Decadal Variation of ENSO Behavior and Its Predictability

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Outline

Examine decadal variation in predictive skill of ENSO

POAMA2 coupled model hindcasts 1960-20010

might expect to see increasing skill due to ARGO/initialization

Recent decade: Nino3 skill dropped, Nino4 skill increased

but: forecast skill for Australian summer monsoon increased

Argue that ENSO behavior has changed and attribute to changed mean state

consistent with other studies > westward shift of coupling

new finding: role for change in warm pool *barrier layer*

Forecast model

POAMA2: T47L17 atmos; MOM2 2x0.5L17 ocean

initialized from assimilated atmos/ocean states

hindcasts 1960-2010 from 1st of each month to 9 months

PEODAS Ocean Reanalyses 1960-2011

P(oama)E(nsemble)O(cean)D(ata)A(ssimilation)S(system)

Same Ocean model as POAMA

Ensemble-based (poor man Kalman filter): covariance T and S

driven by ERA-40 fluxes, SST constrained to Reynolds

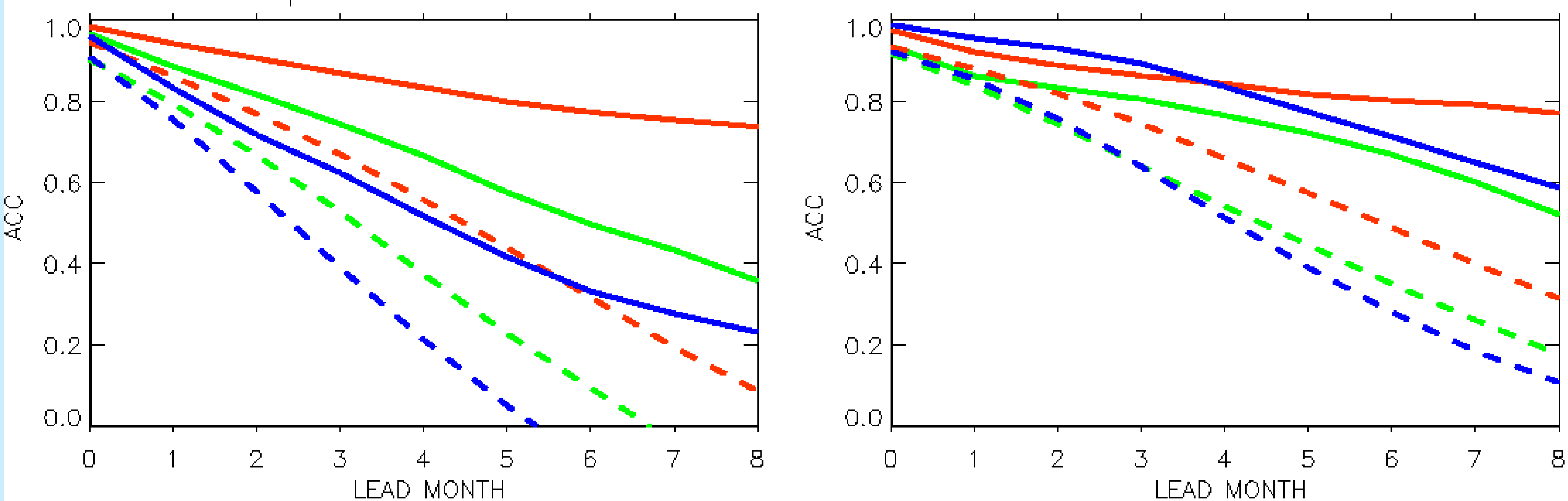
assimilates subsurface T and S from moorings, ARGO, ships

available daily on 2x0.5 deg grid

quality comparable for T and much better S compared to GODAS, CFSR, ECMWF,…

Xue, Y., M. Balmaseda, T. Boyer, N. Ferry, S. Good, I. Ishikawa, A. Kumar, M. Rienecker, A. Rosati, and Y. Yin, 2012. **A comparative Analysis of Upper Ocean Heat Content Variability from an Ensemble of Operational Ocean Reanalyses,** *Journal of Climate,* DOI: http://dx.doi.org/10.1175/JCLI-D-11-00542.1

Nino3 and Nino4 Correlation Skill POAMA Forecasts all start months 1960-2010



1960-1979 1980-1999 2000-2010

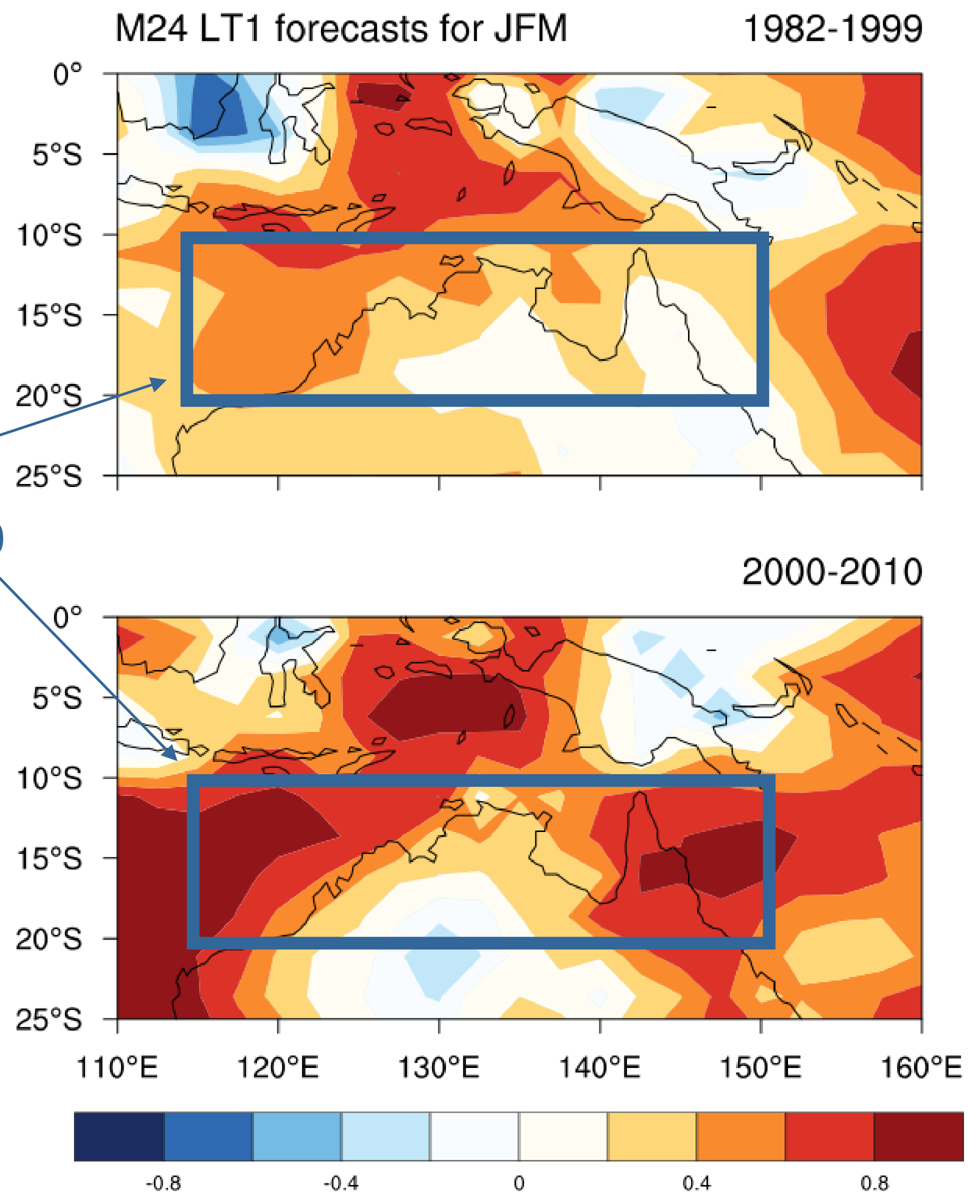
Dashed line in upper panels are persistence, solid are POAMA prediction.

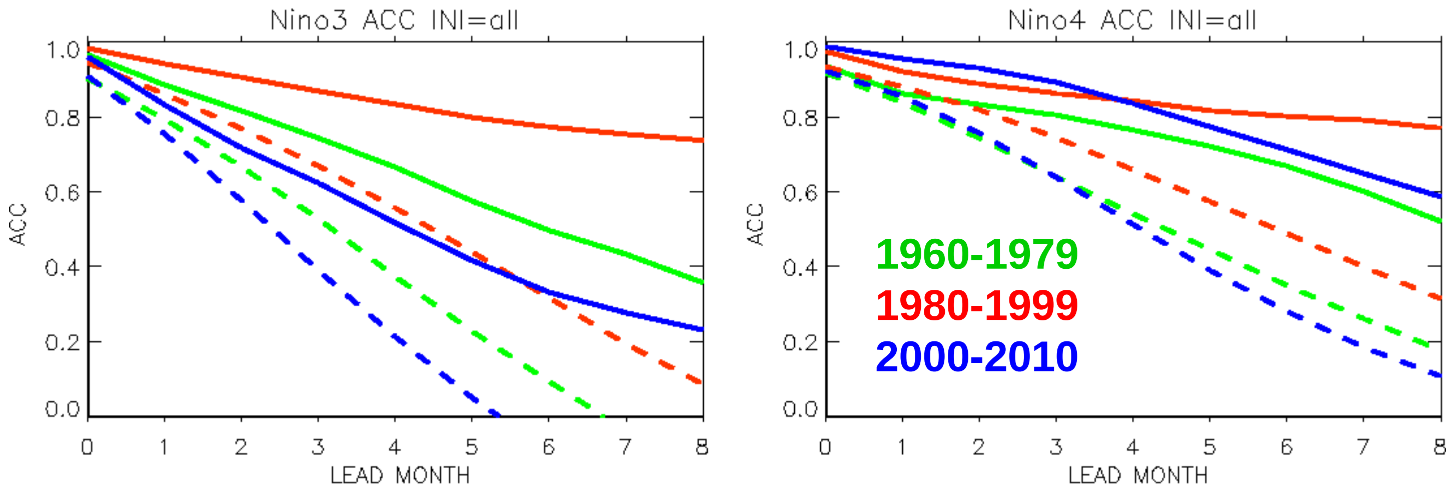
Lead Time 1 month Prediction Jan-Mar rainfall POAMA

Correlation using ensemble mean

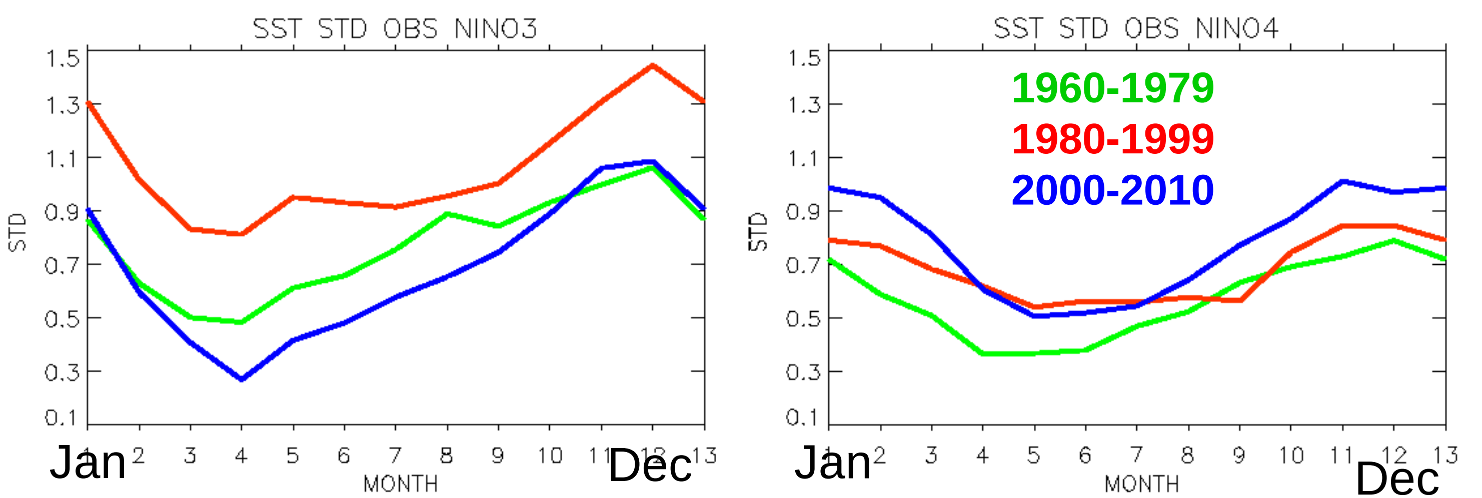
Forecast skill for area mean

	1982-99	2000-10
Land+Ocean	**0.49**	**0.85**
Land only	**0.37**	**0.66**





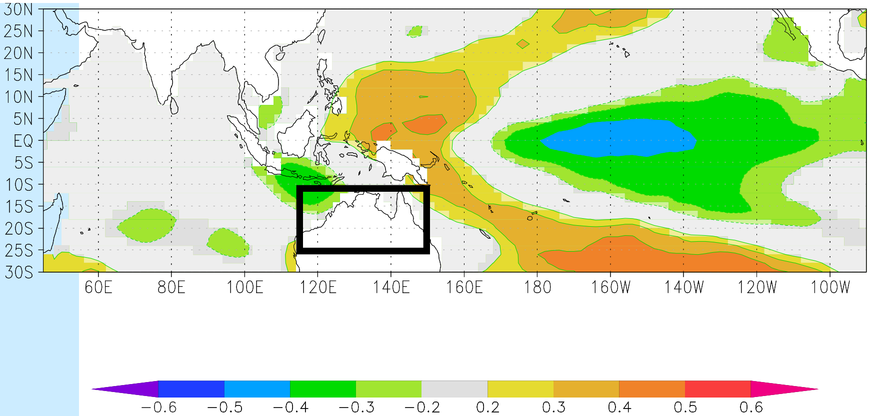
Obs Nino3 & Nino4 Std



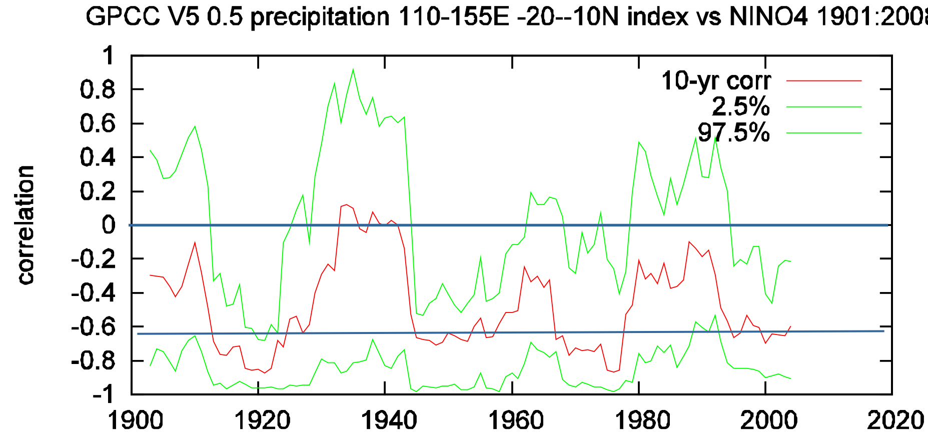
A clear relationship between std and forecast skill is seen among the three periods.

Correlation Australian Summer Monsoon Rainfall (DJFM) with SST 1901-2008

modest relationship with SST in central Pac

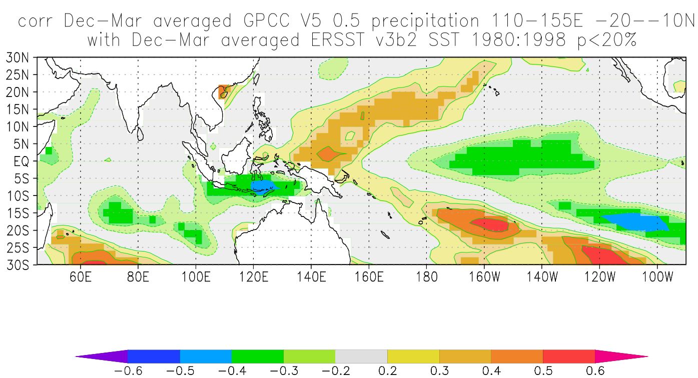


Sliding correlation **ASMR** with **Nino4**

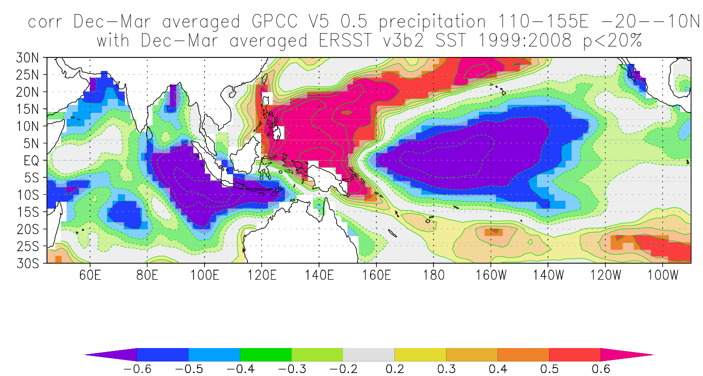


1900 1960 2000

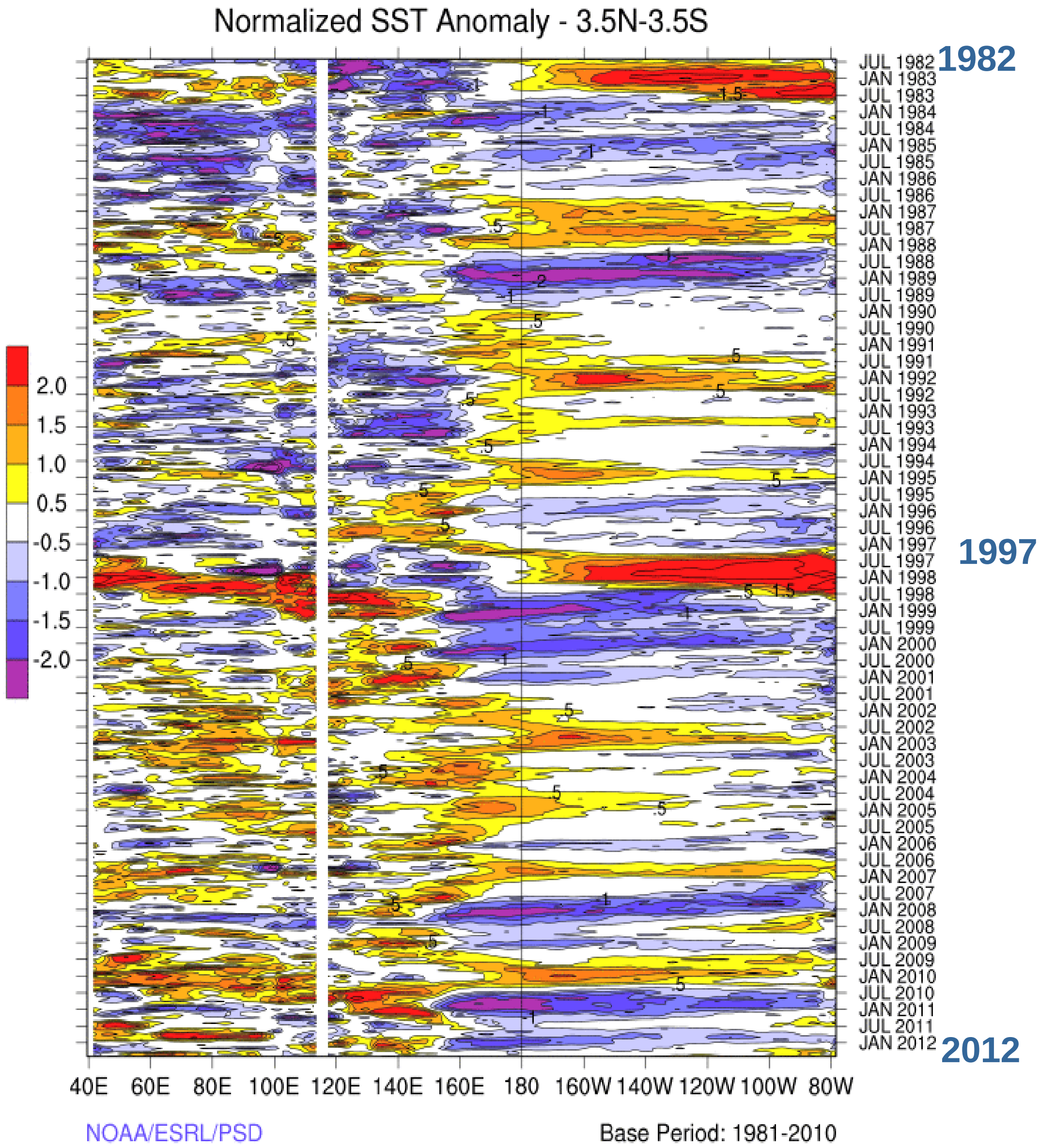
1980-1998



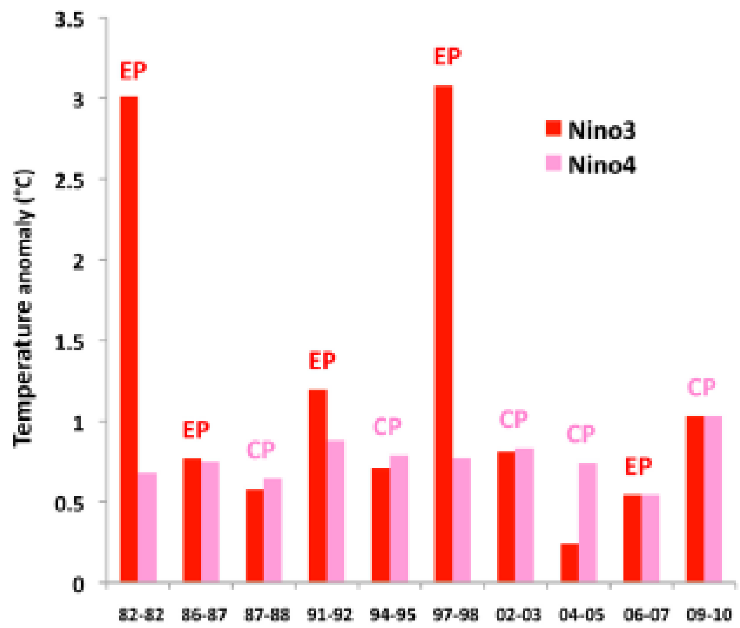
1999-2008



ASMR-SST correlation was weak in the 80-98 but strengthened dramatically since 1998: consistent with increased Nino4 variability



Visually see that ENSO behaviour and mean state changed after 1998



82/3 97/8 09/10

Figure 1. Nino3 (red) and Nino4 (pink) SST anomalies for El Niños between 1980 and 2010. Values are for the peak December to January season. Eastern Pacific (EP) and central Pacific (CP) events are labeled according to various indices described in the text.

CP El Nino

Nino4 > Nino3

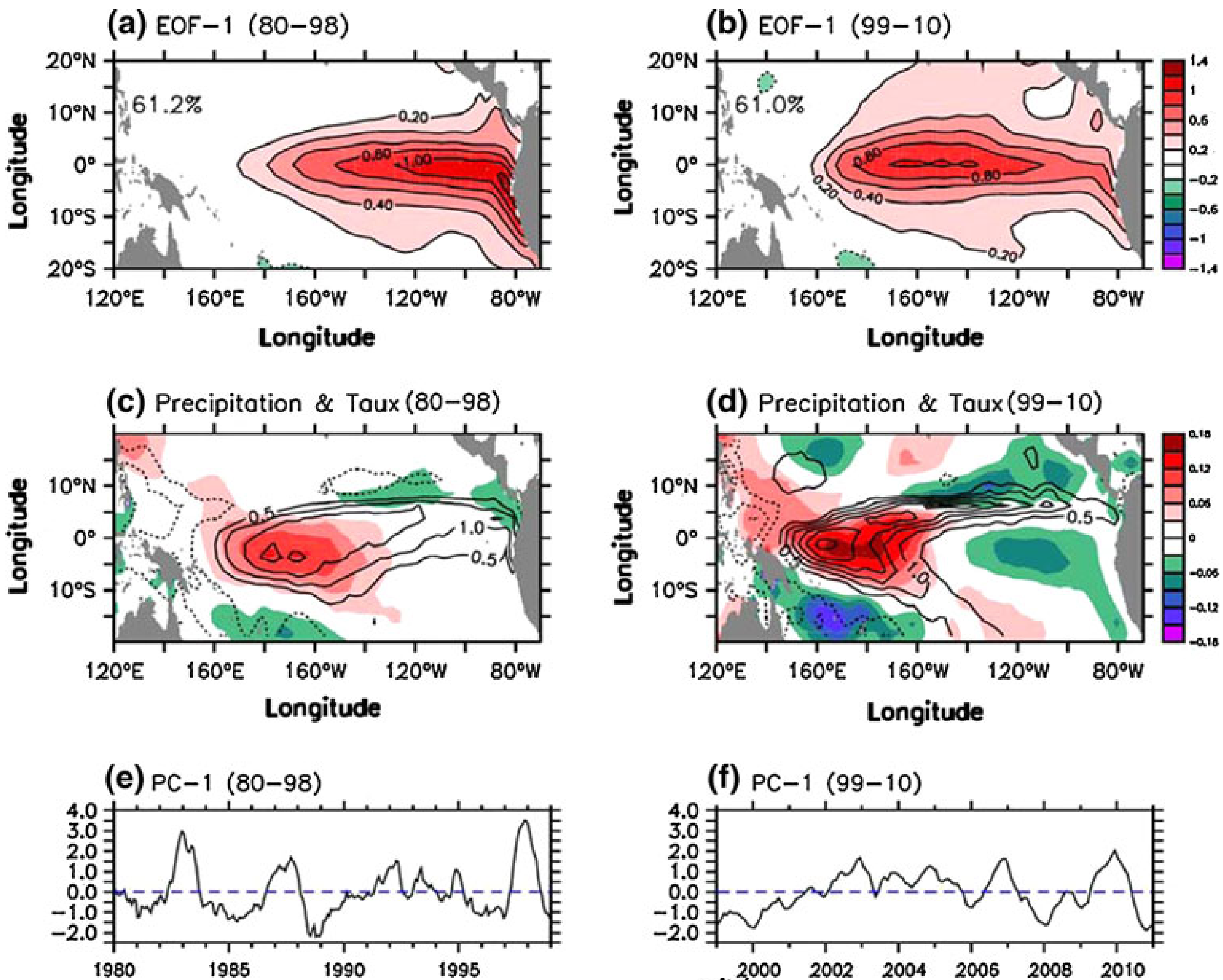
EP El Nino

Nino4 < Nino3

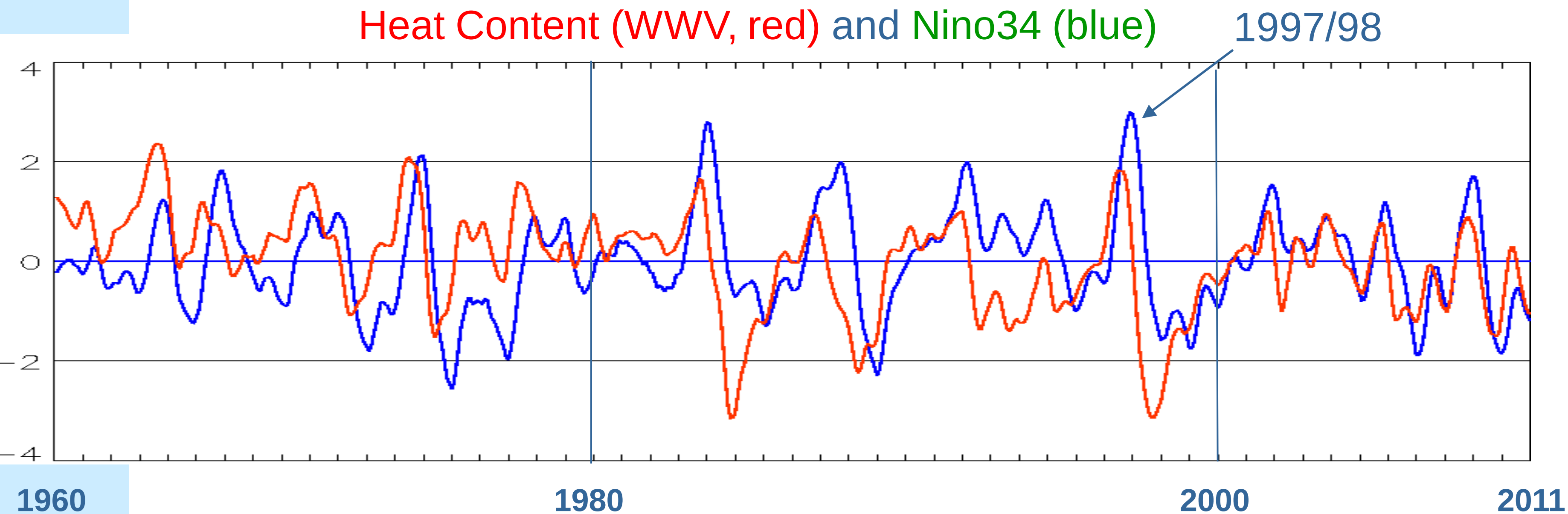
McPhaden et al 2012

CP El Nino more common after 97/98

ENSO Character change can be seen in Leading EOF of Pacific SST: shift to CP El Nino after 1998

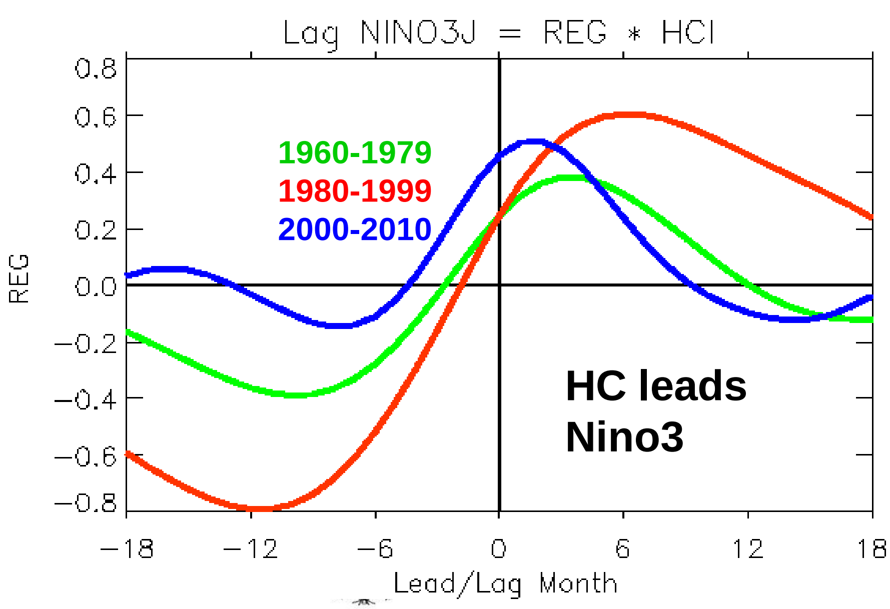


Xiang et al. 2012



“Predictability of EP-ENSO derives from preceding recharge/discharge”

Recent period: weaker recharge/discharge and shorter lag: lower prediction skill



Why did ENSO behaviour change?

Because of a "La Niña-like" mean state change

Mean state changes 1999-2010 minus 1980-1998

Xiang et al 2012

Note: McPhaden suggests the other way around: mean state changed because ENSO behaviour changed (ie, absence of big EP events since 1998)

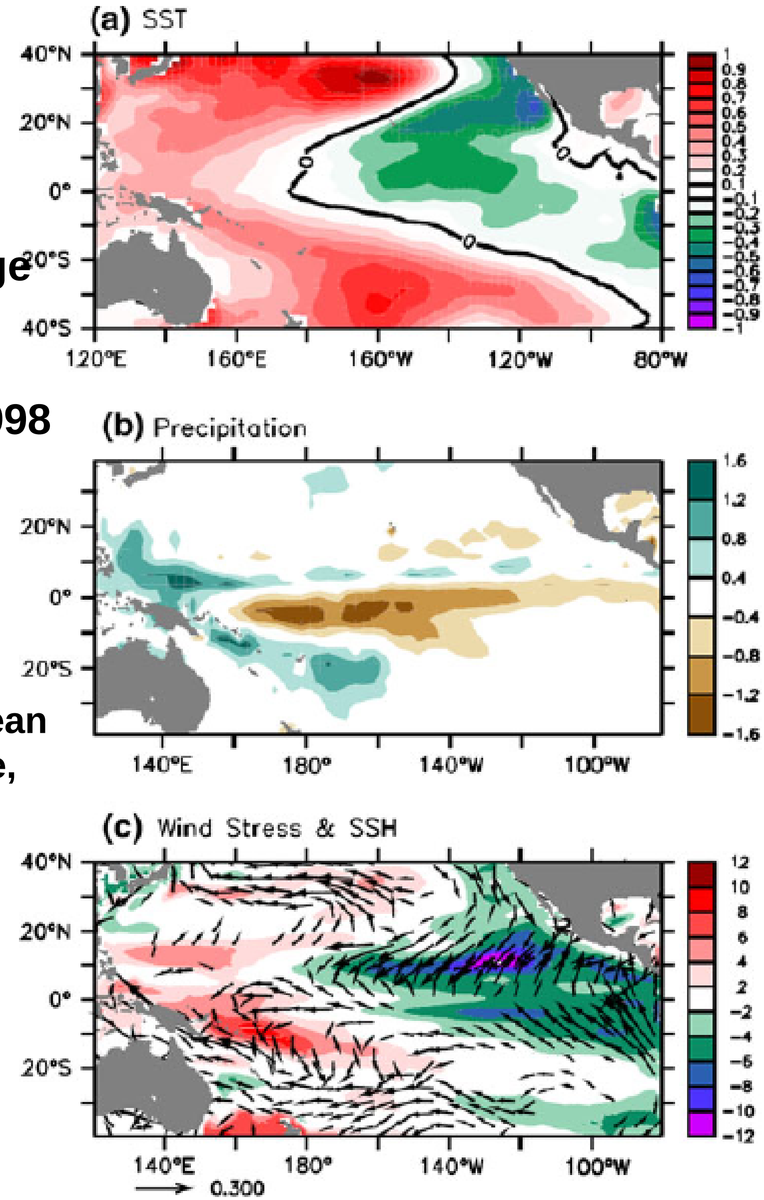
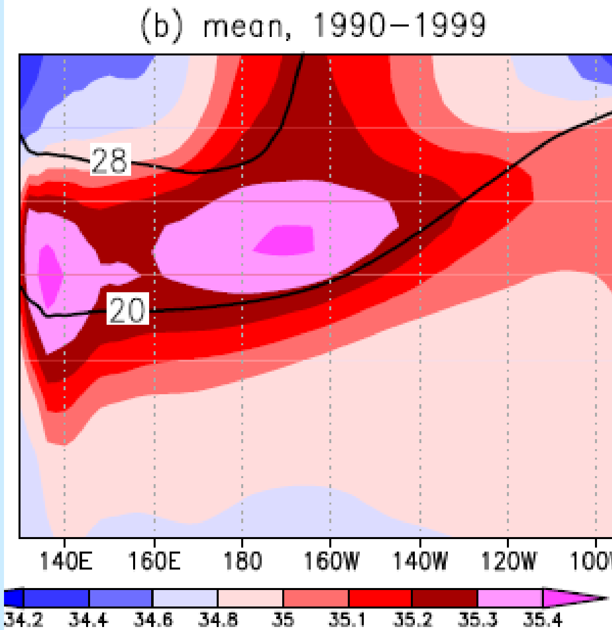


Fig. 7 Epochal differences (1999–2010 minus 1980–1998) of a SST (°C), b precipitation (mm/day), c SSH (*shading* in cm) and surface wind stress (vectors shown only when its absolute value greater than 0.05 dyn/cm^2)

Differences with long term mean

Mean T and S along Eq **PEODAS** analyses



0 m

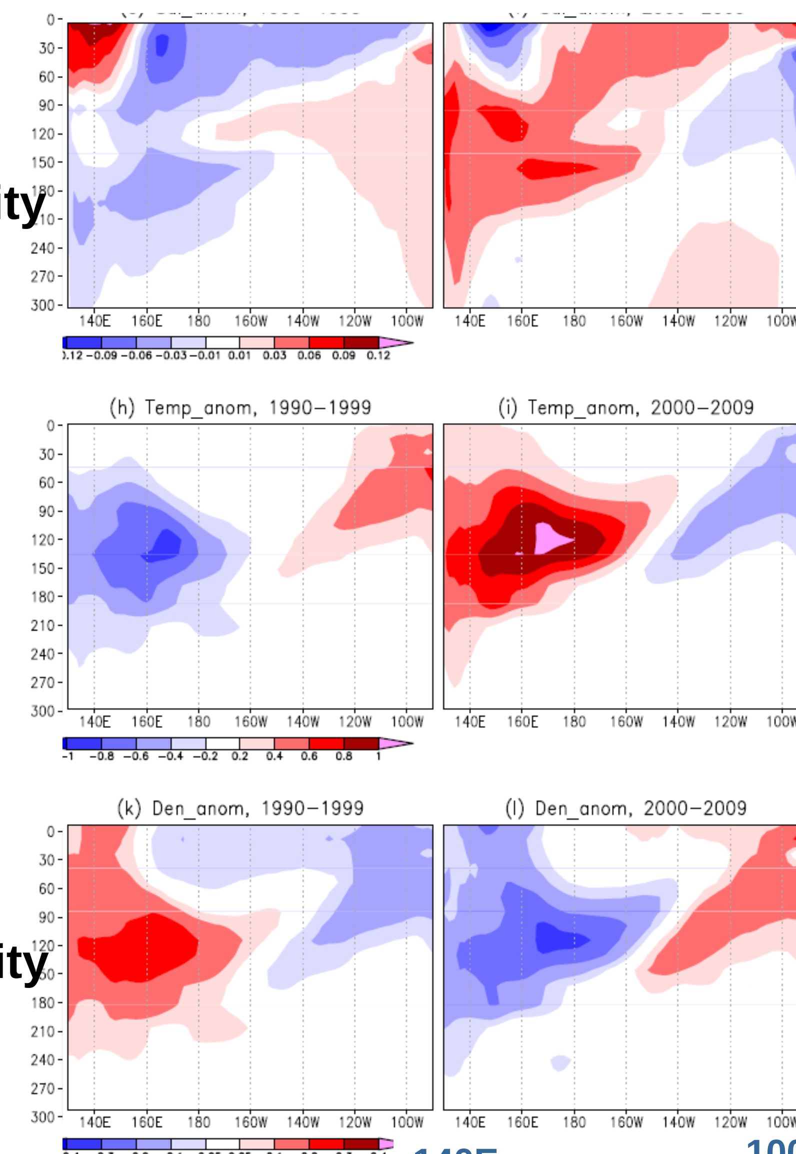
300m

Salinity

Temp

Density

1990-1999 **2000-2009**



0 m

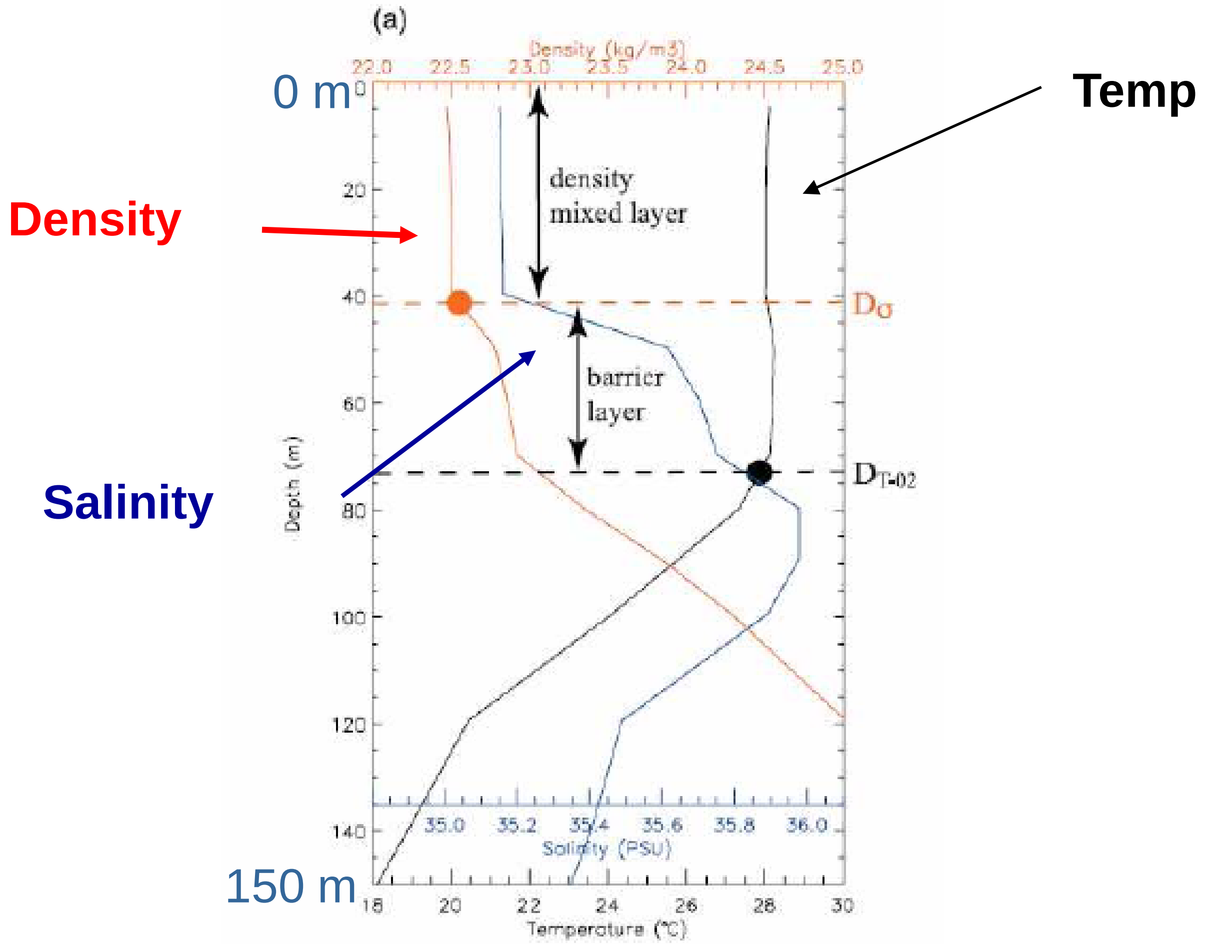
300m

140E

100W

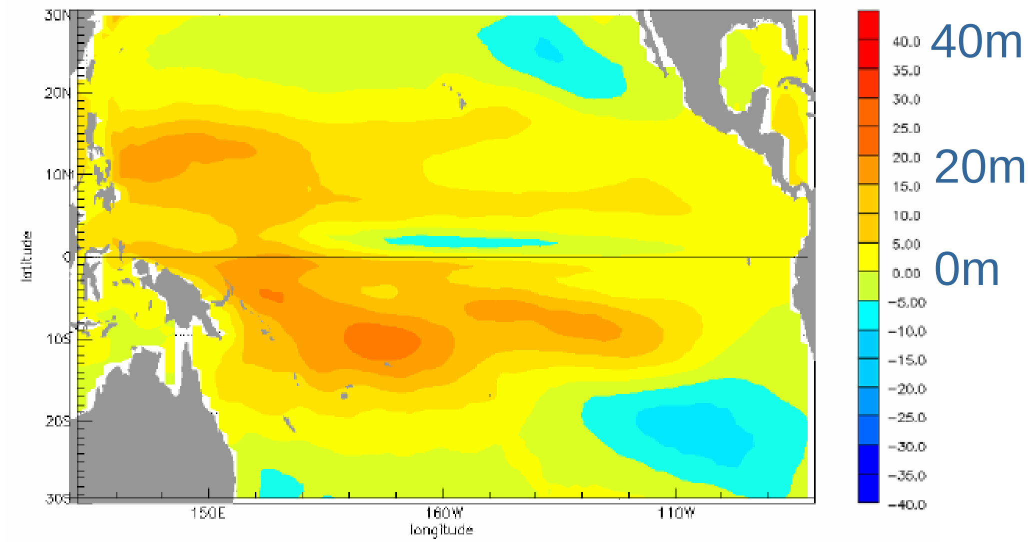
Recent period: Increased near-surface salinity in central Pacific and westward contraction of fresh pool

Examples of barrier layer in fresh pool



.(from *De Boyer Montégut et al.*, 2007)

Mean barrier layer thickness from **PEODAS daily analyses 1980-2007**



Freq of occurrence of BLT exceeding 10m, 20m, and 30m

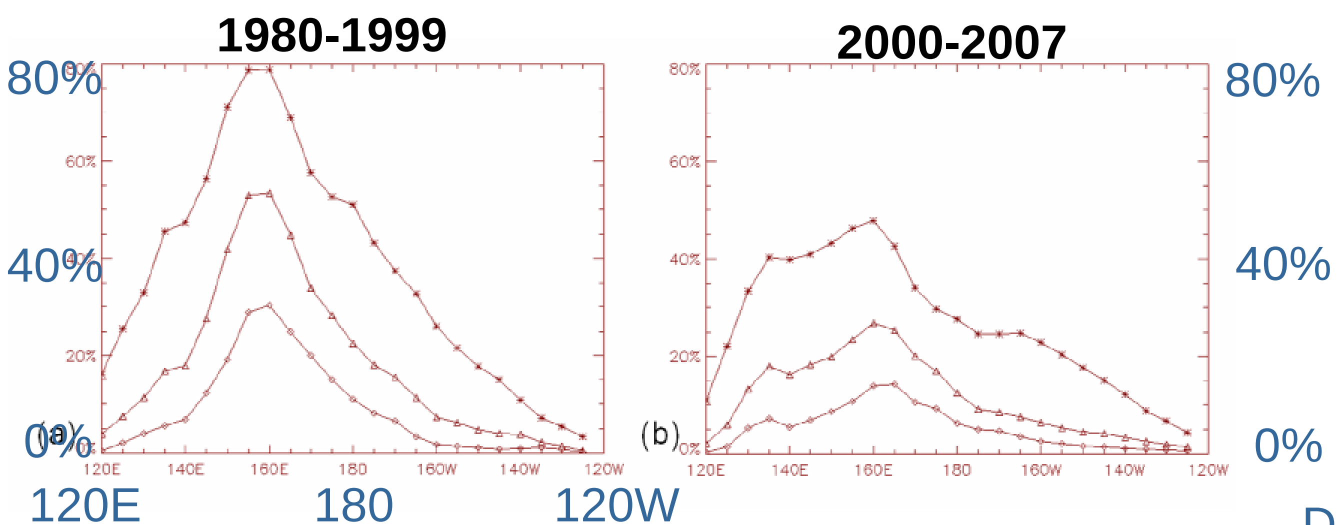
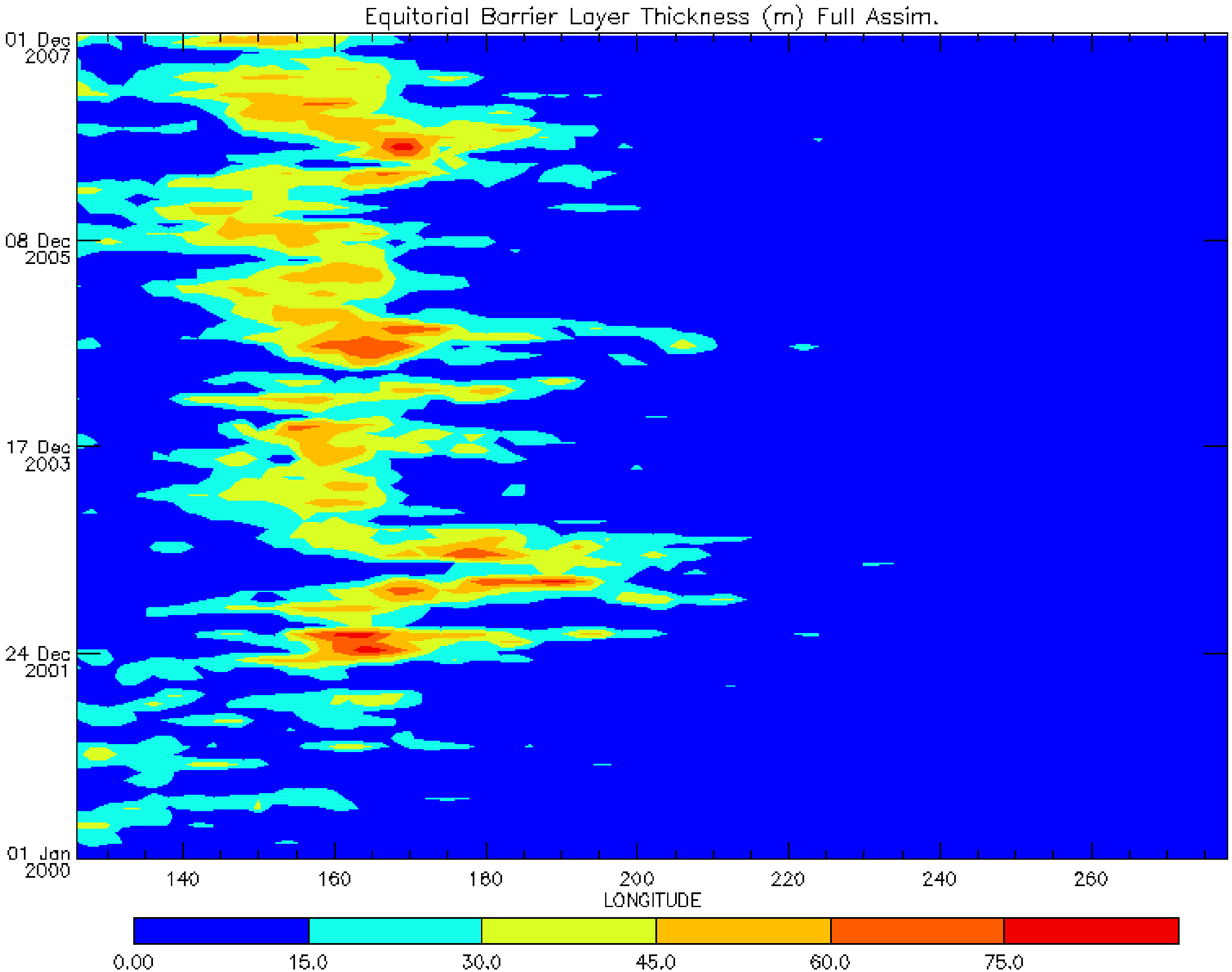


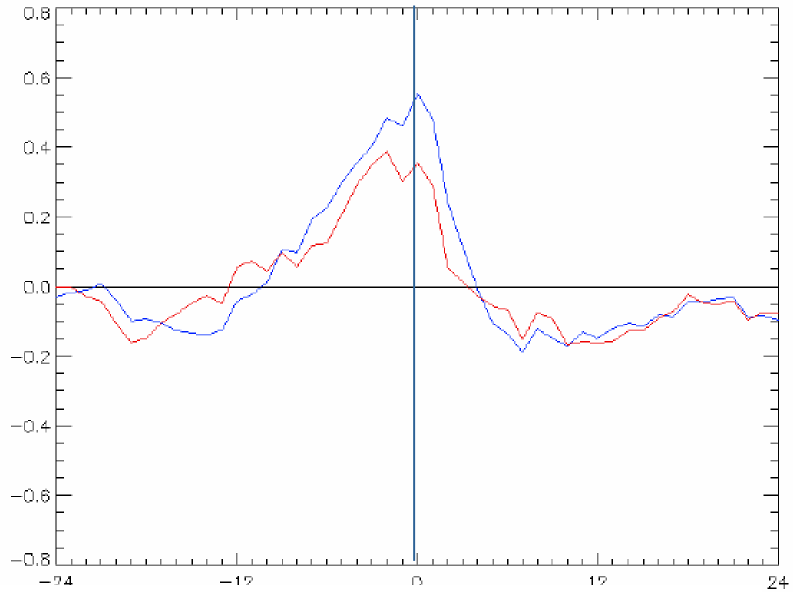
Figure 10 Percentage of individual temperature and salinity profiles with barrier layers thicker than 10m (stars), 20m (triangles), and 30m (diamonds), as computed from PEODAS reanalysis within 5° longitude zonal boxes for the 2°S to 2°N region during the period 1980-2007.

Duong 2010


Equitorial Barrier Layer Thickness (m) Full Assim.
01 Dec 2007
08 Dec 2005
17 Dec 2003
24 Dec 2001
01 Jan 2000
140
160
180
200
220
240
260
LONGITUDE
0.00
15.0
30.0
45.0
60.0
75.0

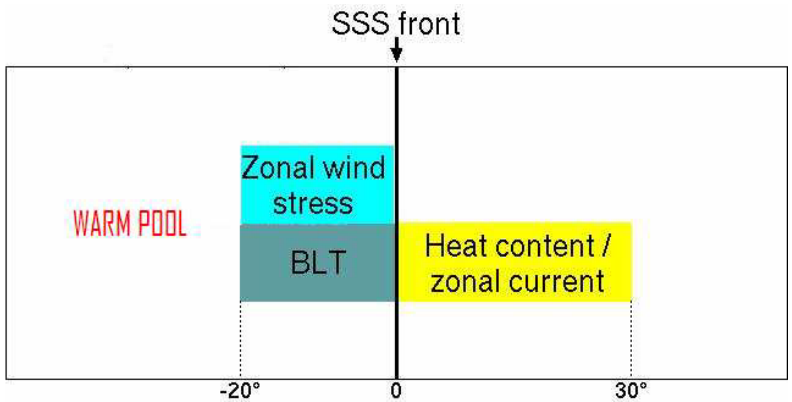
Lag correlation

zonal wind stress (~145-165E) with 0-45m zonal current (165E-165W) PEODAS 1982-2009



24 -12 month +12 24

d corr
zonal wind stress anomalies and mean 0-45m depth zonal current anoma
boxes are those previously defined (see Fig.24).

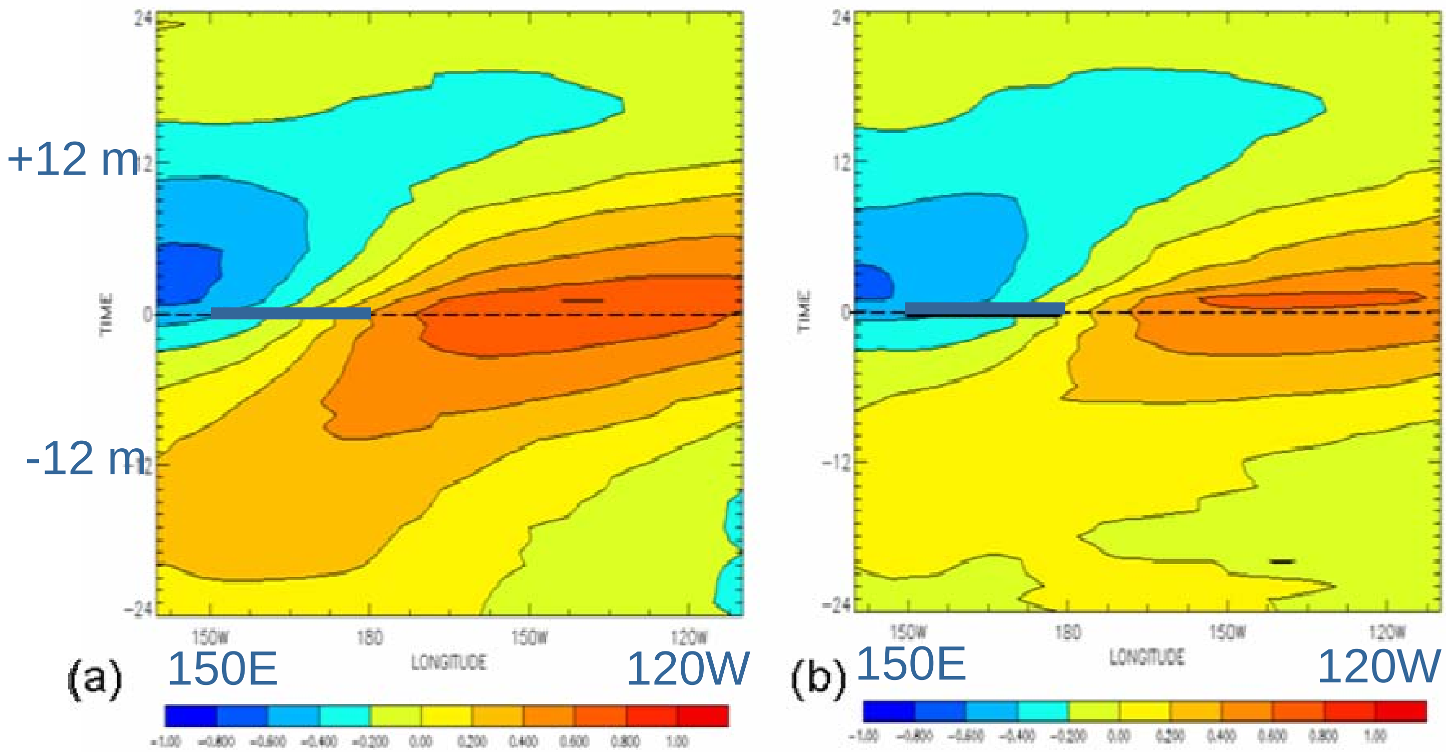


Barrier layer is associated with stronger remote response to localized forcing in warm pool

Blue: correlation wind stress with current

Red: partial correlation wind stress with current holding BLT fixed

Lag Correlation heat content with zonal wind stress in west Pacific box. PEODAS analysis 1982-2008

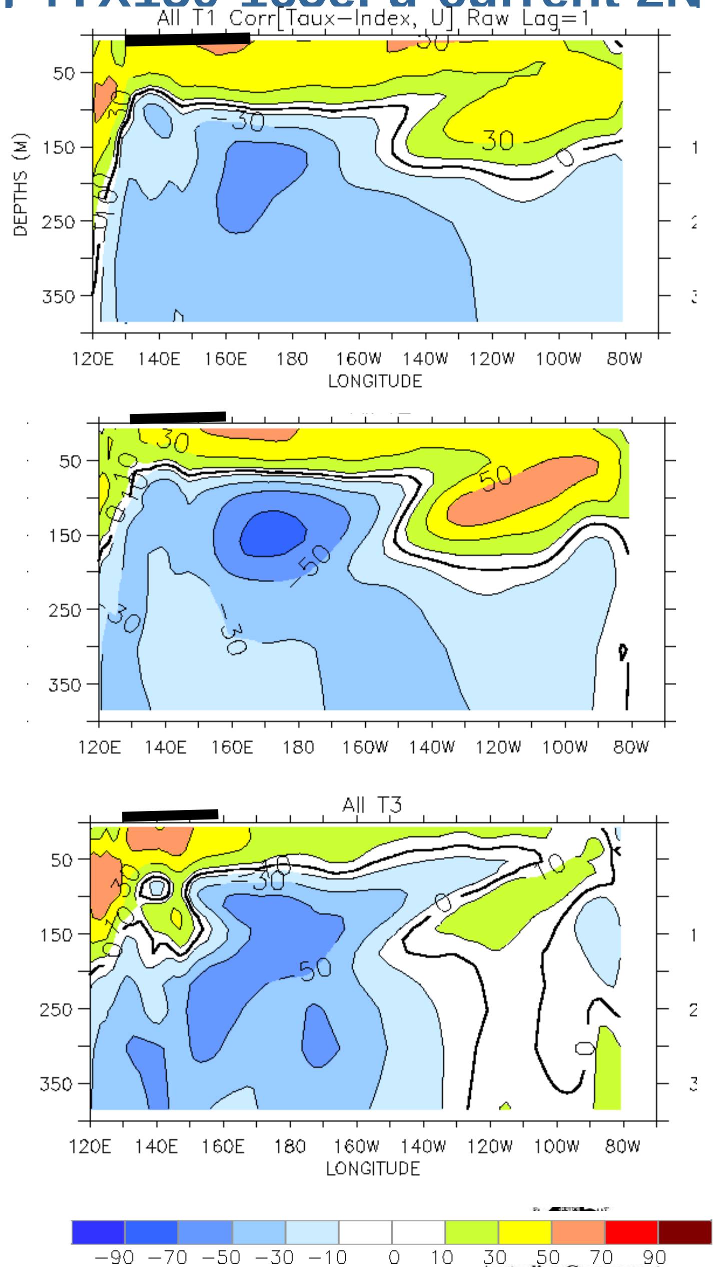


Left: lag correlation zonal wind stress with heat content.

Right: partial wrt BLT

correlation [TX150-165e, u-current 2N-2S one-month lag]

How have barrier layer changes affected ENSO dynamics?



1960-1979

1980-1998

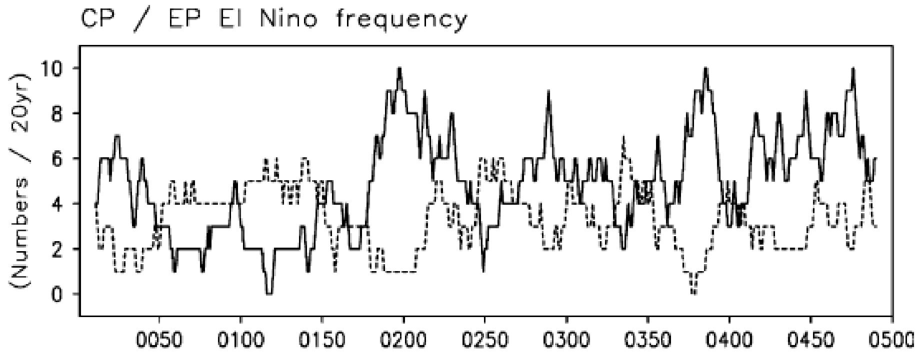
1999-2010

Reduced western Pacific barrier results in muted response further east to wind stress forcing in west, and localized deeper response in west

How else do mean state changes affect ENSO behaviour?

Model results from GFDL: Choi et al 2012

Fig. 2 Twenty-year sliding frequency of CP El Niño (*solid line*) and EP El Niño (*dashed line*). 20-year sliding frequency is defined by counting each El Niño event during the 20-year period



La Niña-like mean state promotes CP El Niño

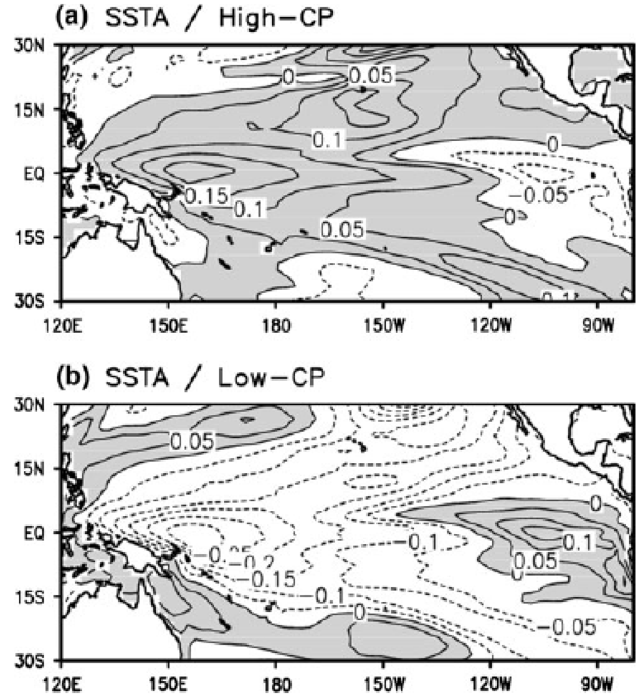
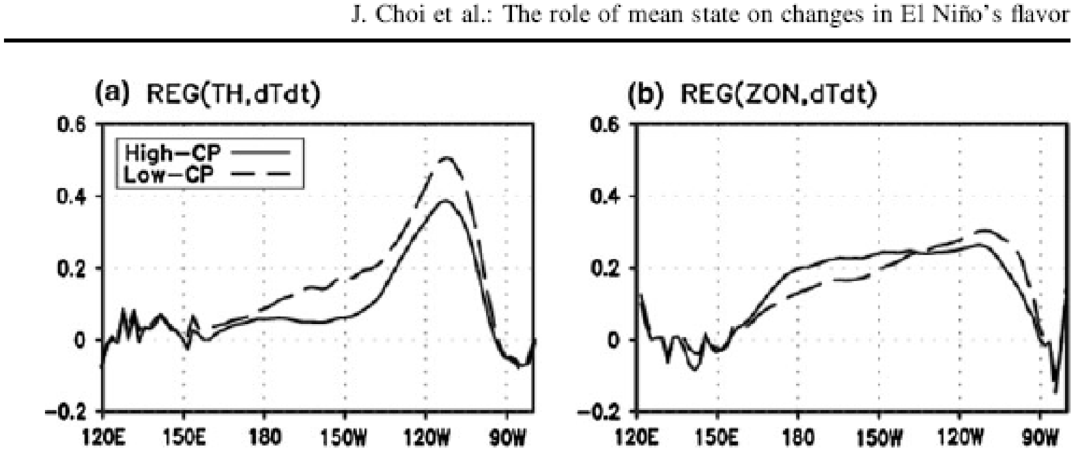


Fig. 3 Composite map of SST anomaly (°C) associated with a High-CP and **b** Low-CP periods

Mean state changes act to shift coupling westward during high CP periods

GFDL CM2.1

thermocline feedback



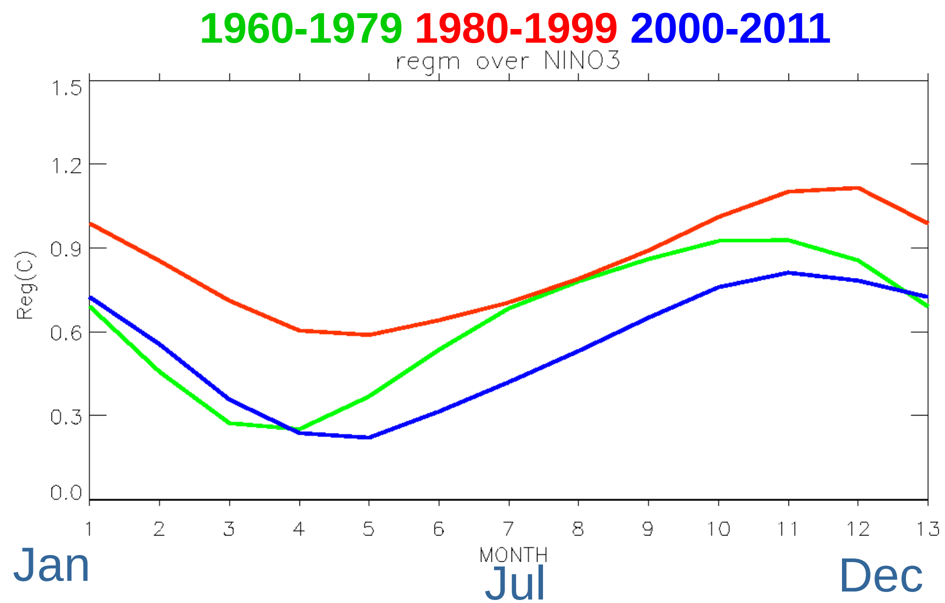
zonal advective feedback

What about observed behavior?

Infer thermocline feedback by regression of Nino3 SST onto thermocline anomaly

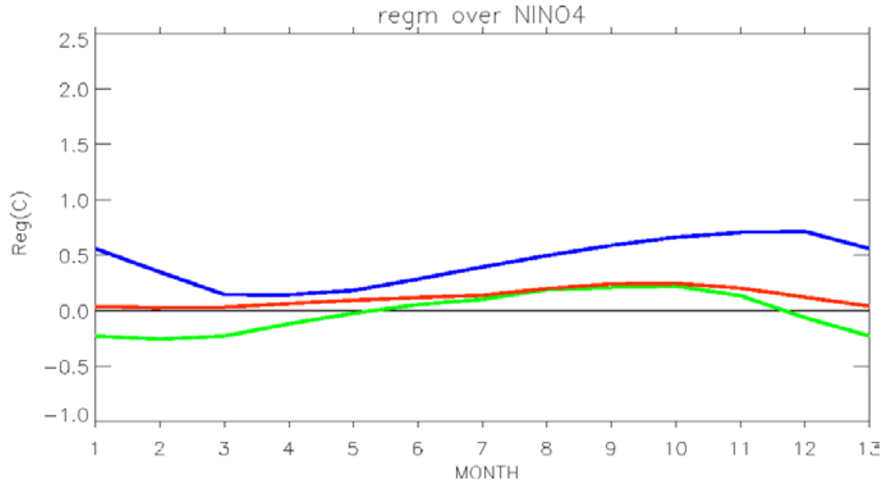
Nino3 SST/HC regression

units Nino3 C per stand HC



Recent period characterised by reduced sensitivity of Nino3 SST to thermocline changes, consistent with Choi et al 2012, Xiang et al. 2012

NINO4 region



Nino4/HC regression

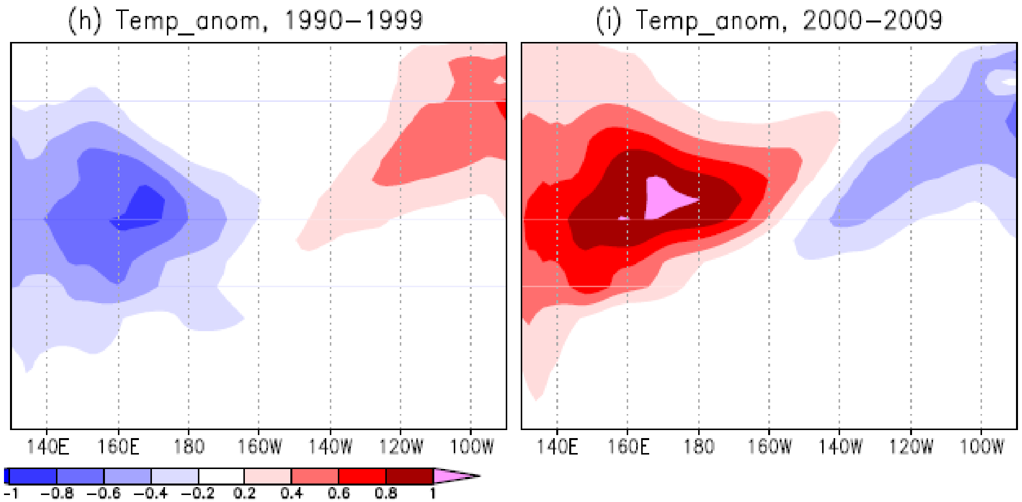
1960-1979
1980-1999
2000-2011

Opposite has occurred further west, thus implying that coupling has shifted west in recent period.

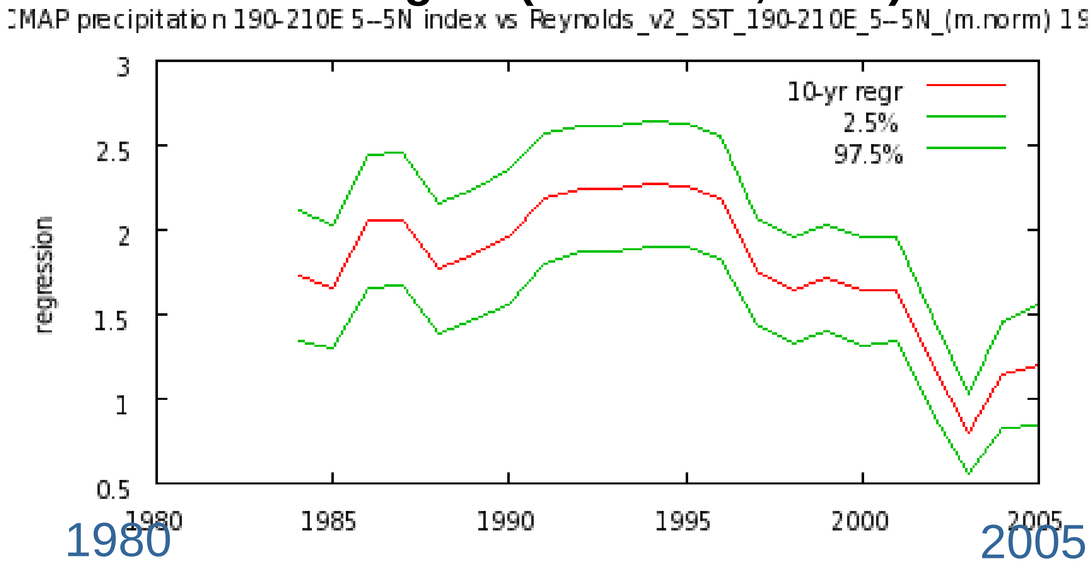
Conundrum: *periods of weak EP El Niño are periods with elevated thermocline in east but have reduced thermocline feedback*:

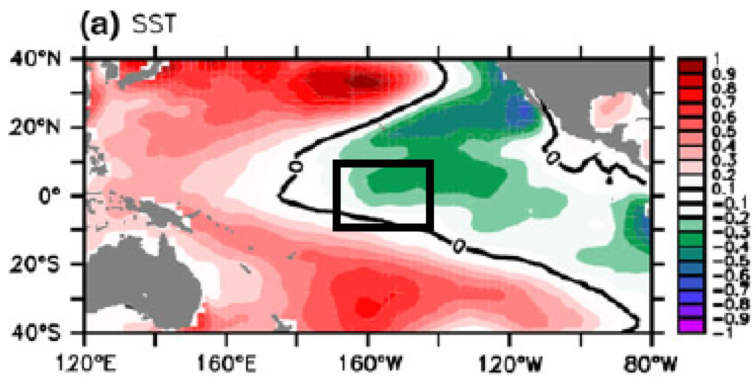
Choi et al argue cold SST in central Pac reduces SST/convective sensitivity (ie local effect)

Xiang et al. argue reduced sensitivity due to increased mean divergence (.e., it's the anomalous SST gradient that matters not just the colder local SST)



Sliding regression of CMAP rainfall onto SST in key central Pacific region (170-150W, 5N-S)





Recent period exhibits much reduced sensitivity of rainfall to SST in central Pacific, consistent with Choi et al. 2012 and Xiang et al. 2012.

Conclusions

Recent mean-state changes have acted to reduce predictability of Cold Tongue (East Pac) El Niño

- Recharge-discharge at heart of ENSO prediction has weakened in recent decade
- Stems from reduced coupling in central Pacific
- Changes in barrier layer have reinforced the westward shift of coupling in recent period

Increased WP-El Niño has increased predictability of Australian summer monsoon rainfall

- simply a signal to noise problem

What about the future?

- Consensus that recent change is primarily internal decadal variability (?)
- Continued contraction of fresh pool and erosion of barrier layer in central Pac would continue to promote El Niño further west.
- Conversely, expansion of fresh pool would act to promote El Niño to the east
  - Prominent model biases in warm/fresh pool need to be addressed and to advance prediction capability