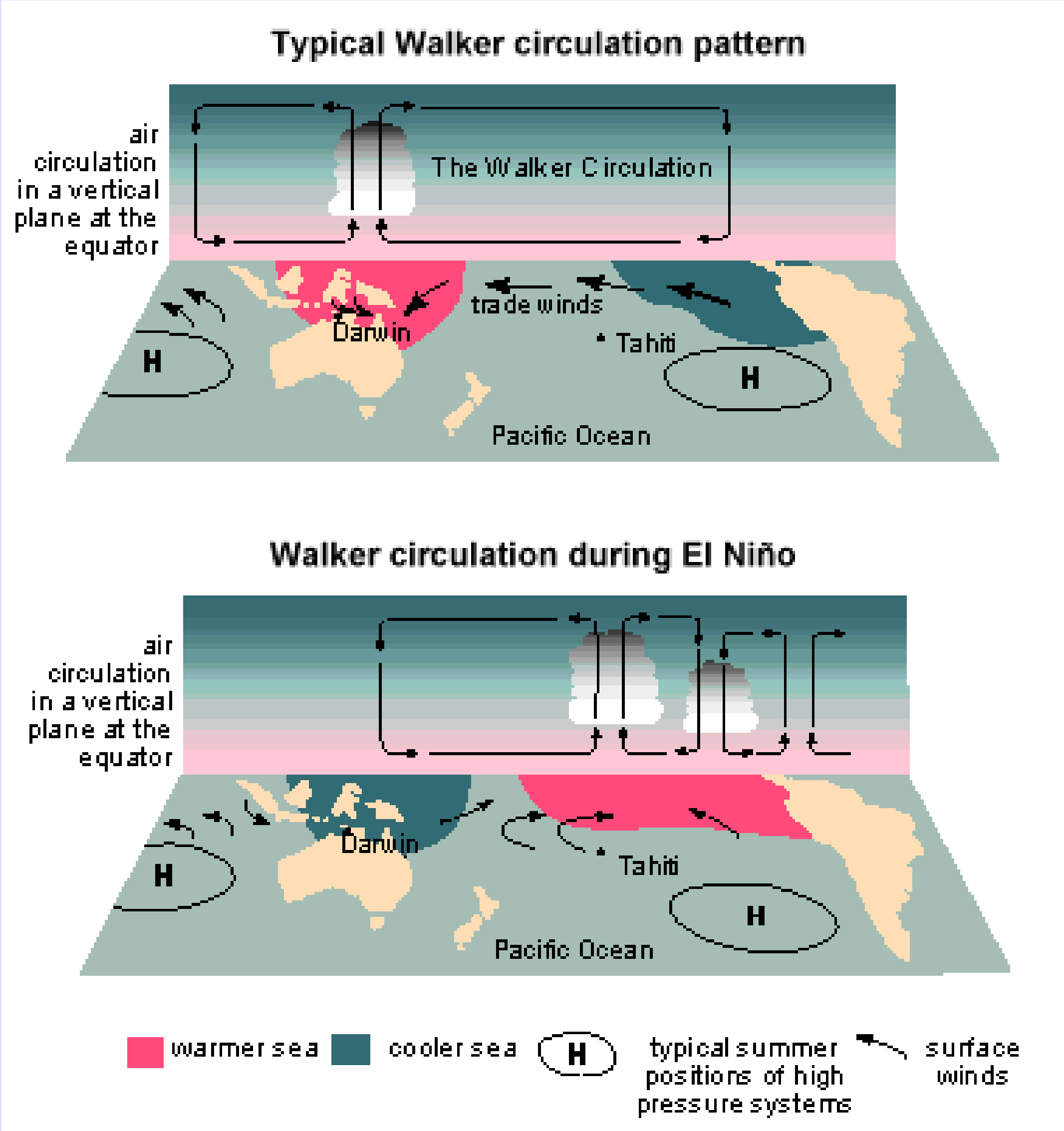
OBSERVATIONS

1. **The interannual variability of the Asian summer monsoon is strongly influenced by ENSO.**
2. **The *'canonical'* ENSO-monsoon relationship implies a drier monsoon season preceding El Nino events (Walker, 1924)**

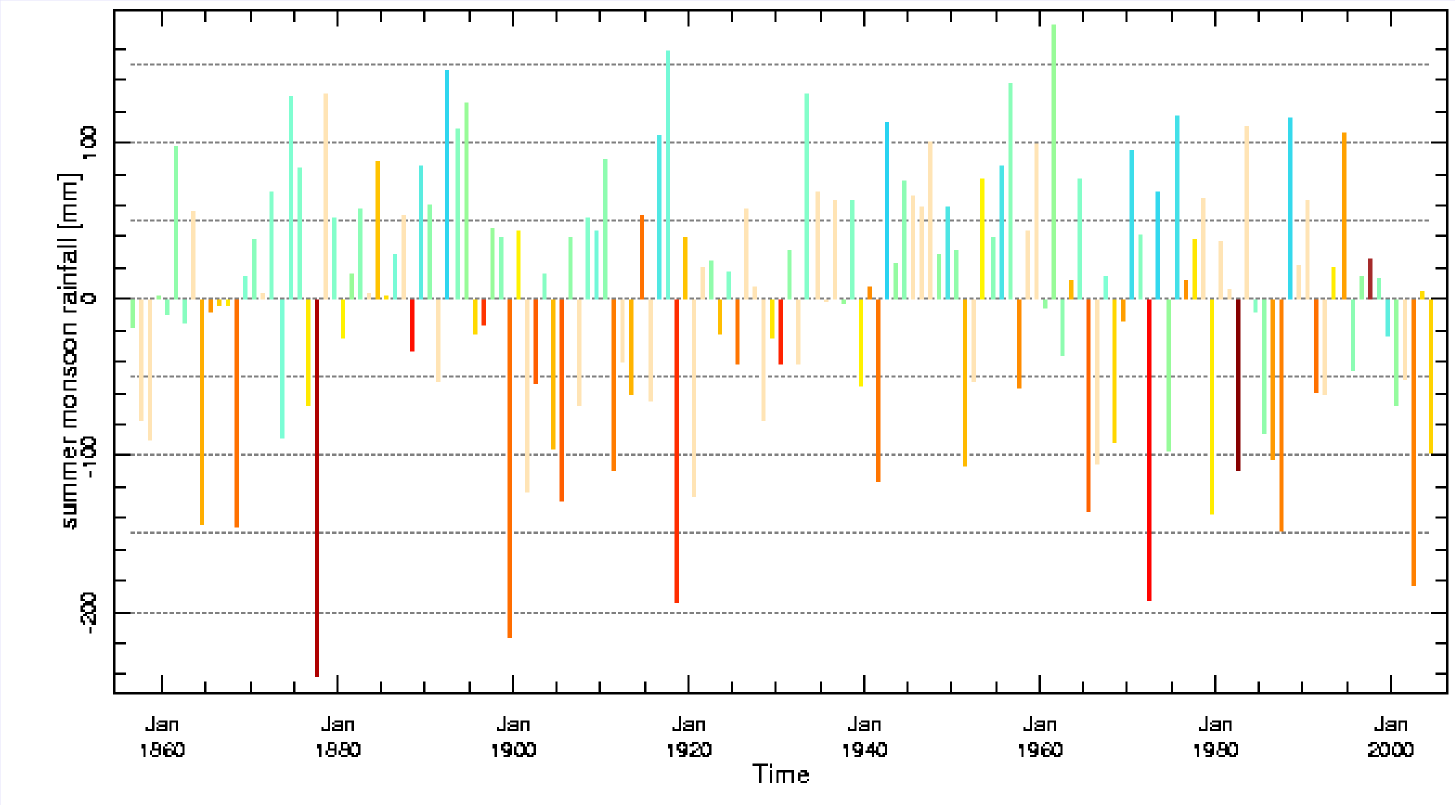
MOTIVATIONS

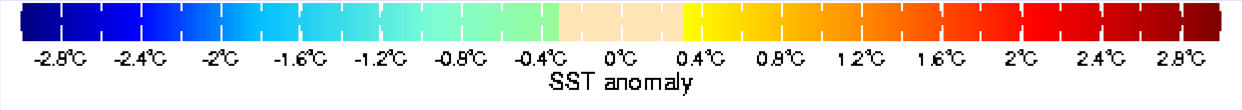
- **Investigate the role of internal and forced variability in the ENSO-monsoon relationship**
- **Understand the role played by the oceanic and atmospheric teleconnections in the tropics. Here we concentrate on the ENSO-Indian Ocean relation**
- **Try to understand how different ENSO characteristic can impact the Indian Ocean circulation and the Indian monsoon with the goal of simulating the ENSO-monsoon relation with the Holocene**

ENSO influence over the Indian Ocean via the atmospherical bridge

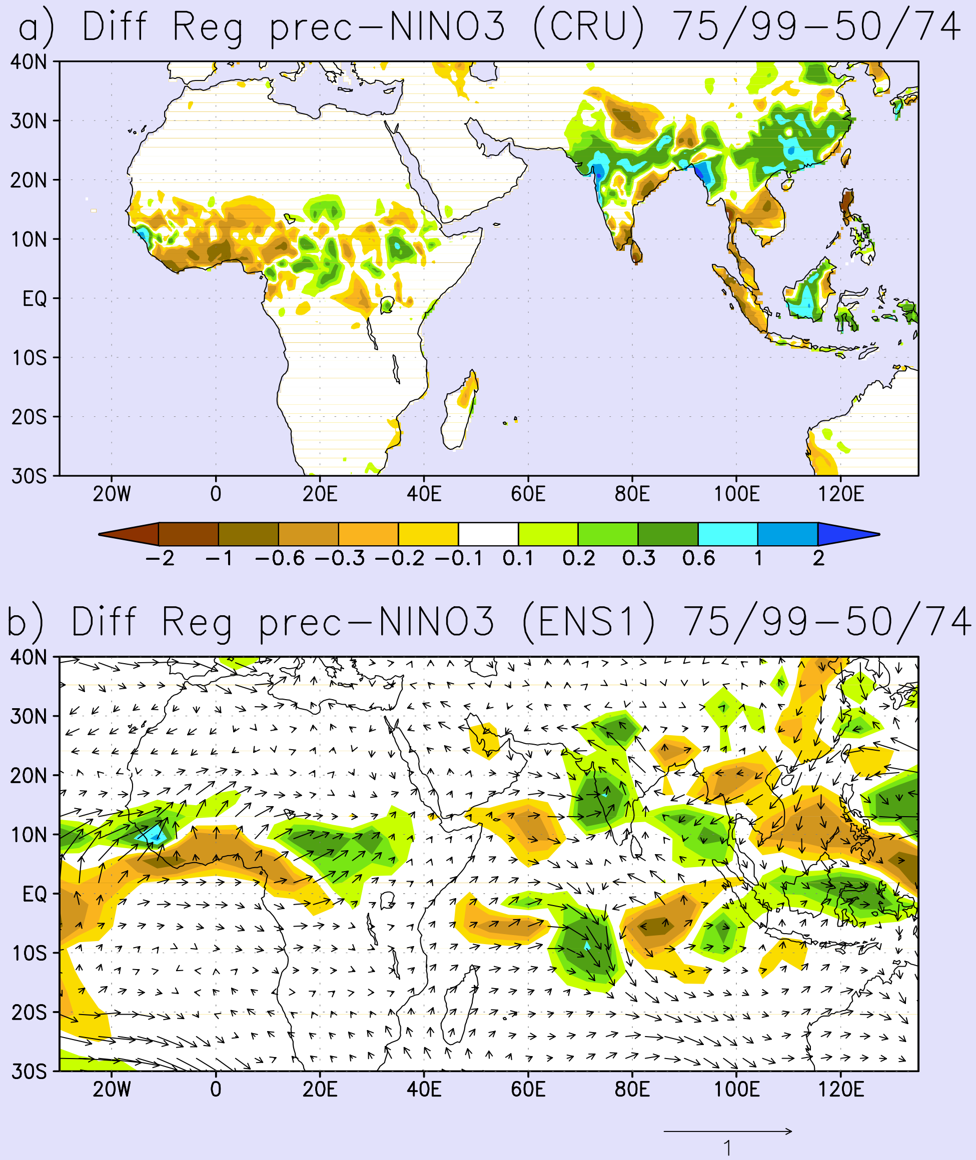


Rainfall Data: Indian Institute of Tropical Meteorology (IITM).
SST Data: Kaplan NINO3 index from Optimal Smoother analysis of MOHSST5 monthly sea surface temperature anomalies. from IRI-Columbia Data Library

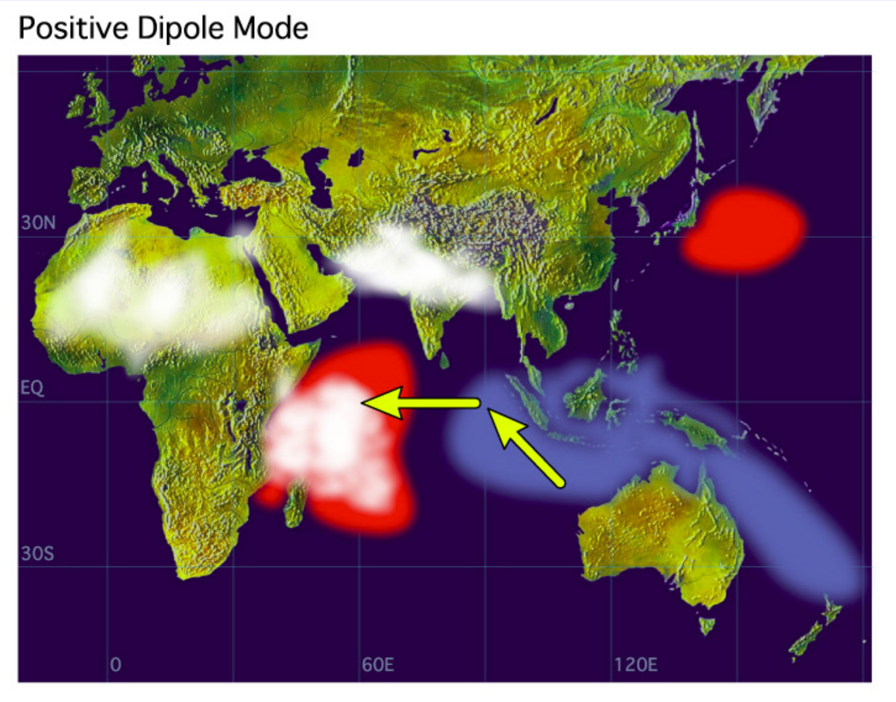




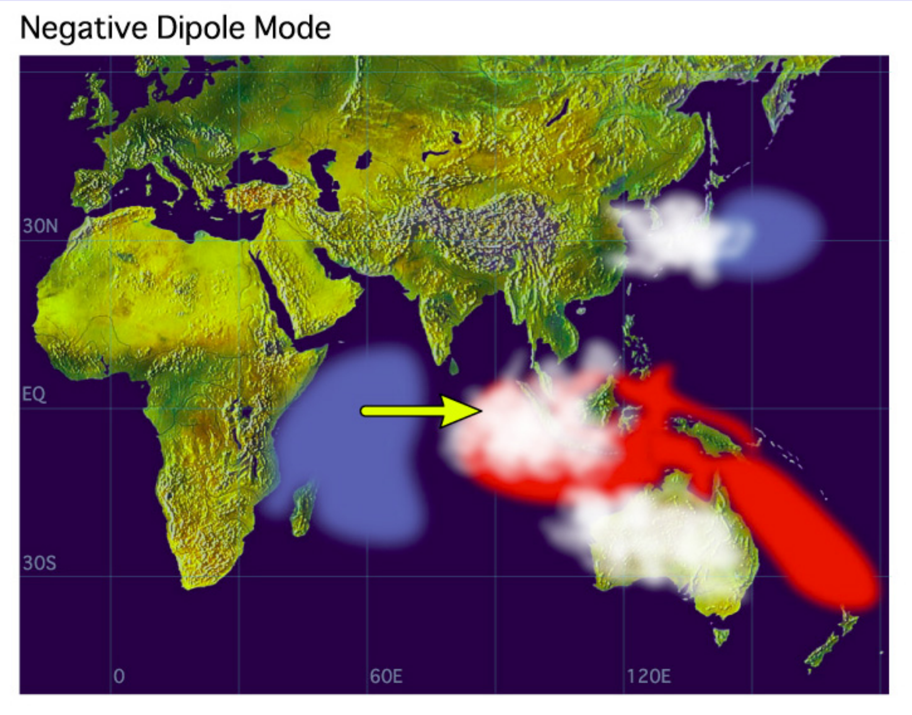
3. Climate Research Unit precipitation data from 1950 to 1999. The record has been divided in two equal 25-years long intervals



The IOZM



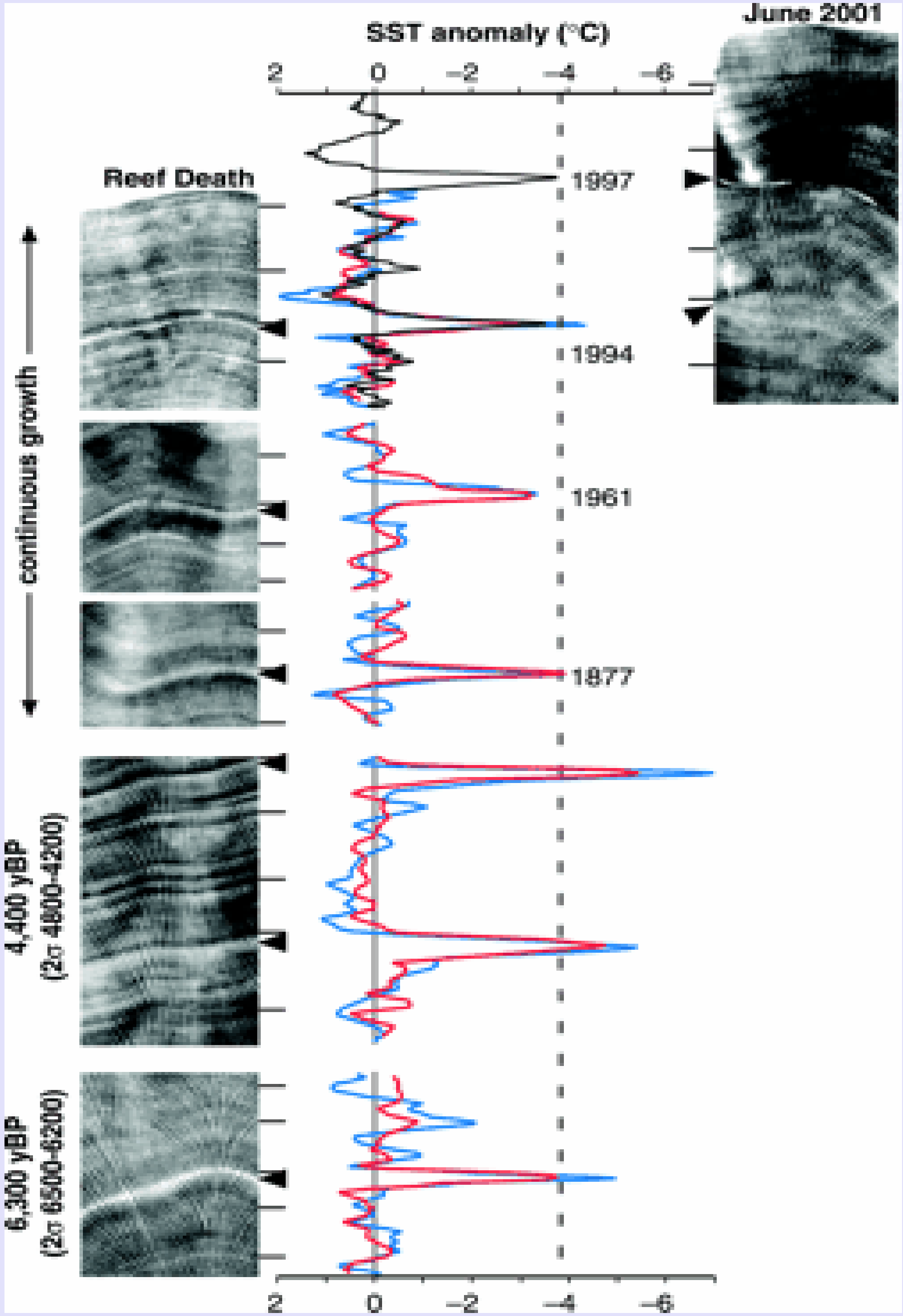
Webster, Moore, Loschnigg
and Leben, Nature 1999
Saji, Goswami, Vinayachandran
and Yamagata, Nature 1999



IOD or IOZM : area averaged SST anomalies over

WTIO (50E-70E; 10S-10N) – SETIO (90E-110E; 10S-0)

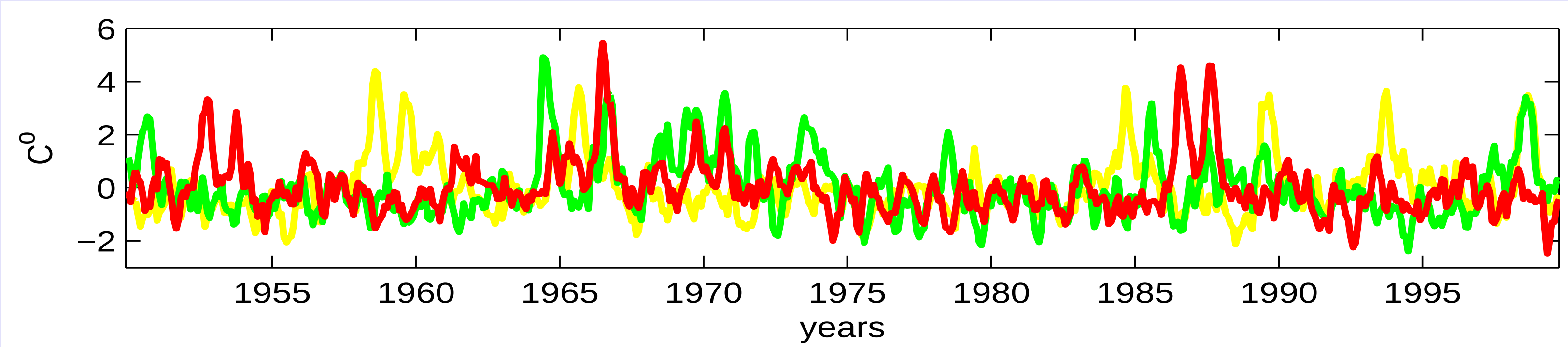
The amplitude of the IOZM events was not always as small as today

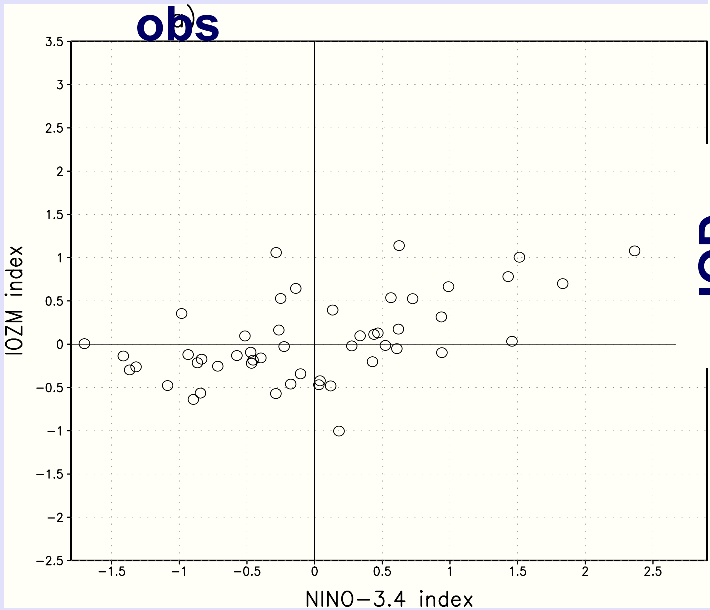


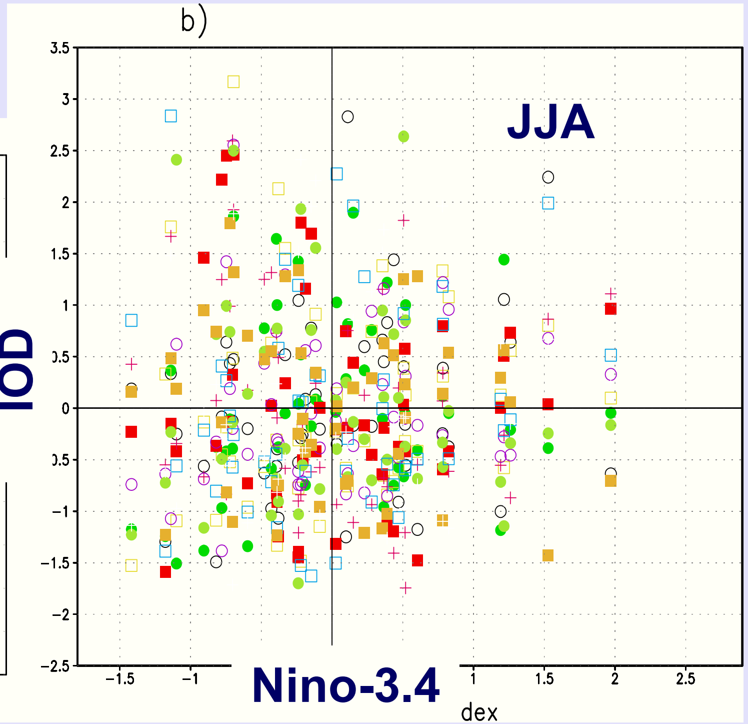
Abram et al.,Science, 2003

Preliminary work: ensemble with regionally coupled model over the IO and observed SSTs elsewhere

- **IOZM area averaged SST anomalies over WTIO (50E-70E; 10S-10N) – SETIO (90E-110E; 10S-0)**







correlations between IOZM and Nino-3.4 in the IO runs:

$-0.11 \leq r \leq 0.13$

$-0.18 \leq rJJA \leq 0.24$

$-0.28 \leq rSON \leq 0.04$

in the obs (HadISST)

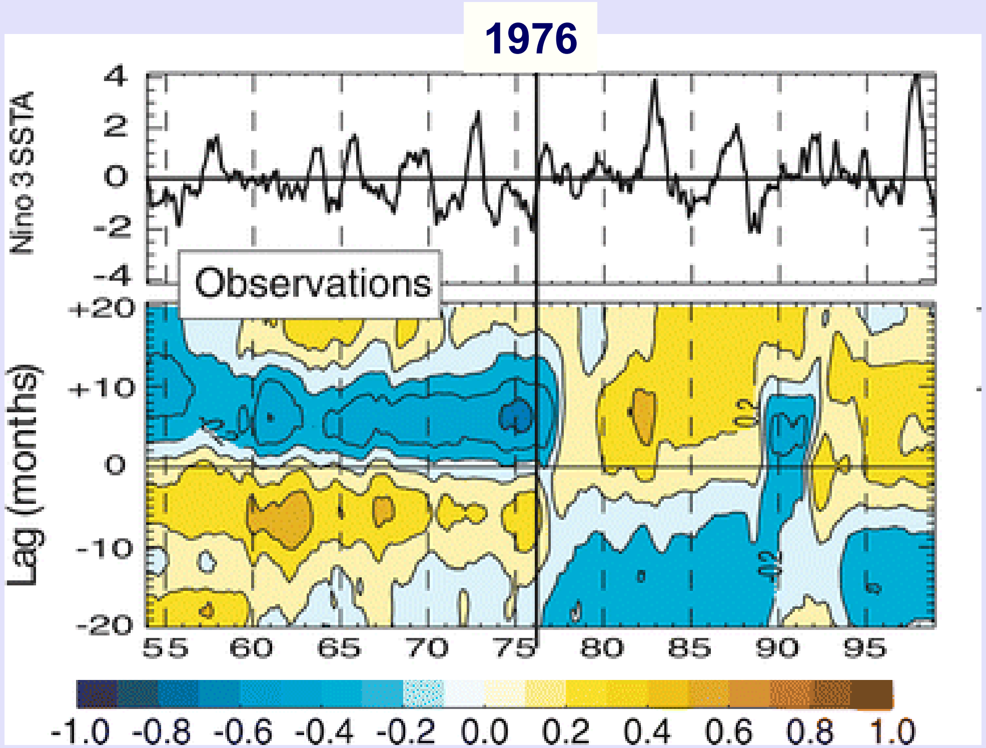
r = 0.32

rJJA = 0.54

rSON = 0.62

Always in the Pacific ..

1976 marks a shift in the basic state of ENSO from S-mode to T-mode
(Fedorov and Philander, 2000, 2001; Trenberth and Stepaniak, 2001)



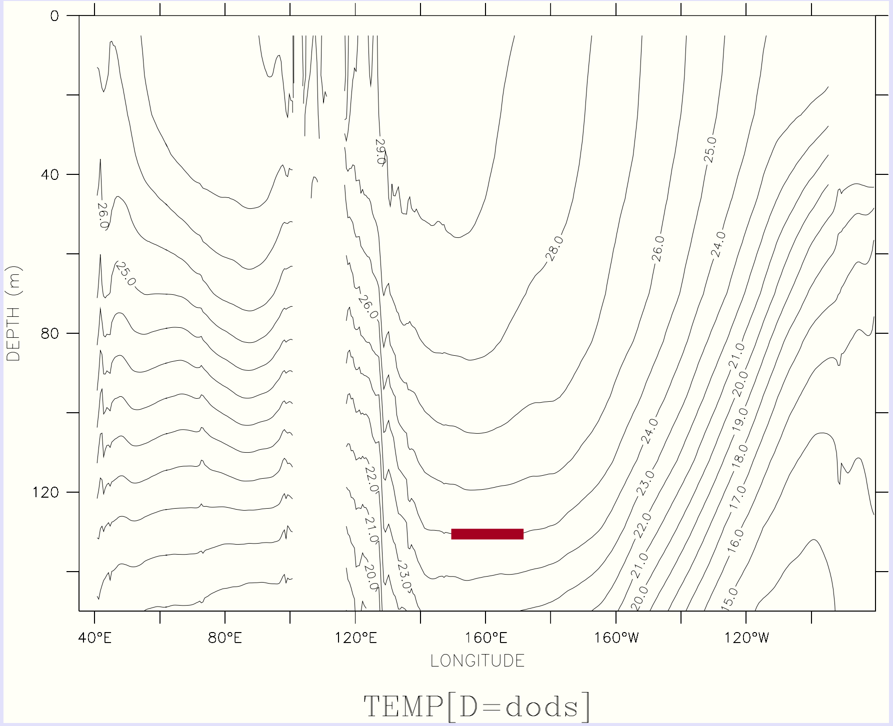
from Guilyardi, 05

Lag correlation of the Trans-Nino index (Nino.1+2 – Nino.4) with Nino.3

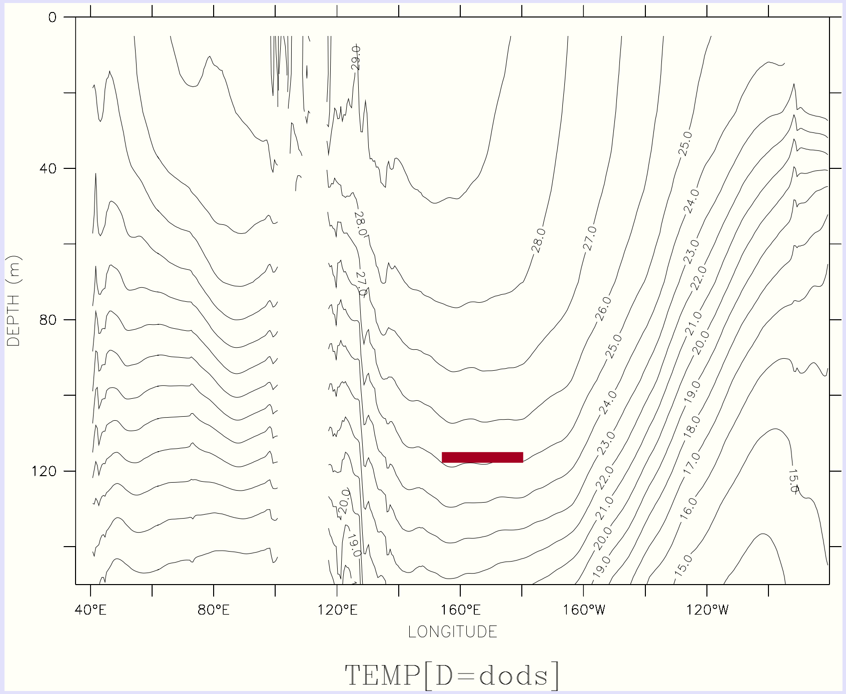
T-mode (delayed oscillator, fast SST-slow wave): 5-7 years periodicity, SSTs vary by thermocline movements, smaller thermocline gradient, eastward propagation of SST anomalies

S-mode (slow SST-fast wave): 2-3 years periodicity, SST determined by advection and entrainment across the thermocline, greater thermocline gradient, westward propagation of SST anomalies (Neelin, 1991; Fedorov and Philander, 2000)

Pre 1976
equatorial thermocline

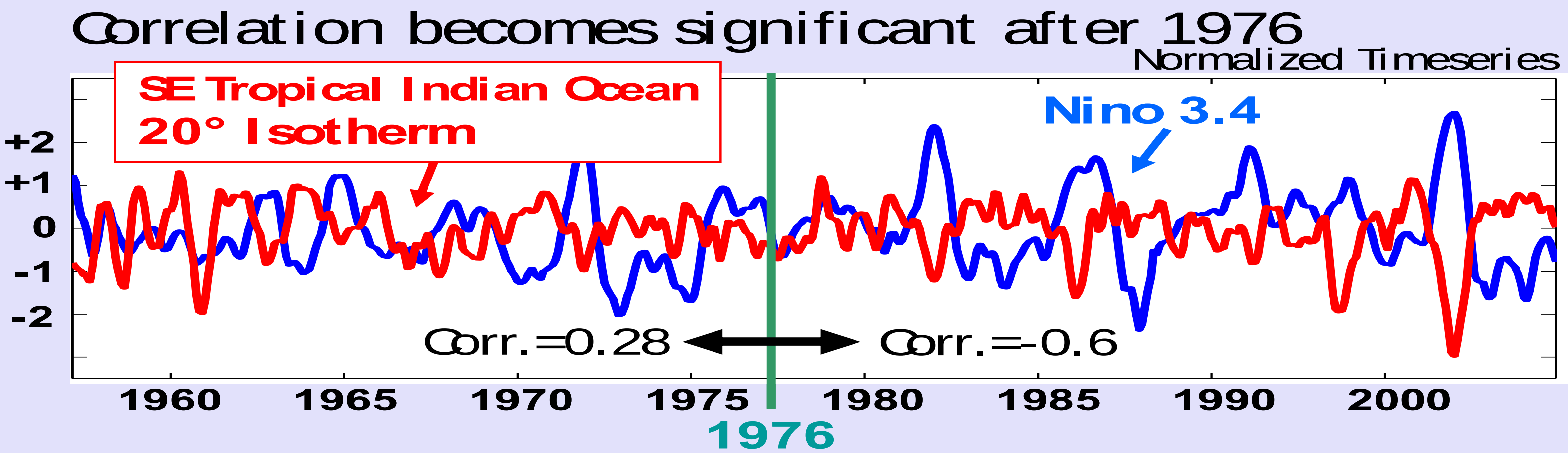


Post 1976
equatorial thermocline

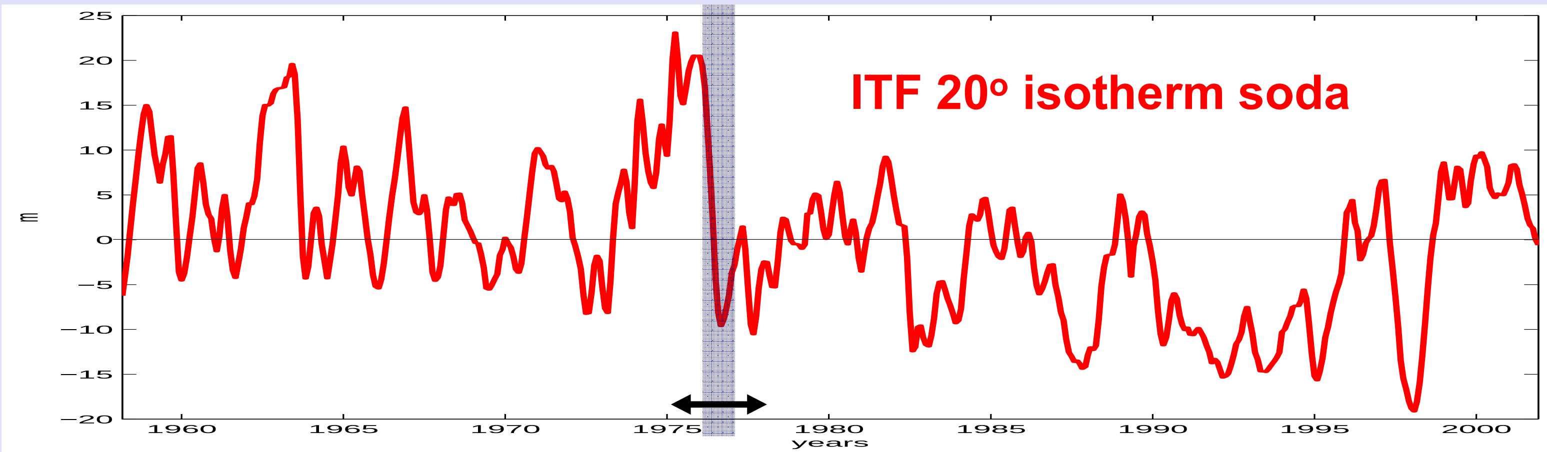


SODA

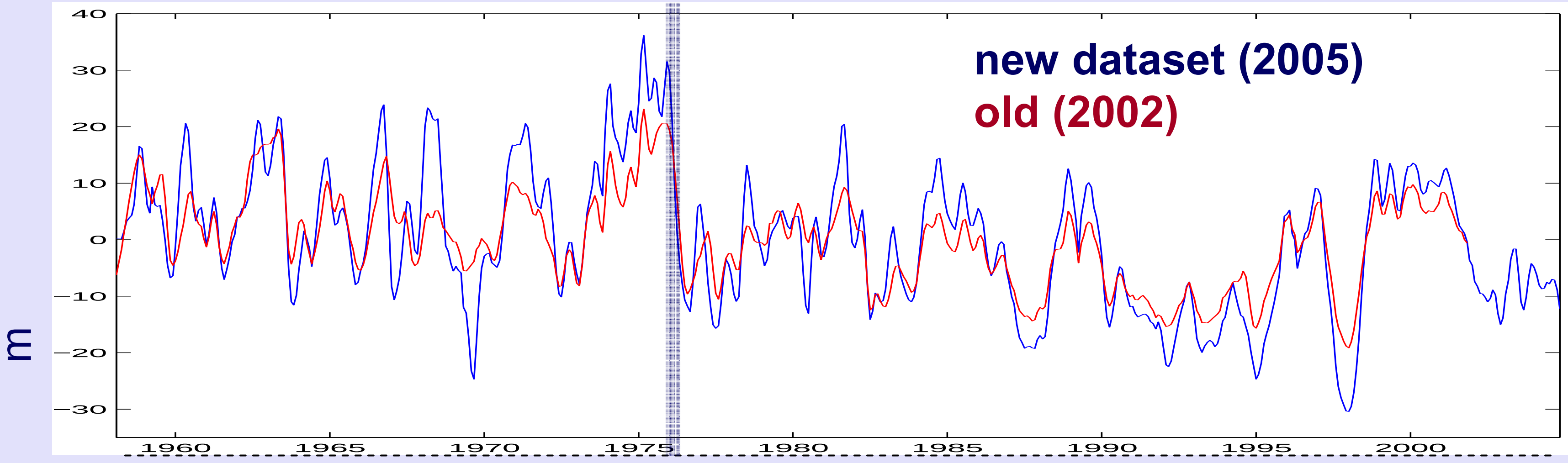
If we look into the Indian-Pacific ocean 'connection'

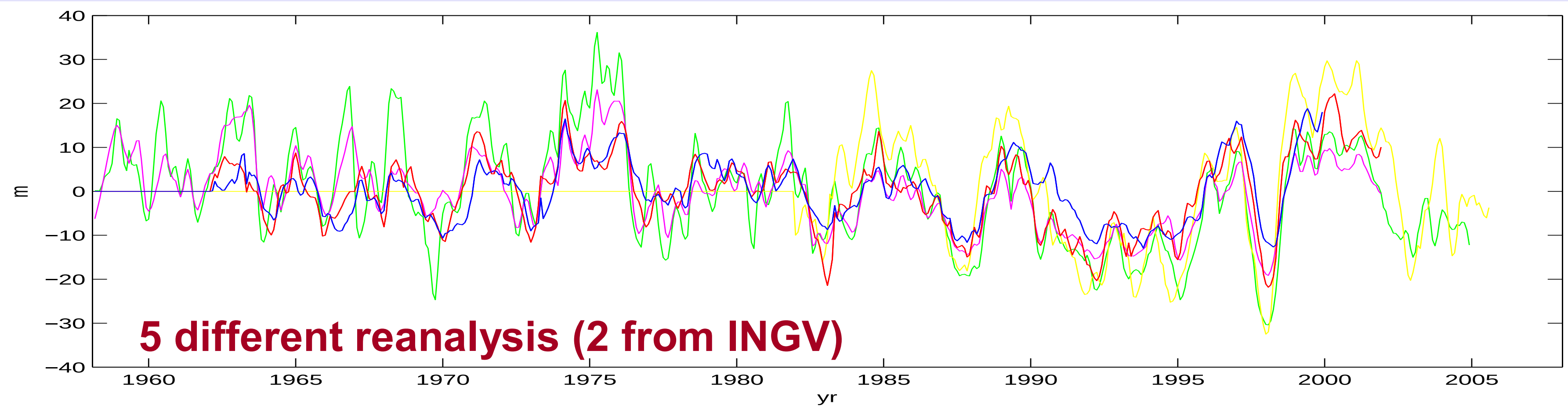


from SODA



Z20 variability at ITF in SODA





Can we trust reanalysis data? Not necessary

BUT sclerosponges from ITF indicates a significant subsurface cooling (~ -2°C), max at 120m depth, during '80 and '90, not supported in either surface instrumental or shallower coral proxy record (Moore et al., 2000)

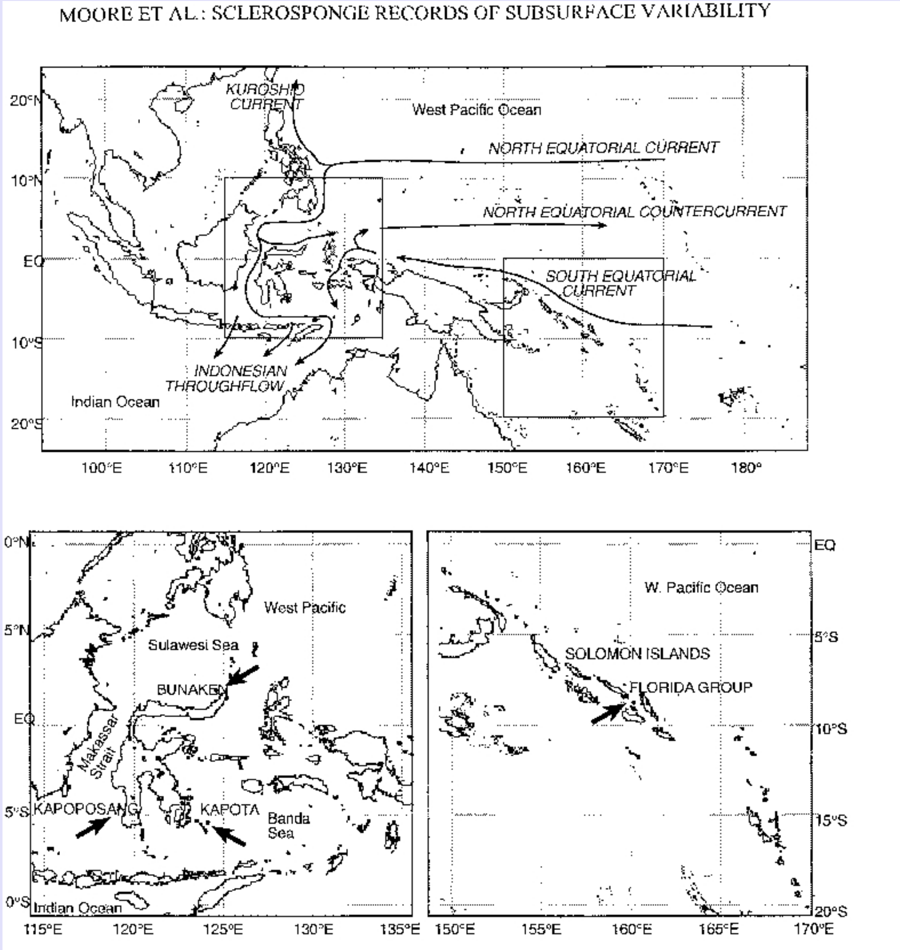


Figure 2. Site map for the sclerosponge samples analyzed.

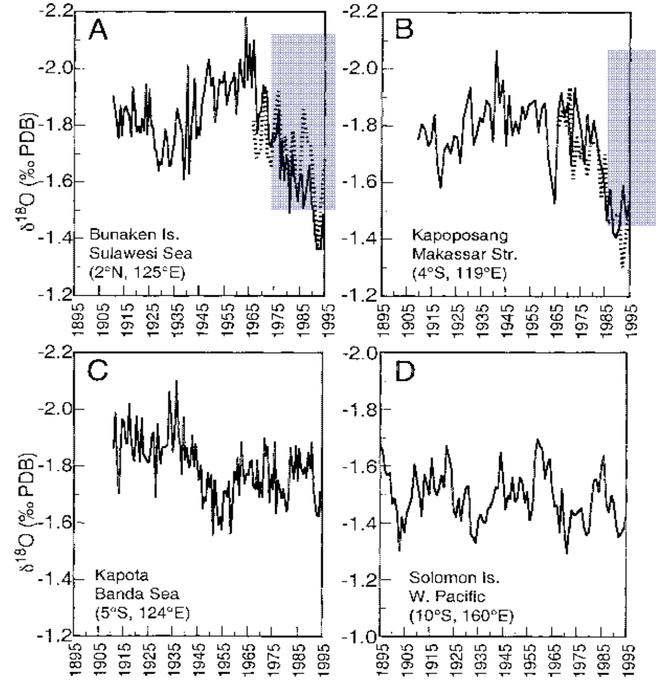


Figure 5. Sclerosponge δ18O records from the Indonesian Seaway and the Solomon Islands. Y axes are reversed so that the data correspond to temperature. Age models assume linear growth and are constrained by a Th/U data at the base of each sponge. As in Figure 4, dashed lines indicate records from separate specimens collected at the same site.

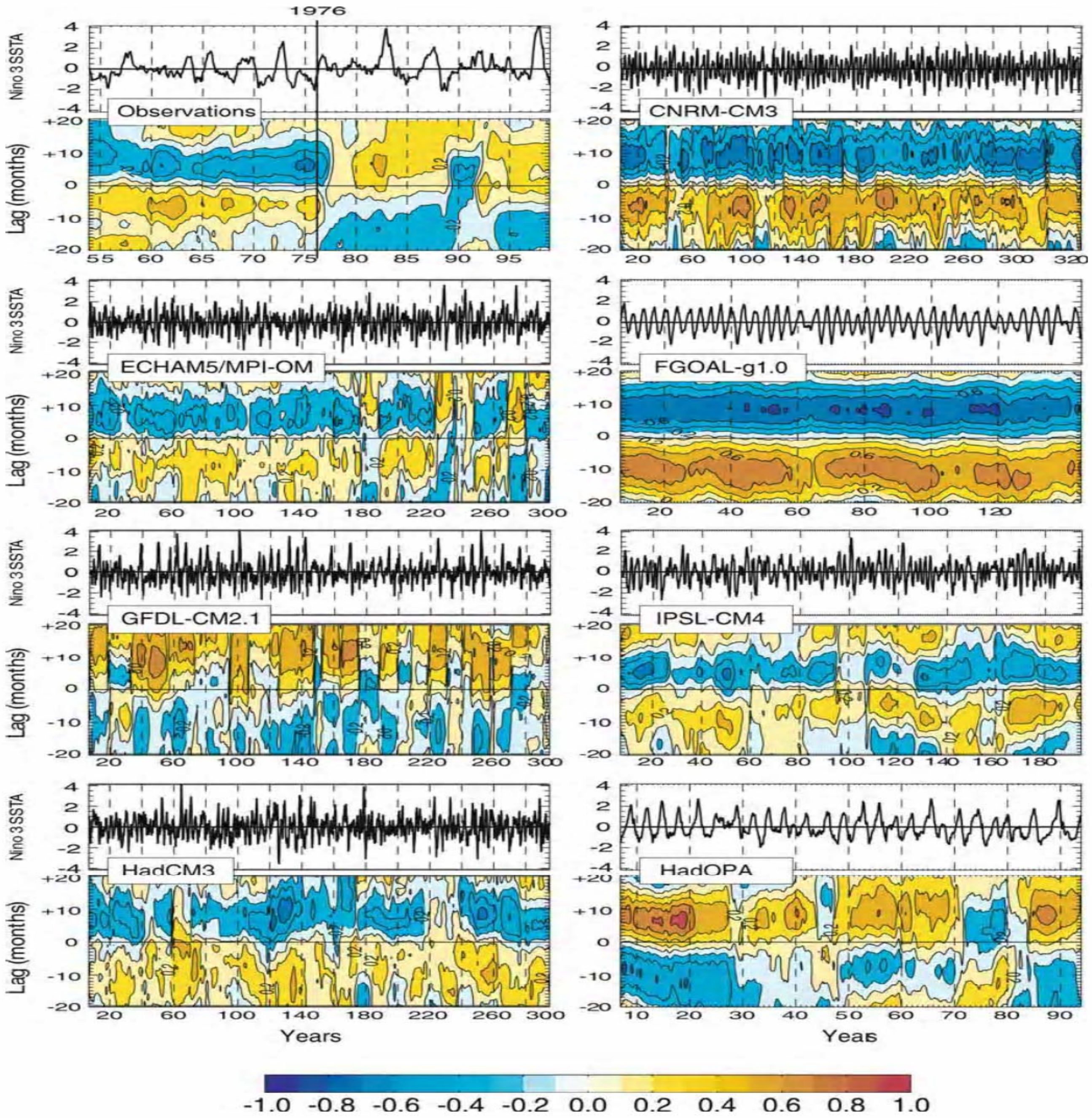
Working hypothesis

- changes in the oceanic ‘connections’ related to changes in the ENSO properties, i.e.

  a shift from S-mode to T-mode

  can modify the probability of having a positive IOZM event co-occurring with El Nino

- Can such a shift be modeled and can we use models to infer the impacts of such a shift?


1976
Nino3SSTA
Lag (months)
Observations
CNRM-CM3
ECHAM5/MPI-OM
FGOAL-g1.0
GFDL-CM2.1
IPSL-CM4
HadCM3
HadOPA
Years
Yeas
-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0

MODEL SET-UP

- **ICTP AGCM, 8-layers, T30 resolution** (Molteni, 2003; Bracco et al., 2004; Kucharski et al., 2006)
- **MICOM 2.9, 0.5-1*1 resolution in a regional configuration** (Bleck et al., 1992)
- **Los Alamos coupler adapted by KNMI**

  (Hazeleger et al., 2004)

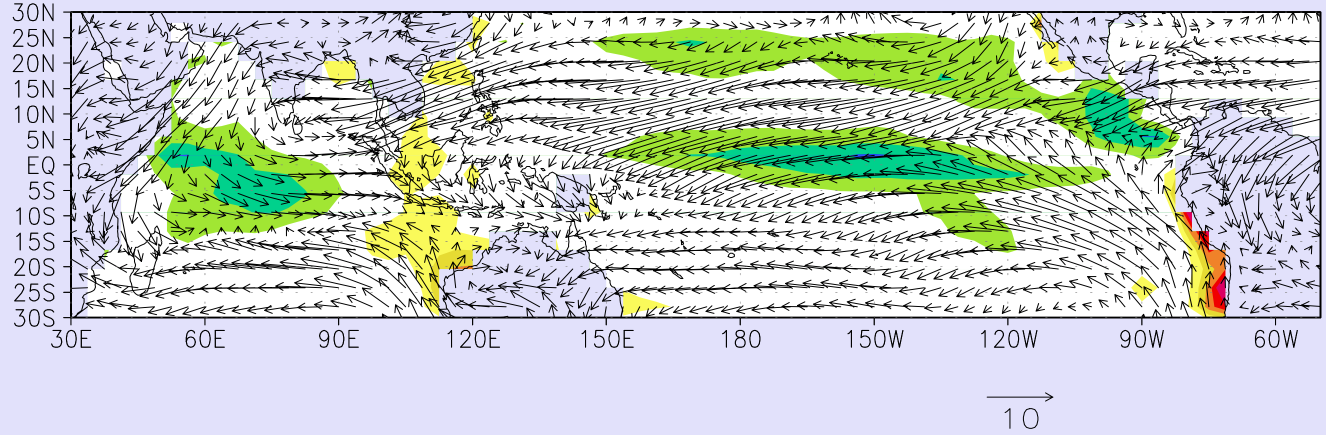
SST correction according to

$$SST_A = SST_{cl} + \alpha[SST_O - \langle SST_O \rangle]$$

with α varying between 0 and 1 over a training period, then set to 1

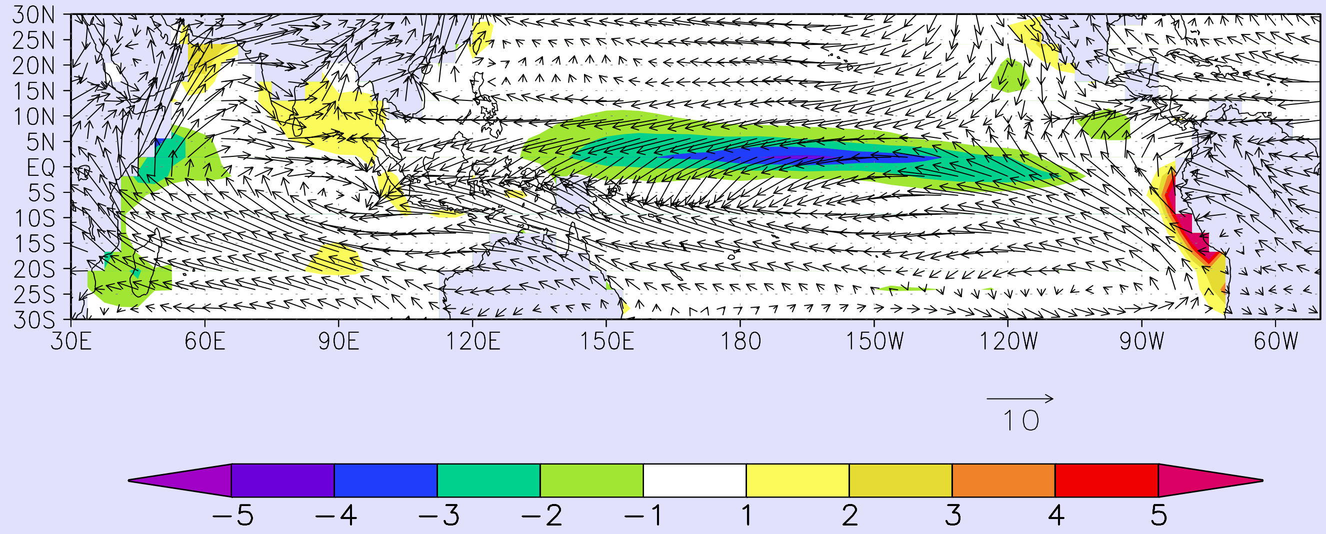
- **T- like ensemble: 2 member ensembles, 150 years long, with CGCM in the Tropical Pacific + Indian Ocean (35S-30N) and climatological SST elsewhere. Training Period 20 years**

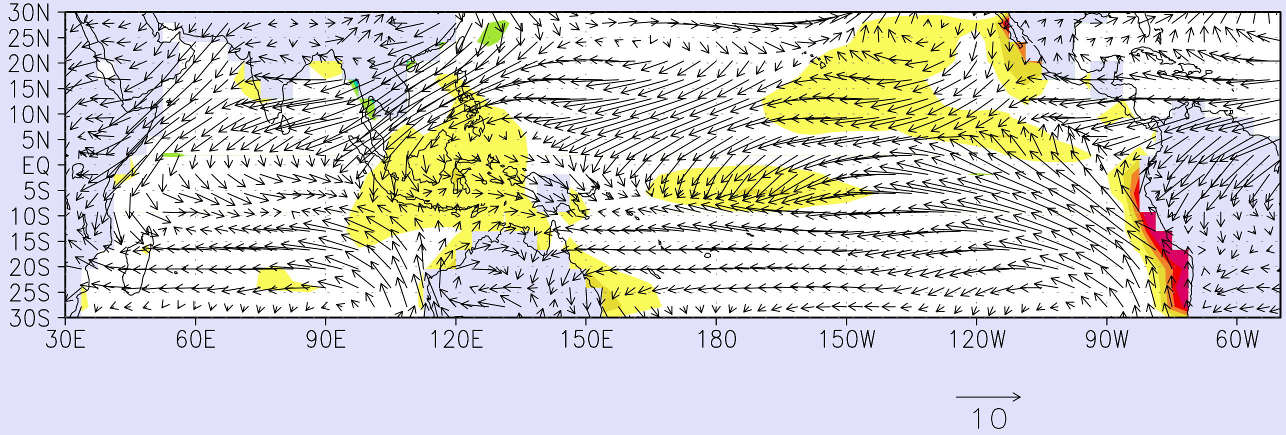
- **S-like ensemble: as above but with a training period of 10 years**



10 years S

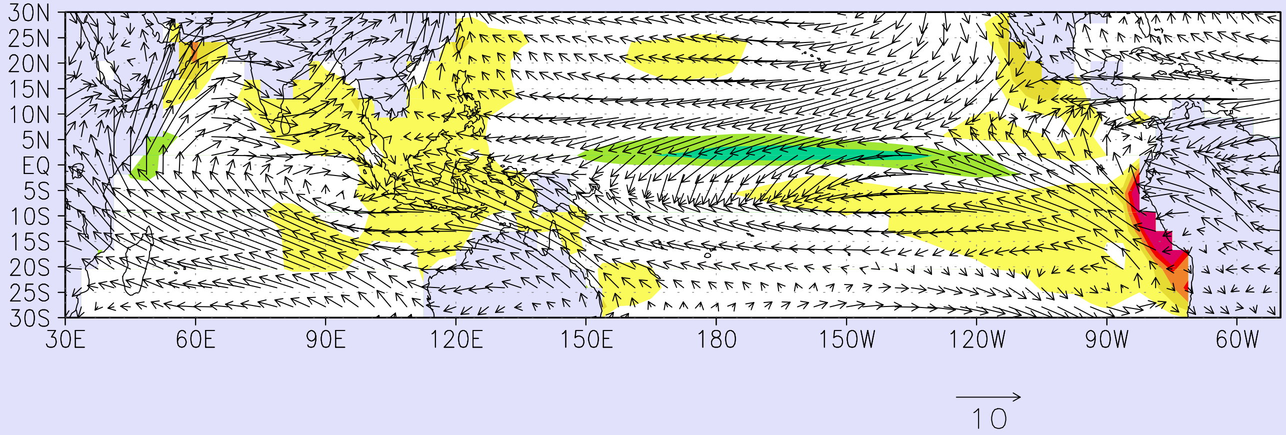
SST ERROR IN DJF (above) and JJA (below)
+ 950hPa WIND CLIMATOLOGY

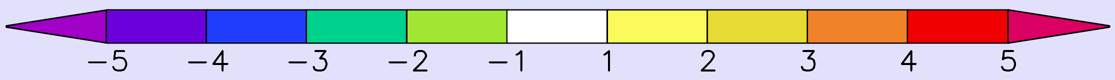


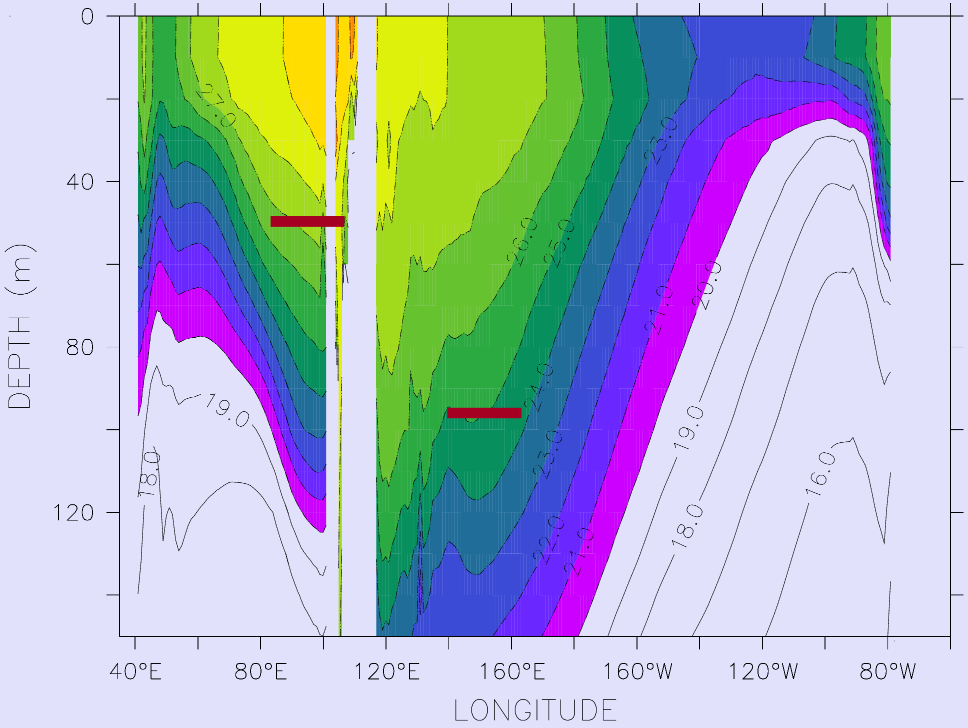


20 years T

SST ERROR IN DJF (above) and JJA (below) + 950hPa WIND CLIMATOLOGY

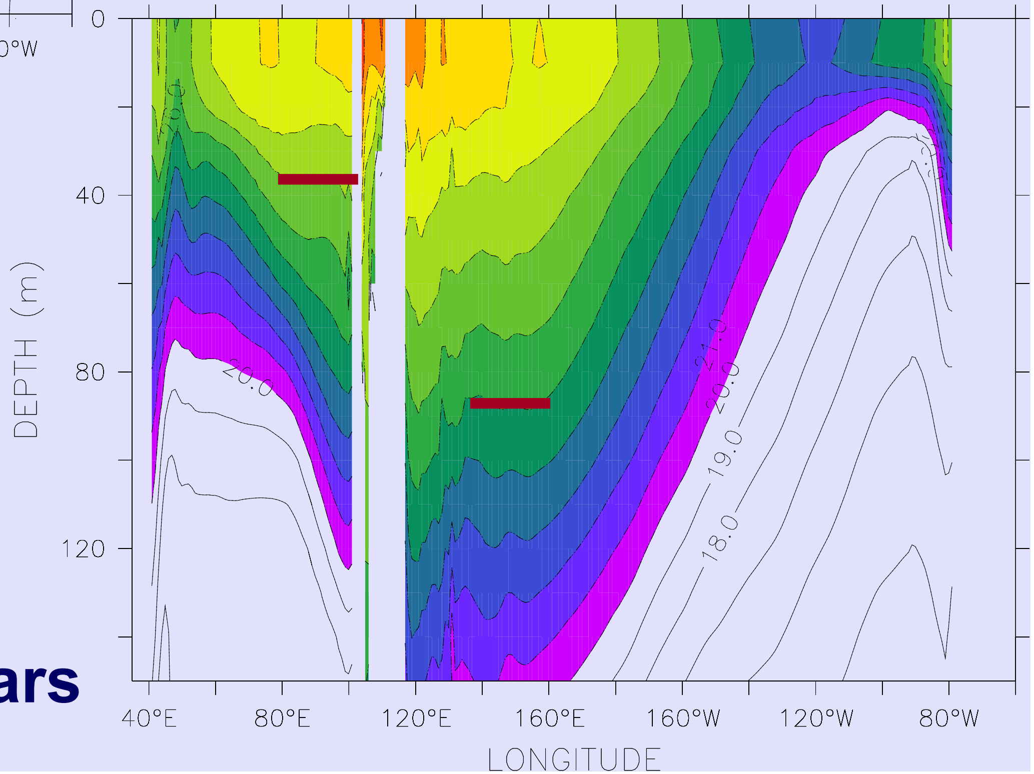






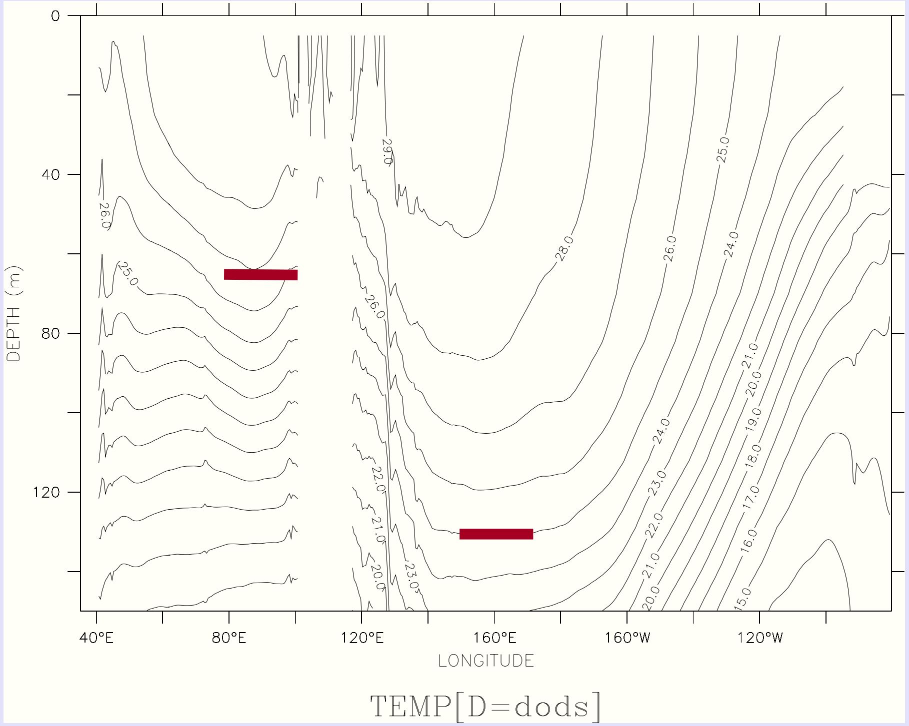
10 years

Thermocline differences ok with pre/post 76 shift and S/T mode

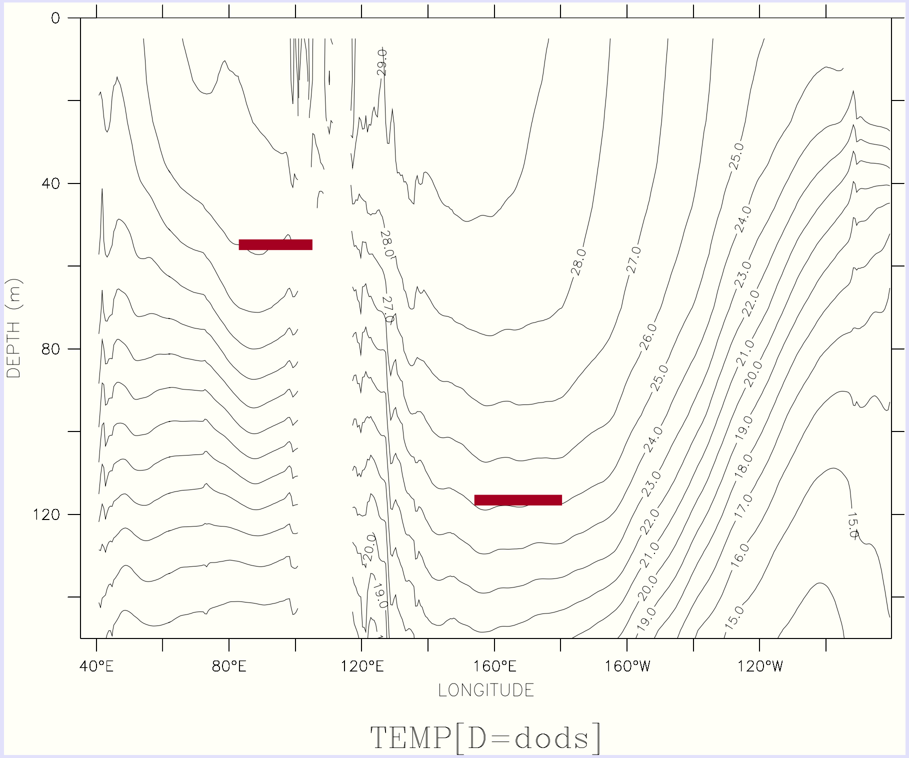


20 years

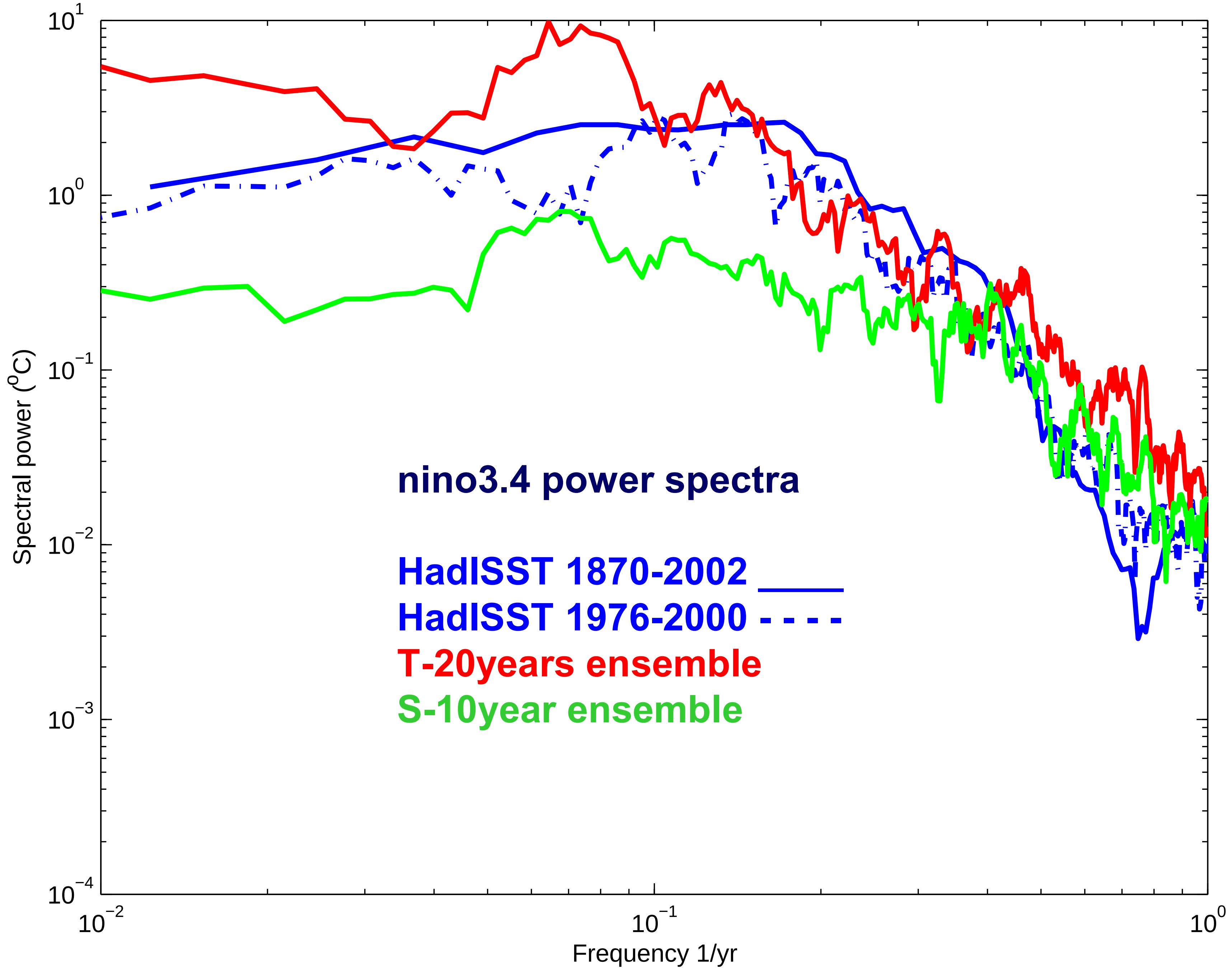
Pre 1976
equatorial thermocline



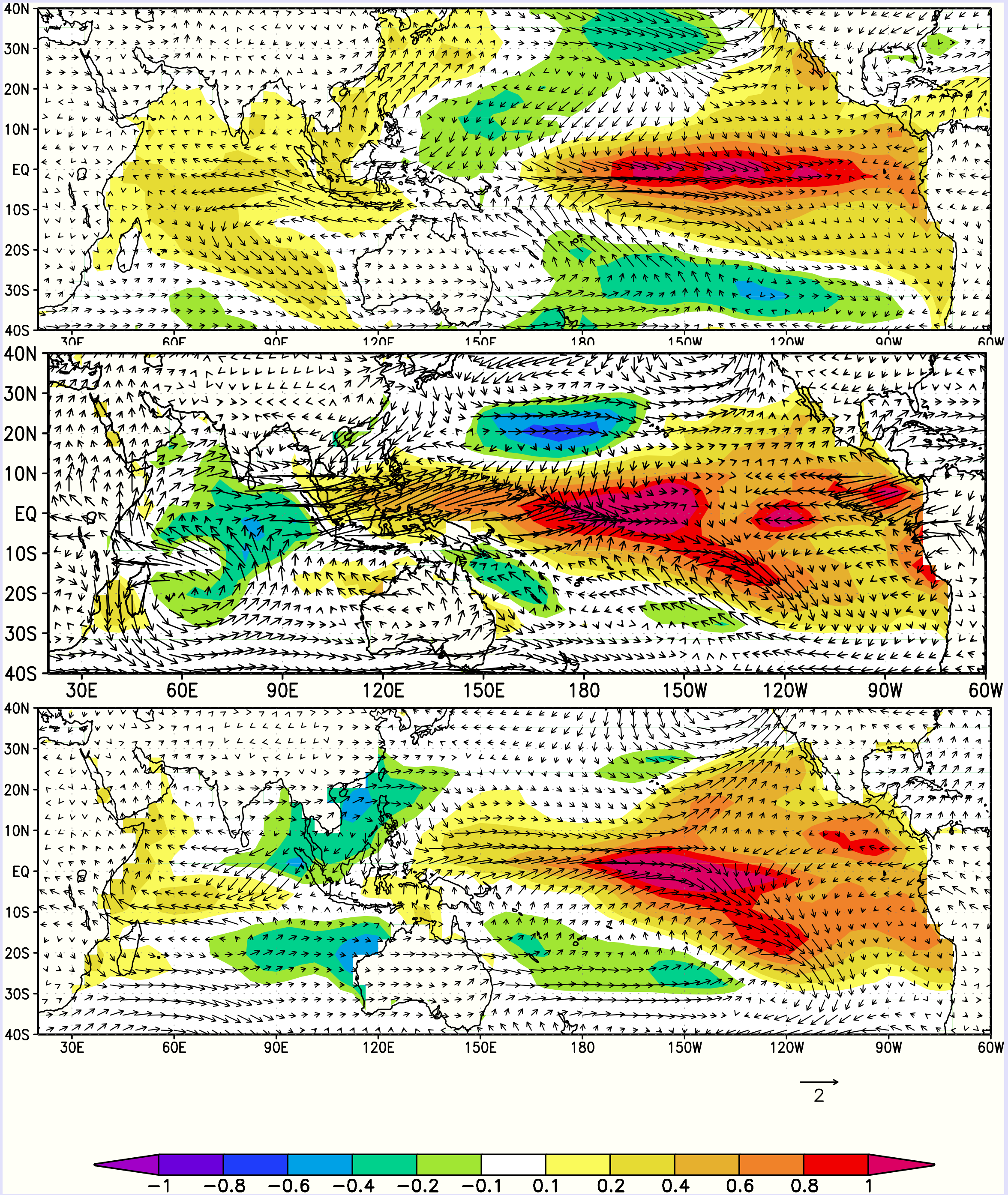
Post 1976
equatorial thermocline



SODA



nino3.4 power spectra
HadISST 1870-2002
HadISST 1976-2000
T-20years ensemble
S-10year ensemble
Spectral power (°C)
Frequency 1/yr
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-2}
10^{-1}
10^{0}



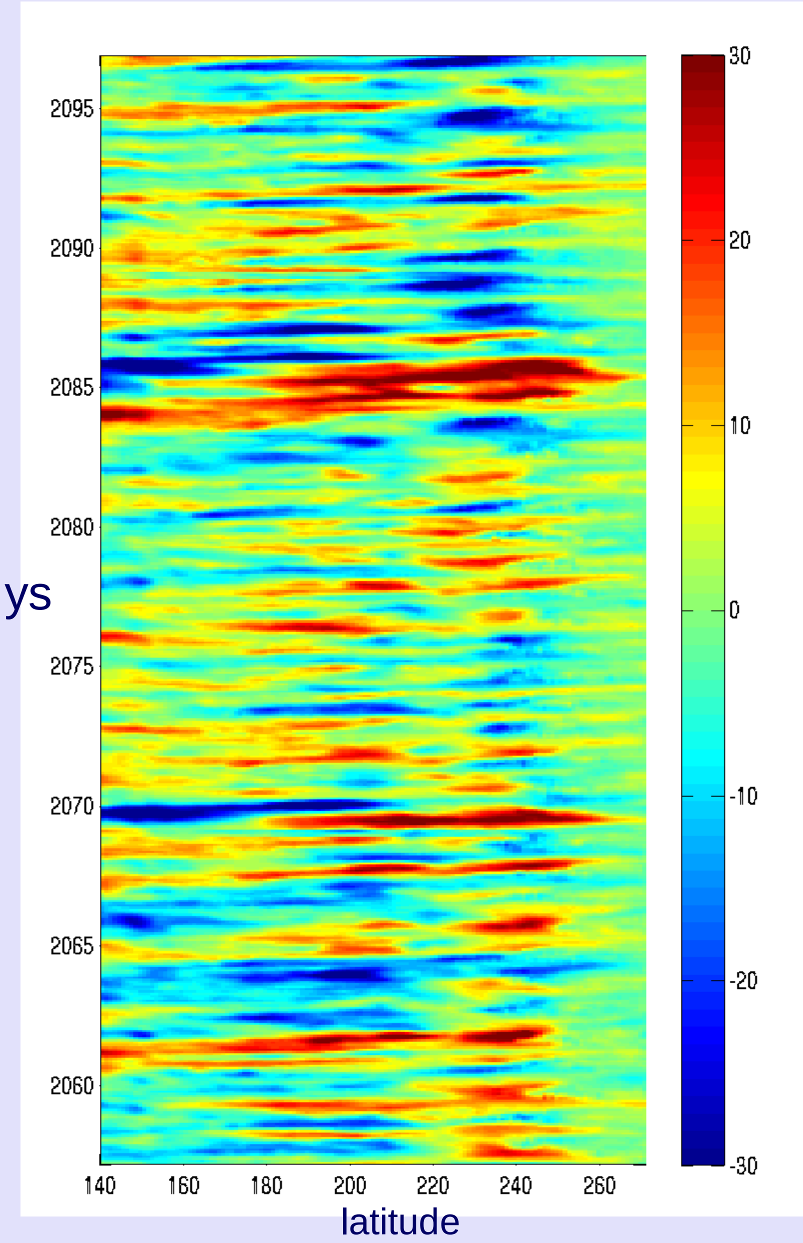
Hadlsst

S-10 years

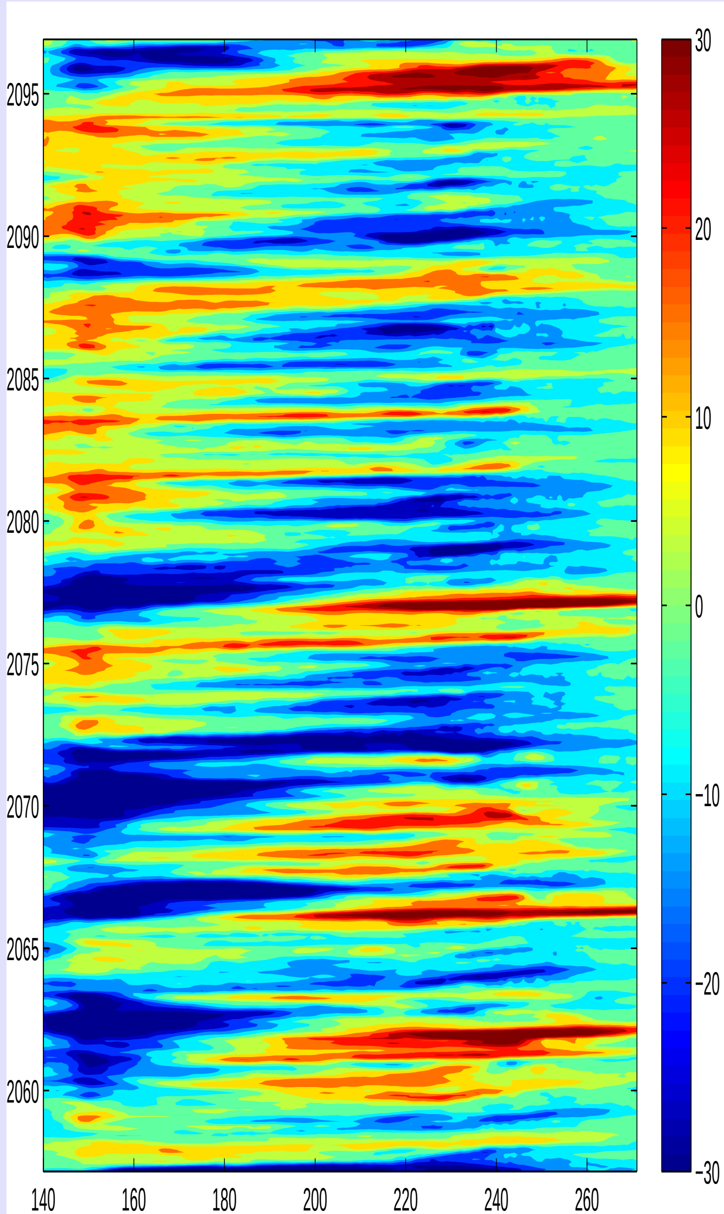
T-20 years

Evolution Thermocline anomalies at the equator

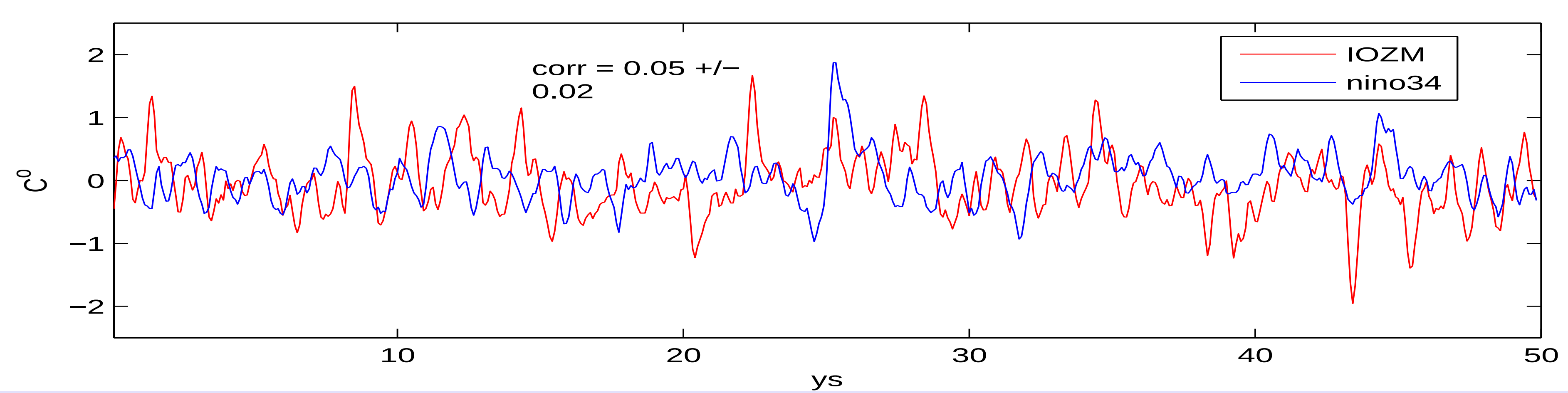
S-like mode



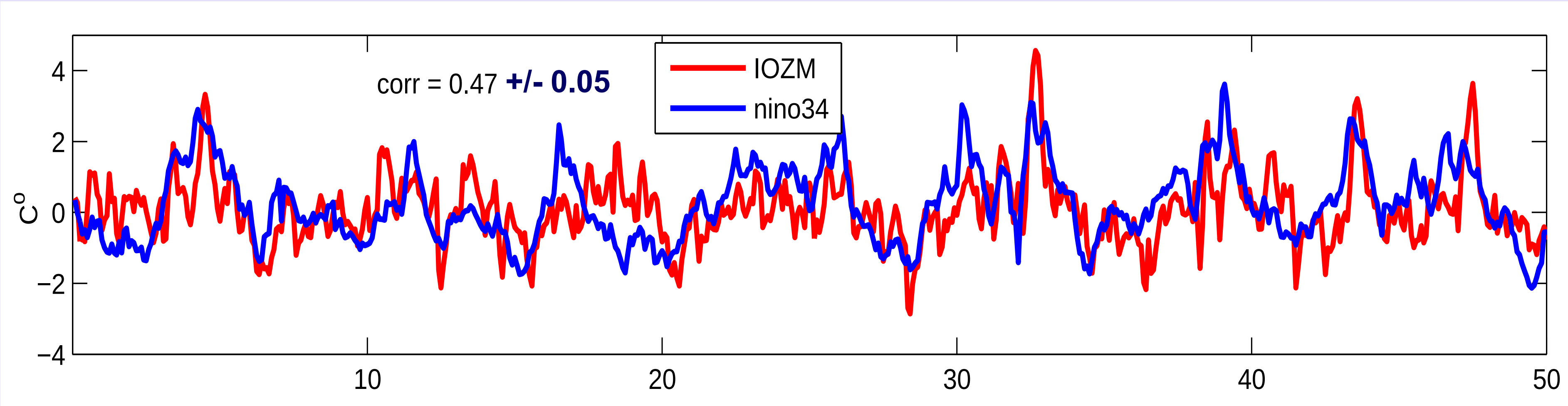
T-like mode



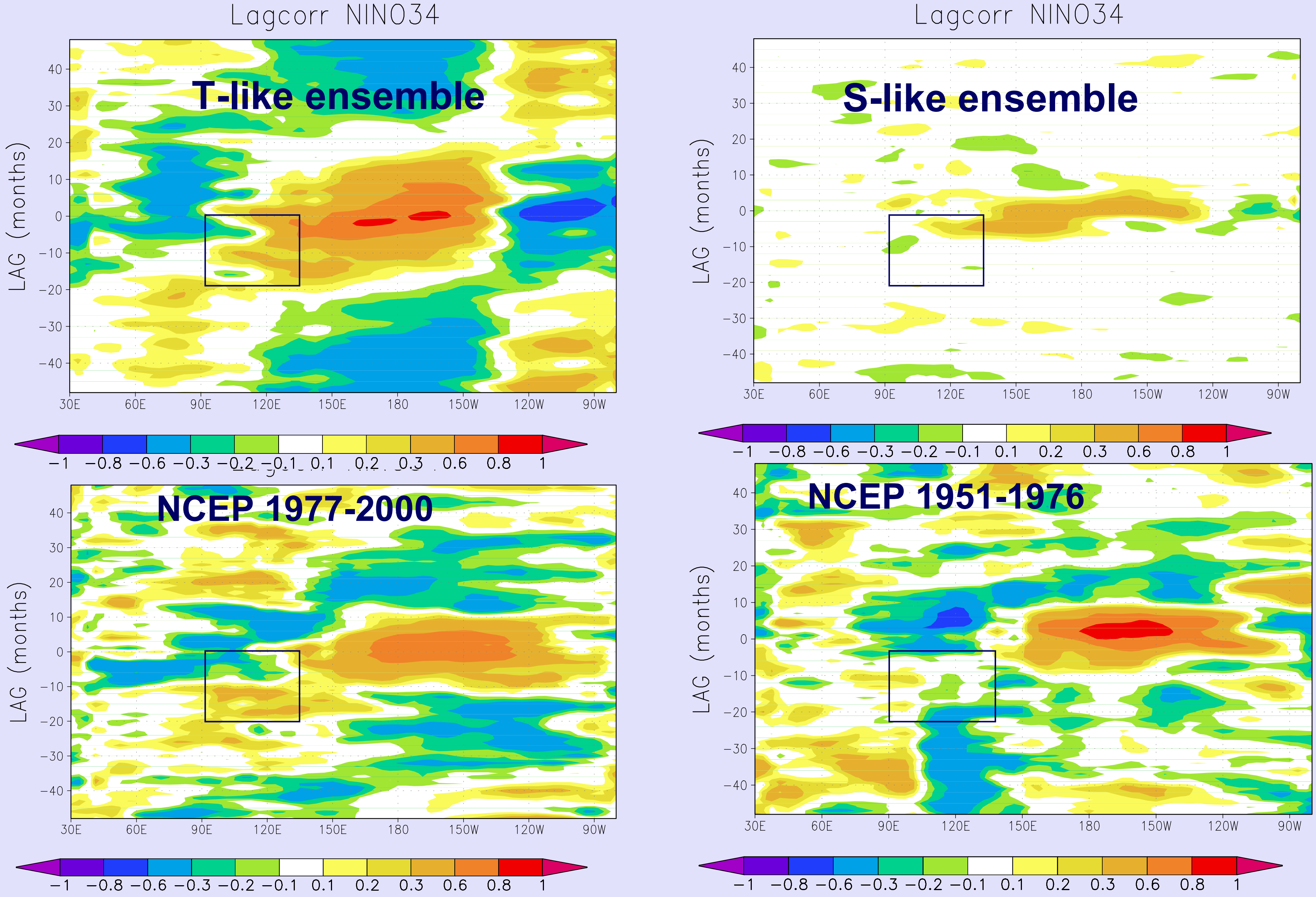
S-mode ENSO   ENSO variance = 0.35 (obs 0.63)



T-mode ENSO   ENSO variance = 1.1 (obs 0.73)



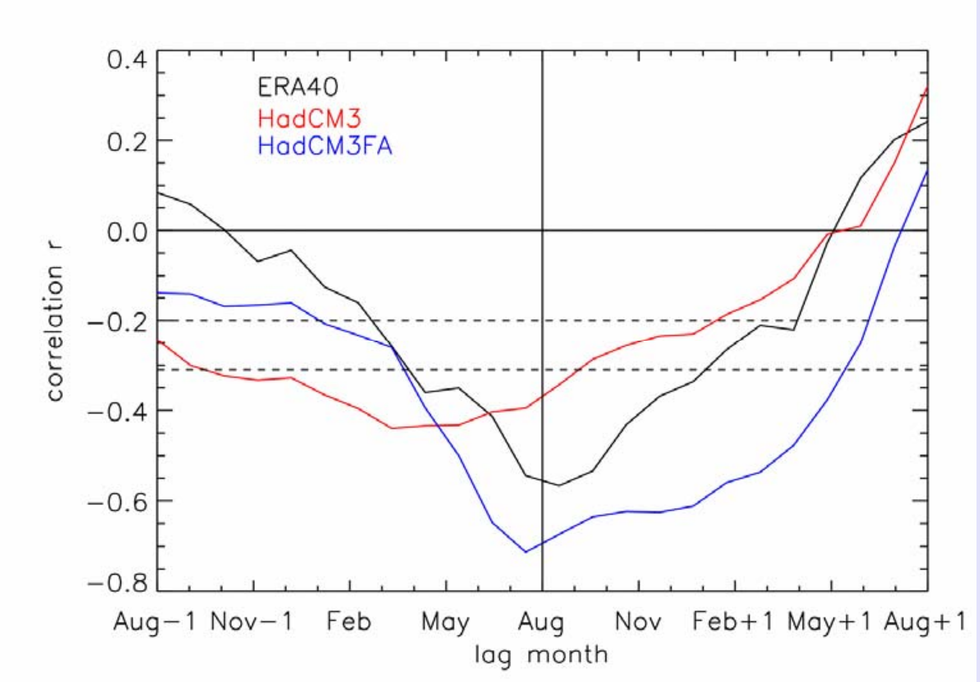
what is causing the IOZM and the nino3.4 indices to be so strongly correlated in the T-mode like experiments?
PERSISTENCY of the anomalies in winds and ssts

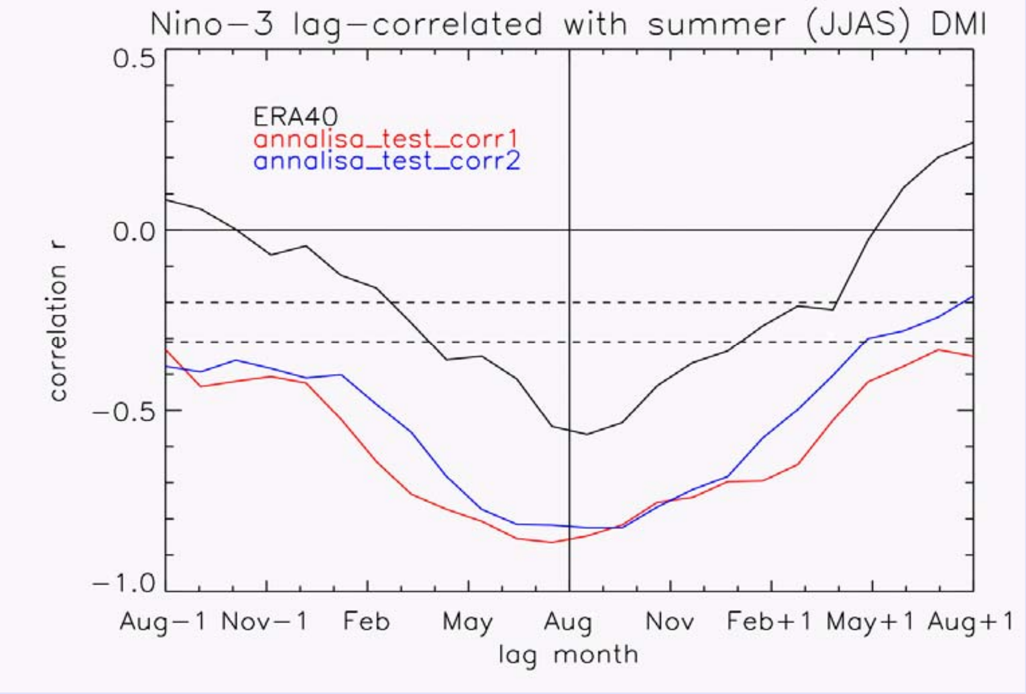


Lag-correlation of summer Dynamical Monsoon Index and Nino3.

It is standard measure of the how well a model can capture the atmospheric teleconnection

induced by the shift of the Walker cell over the Pacific





courtesy of Andy Turner, Reading University

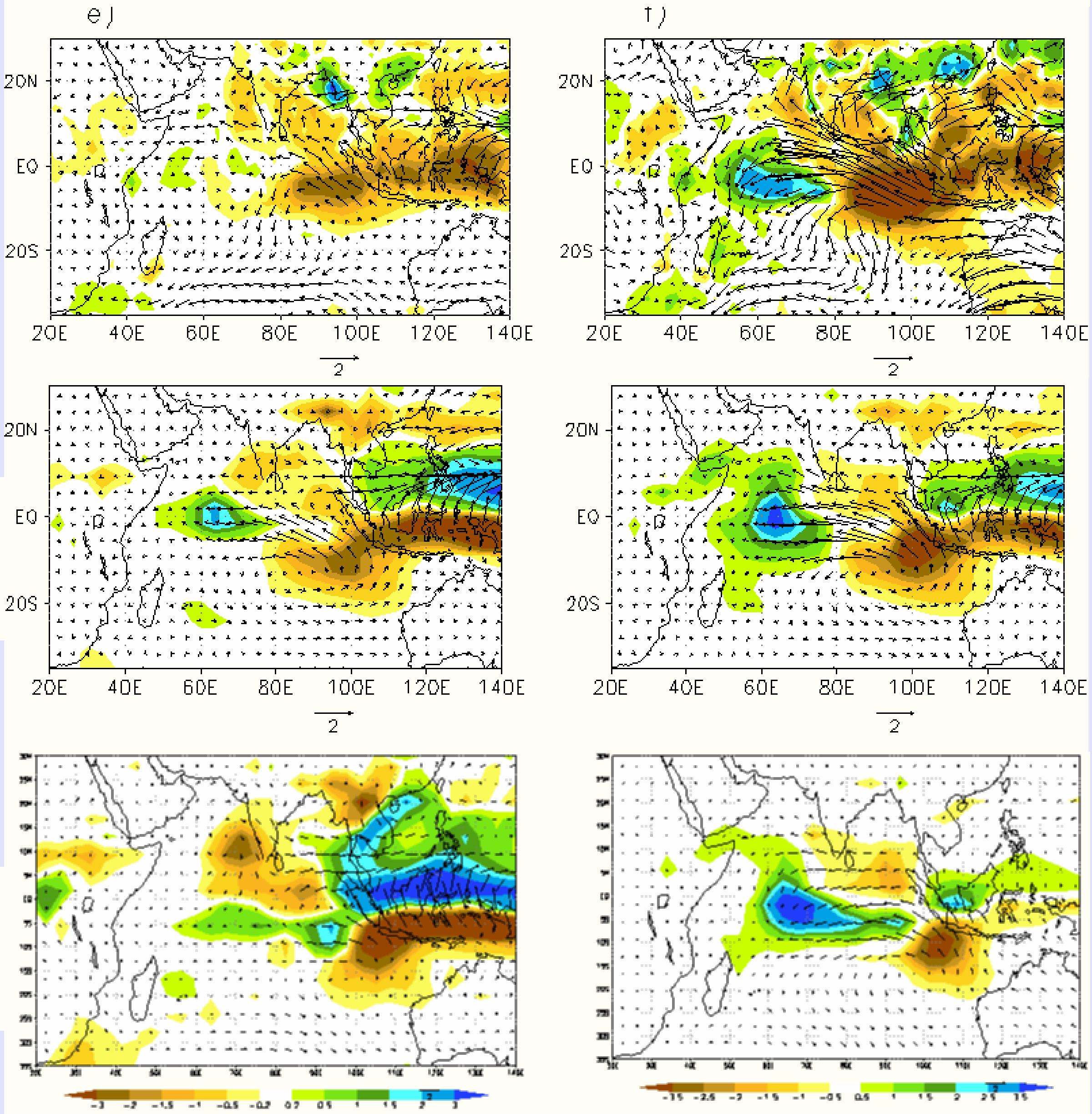
Wind and precip regressions

Nino 3.4 reg map | **IOZM reg map**

CMAP

T-like mode

S-like mode



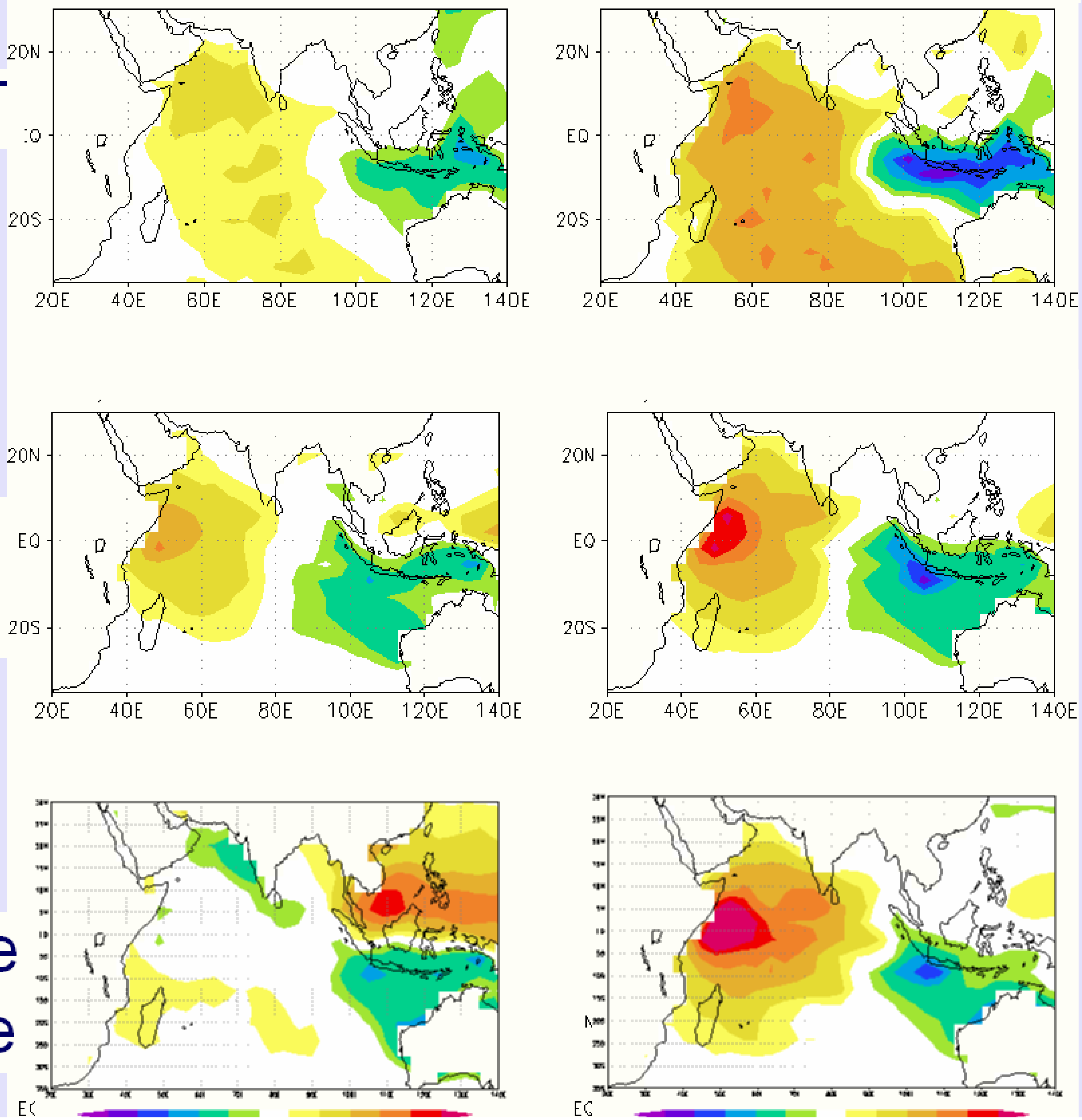
SST regressions

Nino 3.4 reg map | **IOZM reg map**

HadISST

T-like mode

S-like mode



cor. coef.	1950-1999
CRU, nino3 JJAS	-0.59
IMR T-like, nino3 JJAS Year round	-0.50+/- 0.17 -0.4 +/- 0.1
IMR S-like, nino3 JJAS Year rond	-0.35 +/- 0.05 non significant!

in the S-like ensemble the correlation between IMR and ENSO is lower because ENSO is much weaker! The role of IOZM is crucial in East Africa for the short rains in fall, but not so much over India.

Summary

- ENSO and the IOZM are connected via the atmospheric bridge and through the ocean subsurface as well. The baroclinic component of the Indonesian Throughflow (ITF) is responsible for the oceanic bridge. Whenever ENSO is in a T-mode state, its greater persistency reinforces this oceanic connection. During the 1977-2000 period a shallower than average thermocline in the west Pacific and at the ITF, due to persistent eastward zonal wind anomalies in those regions, allowed for a better transfer of the thermocline anomalies associated with ENSO to the eastern Indian Ocean, thus favoring the co-occurrence of positive IOZM events and El-Ninos (as, for example, in 1997).
- T-mode El Nino events are on average of large amplitude and cause significant reduction in the monsoon precipitations over the Indian peninsula. Such a reduction is greater than during (weaker) S-mode El-Ninos.
- The IOZM exerts a limited influence on the interannual variability of the Indian monsoon rainfall over the June-to-September season in the model. It is however important over Indonesia, for the countries facing the South Cina Sea and for China and Japan.
- In the limit of the model results the co-occurrence of positive ENSO and IOZM events does not result in a weakening of the ENSO-monsoon relationship.