Weakened Interannual Variability in the Tropical Pacific Since 2000

Zeng-Zhen Hu[1]

(Arun Kumar[1], Hong-Li Ren[2,3], Hui Wang[1,4], Michelle L'Heureux[1], and Fei-Fei Jin[2])

(1) Climate Prediction Center, NCEP/NWS/NOAA, MD 20740, USA

(2) Department of Meteorology, the University of Hawaii, HI 96822, USA

(3) Laboratory for Climate Studies, NCC/CMA, Beijing 100081, China

(4) WYLE Science, Technology and Engineering Group, Virginia, USA

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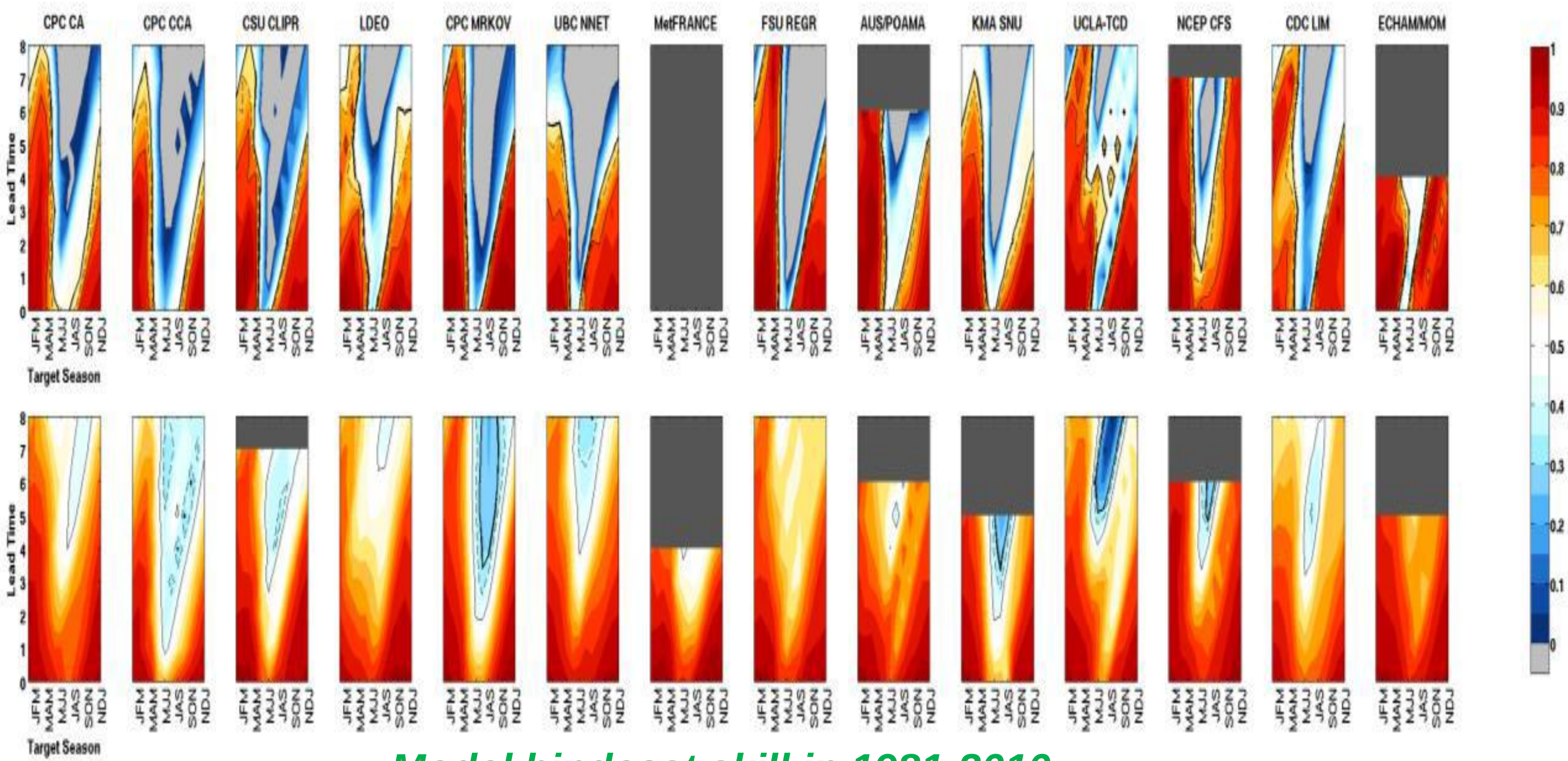
Have we been improving our ENSO prediction skills?

Compared with 1981-2011, ENSO prediction skill decreases in 2002-2011

Model real time prediction skill in 2002-2011



Model hindcast skill in 1981-2010

Temporal correlation between model forecasts and observations as a function of target season and lead time for (top) real-time forecasts and (bottom) hindcasts for the 1981-2010 period for models having long-term hindcasts. Thick solid contour shows the 90% significance level, dashed contour the 95% level, and thin solid contour the 99% level for sample sizes of 9 (top) and 30 (bottom). *(from Barnston, A. G., M. K. Tippett, M. L. L'Heureux, S. Li, and D. G. DeWitt, 2012: Skill of real-time seasonal ENSO model predictions during 2002-2011—Is our capability increasing? BAMS, 93 (5), 631-651.)*

Have we been improving our ENSO prediction skills?

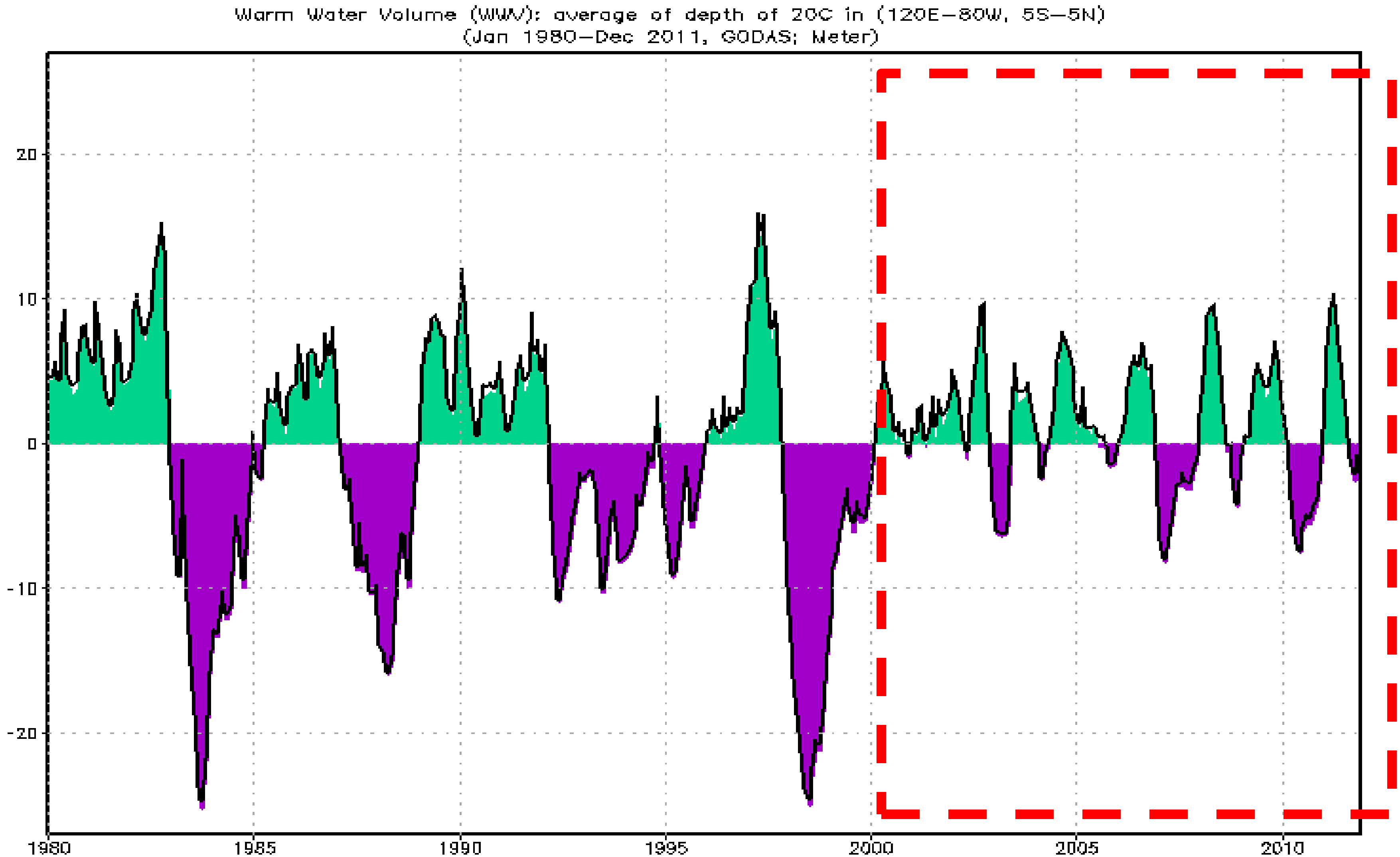
No!

Why?

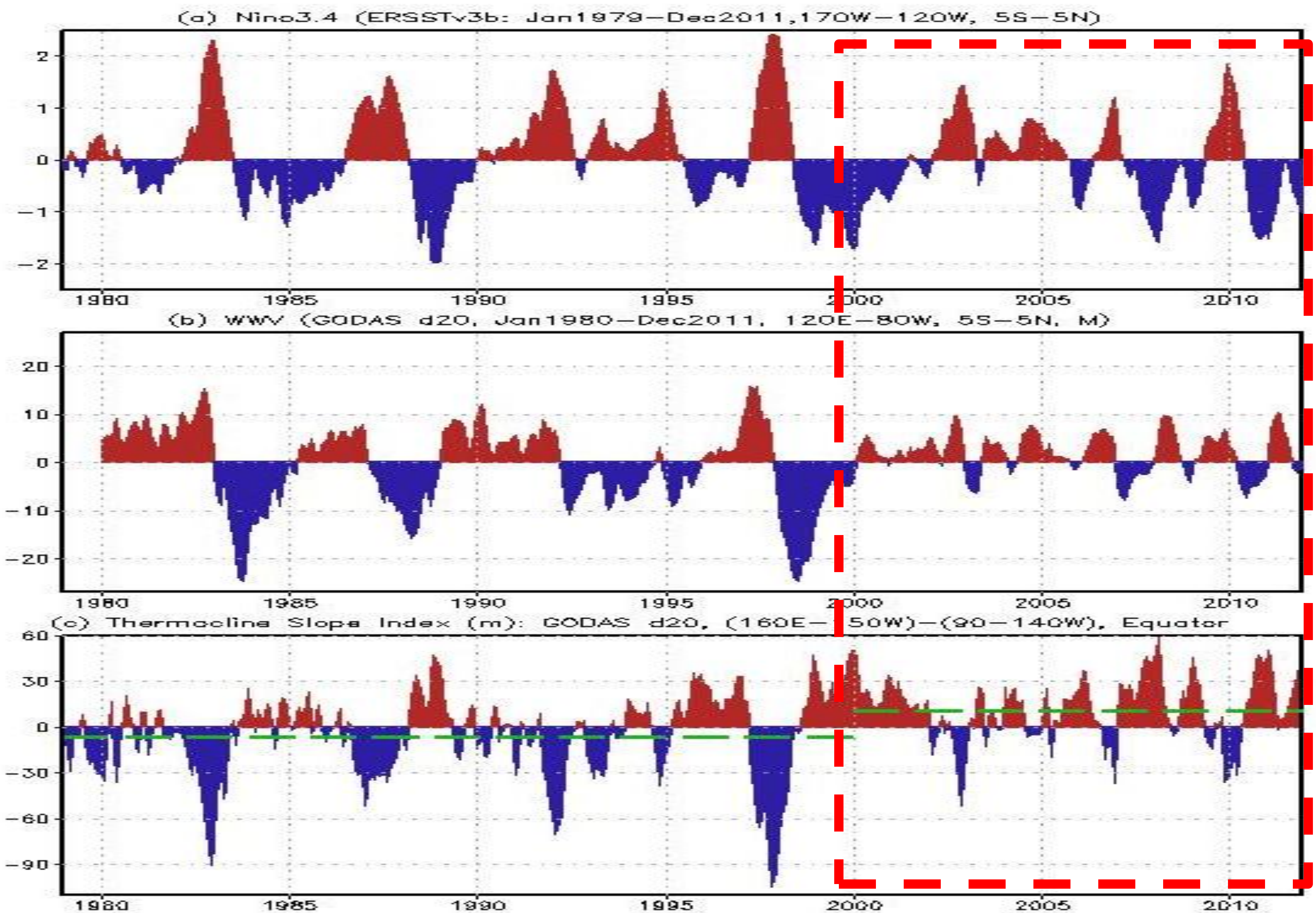
We know that the tools (models) have been improved or at least do not degrade, why the ENSO prediction skill decreased?

***It must be the ENSO features changed*.**

WWV variability was much smaller since 2000



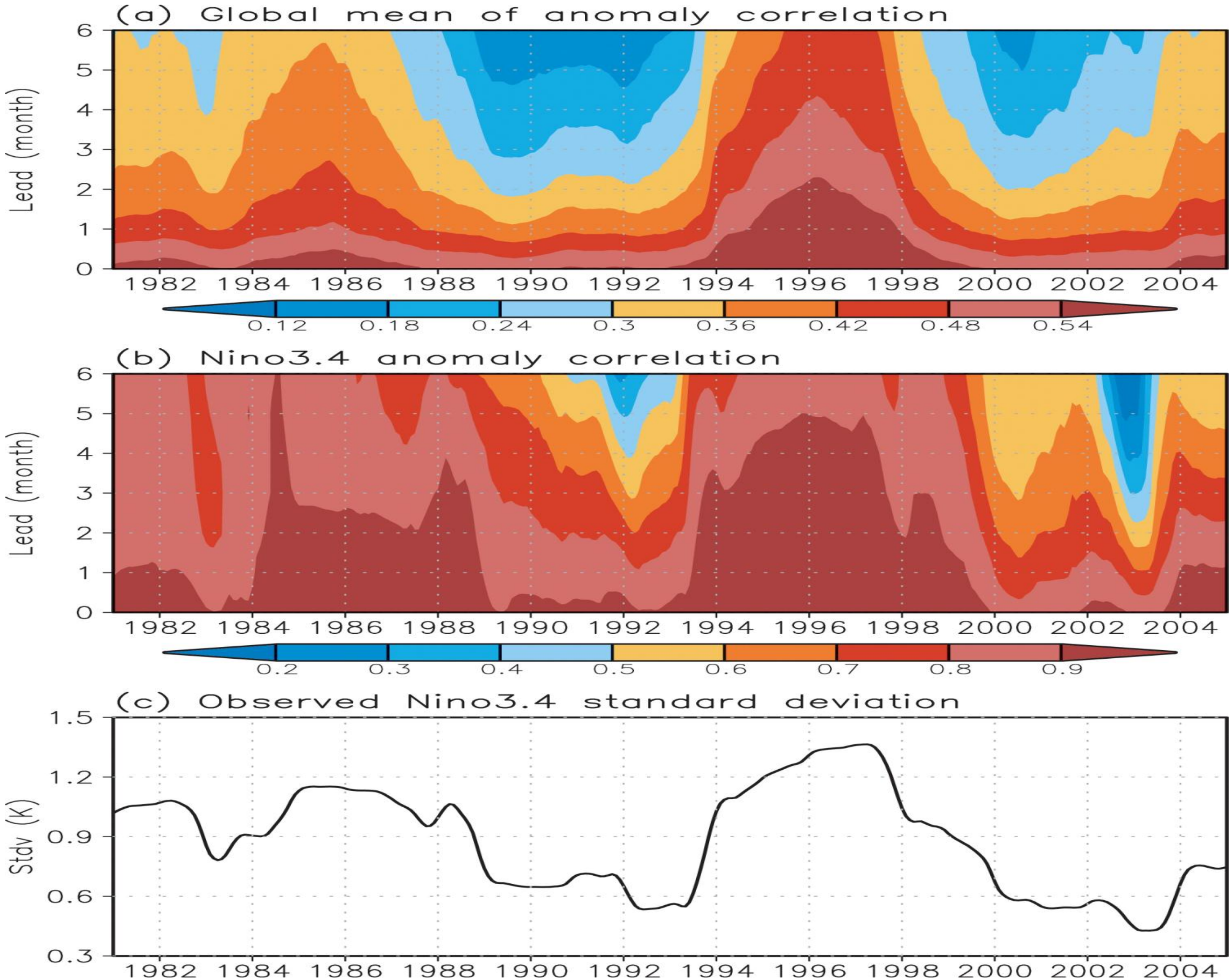
NINO3.4, WWV, thermocline slope variability suppressed since 2000



Variances in two periods and test

(Monte-Carlo test for 1,000 times of resampling time series)

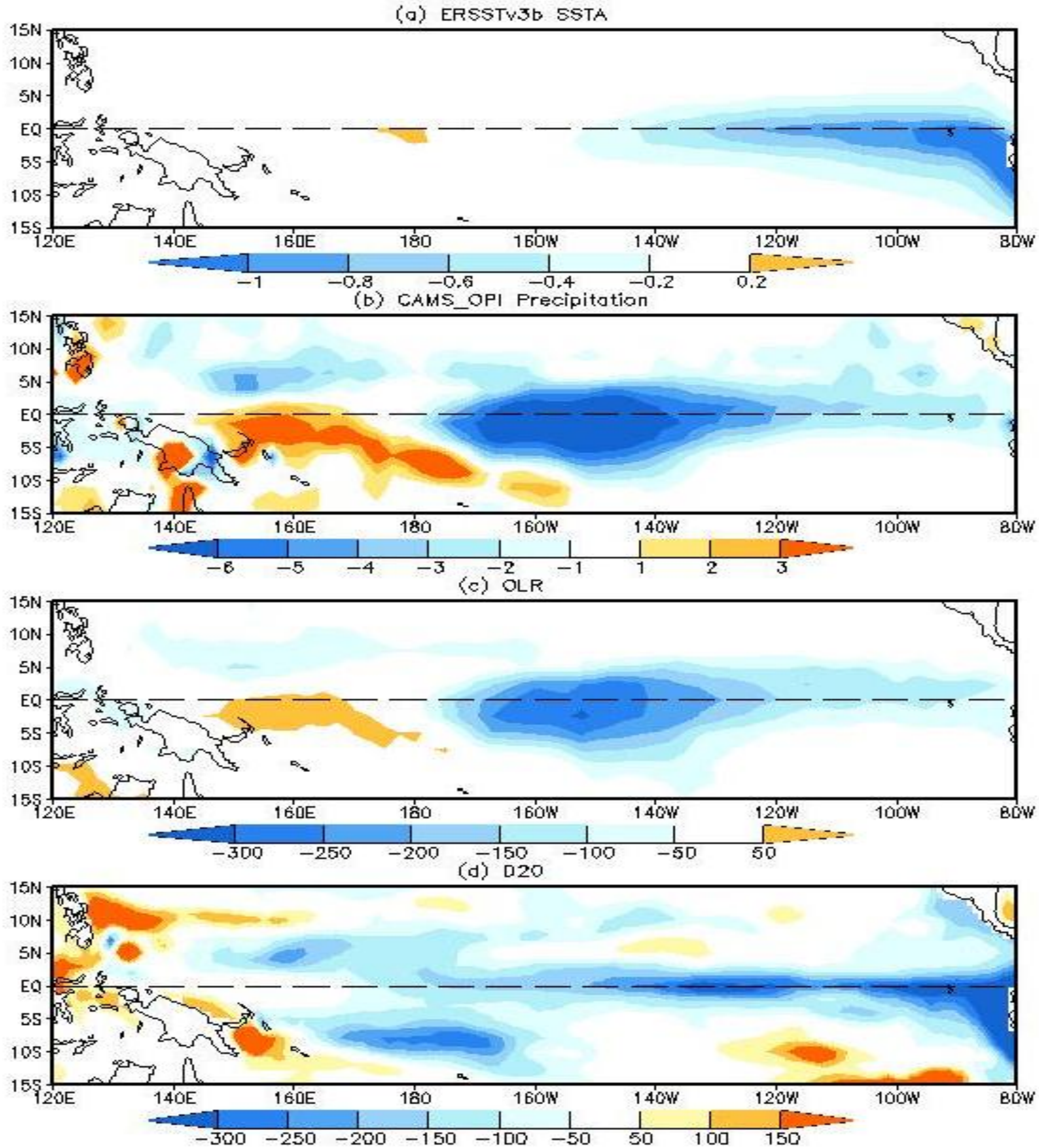
Indices	1979-1999 (1980-1999)	2000-2011	Differences (%)	Chance having larger than or equal to the observed absolute variance differences
Nino3.4	0.80	0.58	-0.22 ***(-28%)***	4.4%
WWV	73.0	17.2	-55.8 ***(-42%)***	0.0%
Thermocline slope	706	412	-294 ***(-76%)***	1.6%



Thus, the decrease of ENSO prediction skill since 2000 may be due to the fact that ENSO variability was reduced,

since larger anomaly is tied up with higher prediction skill.

(From: Wang, W., M. Chen, and A. Kumar, 2010: An assessment of the CFS real-time seasonal forecasts. *Wea. Forecasting*, **25**, 950-969.)



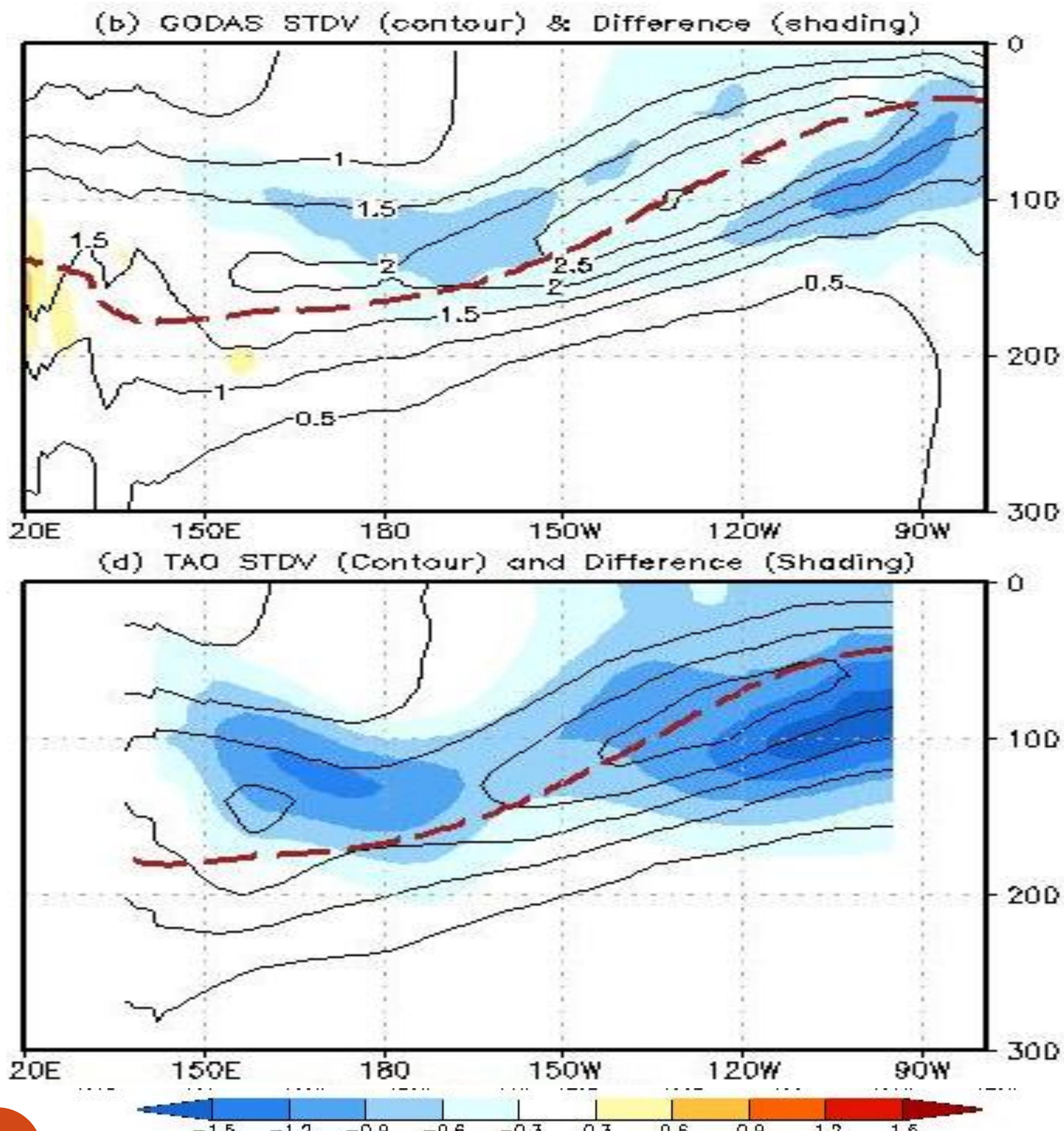
SST, prate, OLR, surface wind stress variance differences: <2000-2011>-<1979-1999>

Suppressed variability:

(a) SSTA in the eastern;

(b) Precipitation, and deep convection in the central-eastern tropical Pacific;

© D20 along equatorial central and eastern Pacific, and around 5°N/S in the western Pacific.



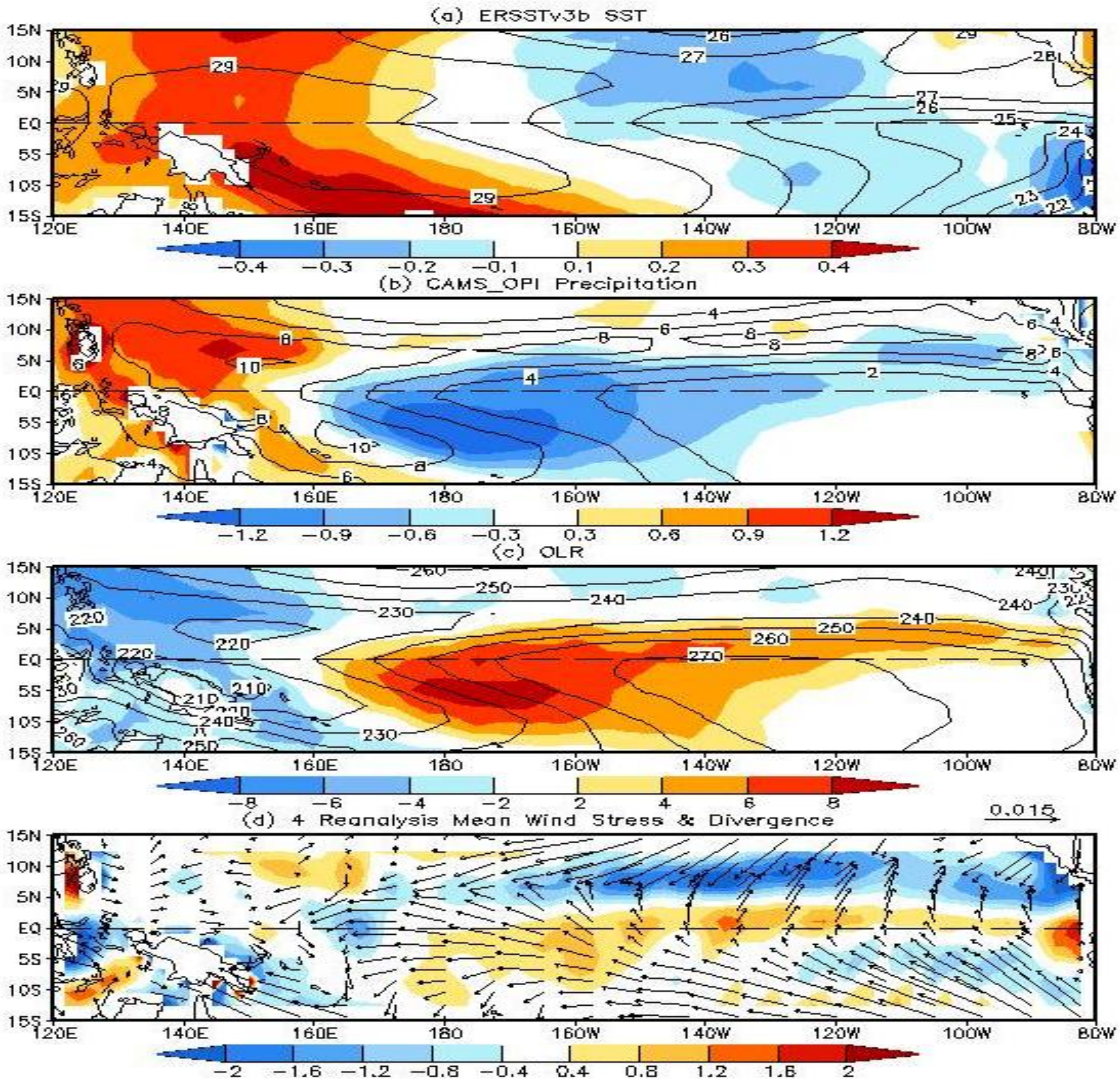
Standard deviation: mean (contour) and long-term difference (shading) for GODAS (top) & TAO (bottom)

Variability: Suppressed trend along the thermocline during 1979-2011 in GODAS and 1993-2011 in TAO.

We saw a coherent decrease of variability of SST, WWV, thermocline slope, OLR, and precipitation in the tropical Pacific.

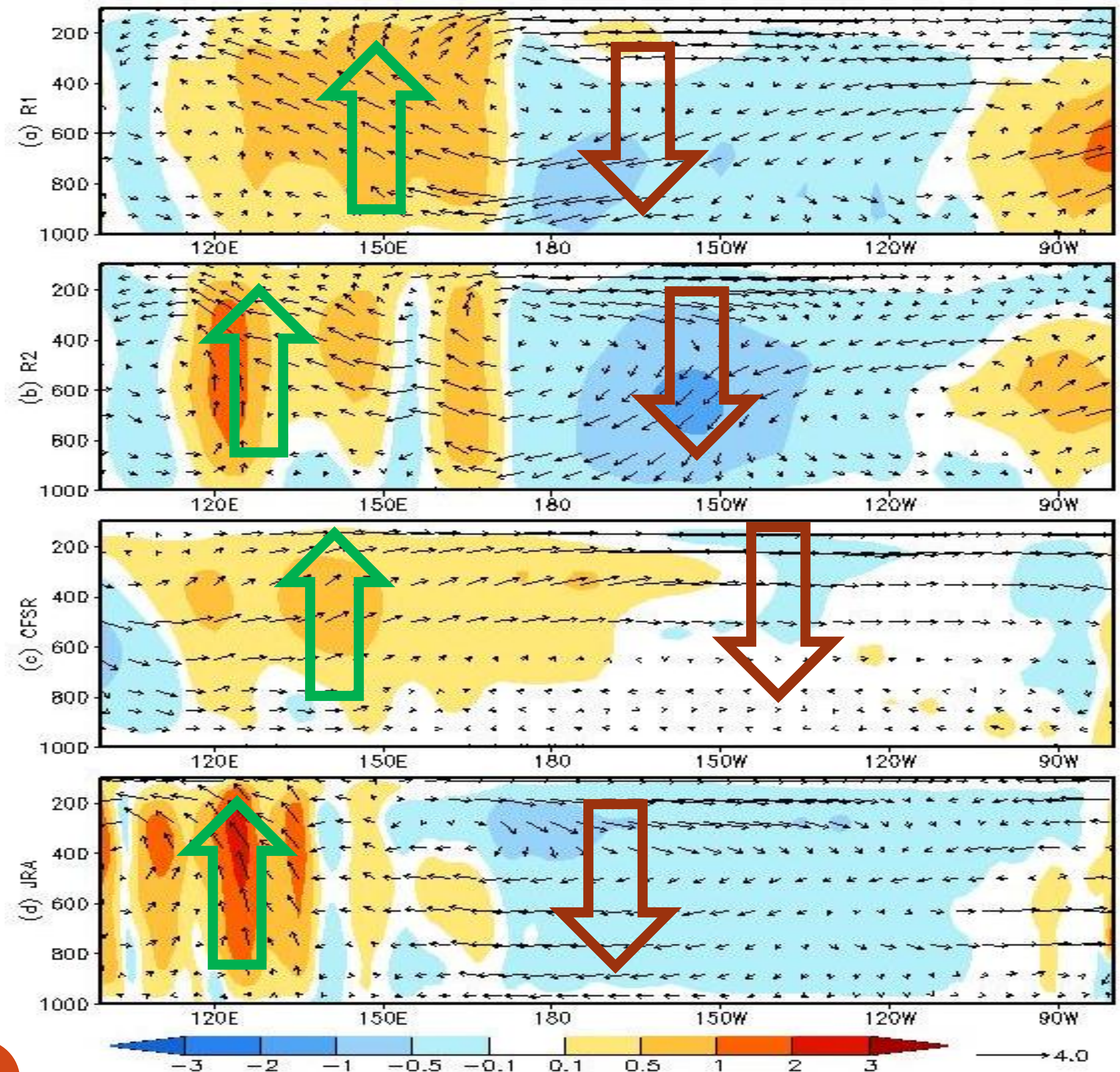
What cause the variance decrease?

It must be the mean state changes.



SSTA, prate, OLR, surface wind stress/divergence changes: <2000-2011>-<1979-1999>

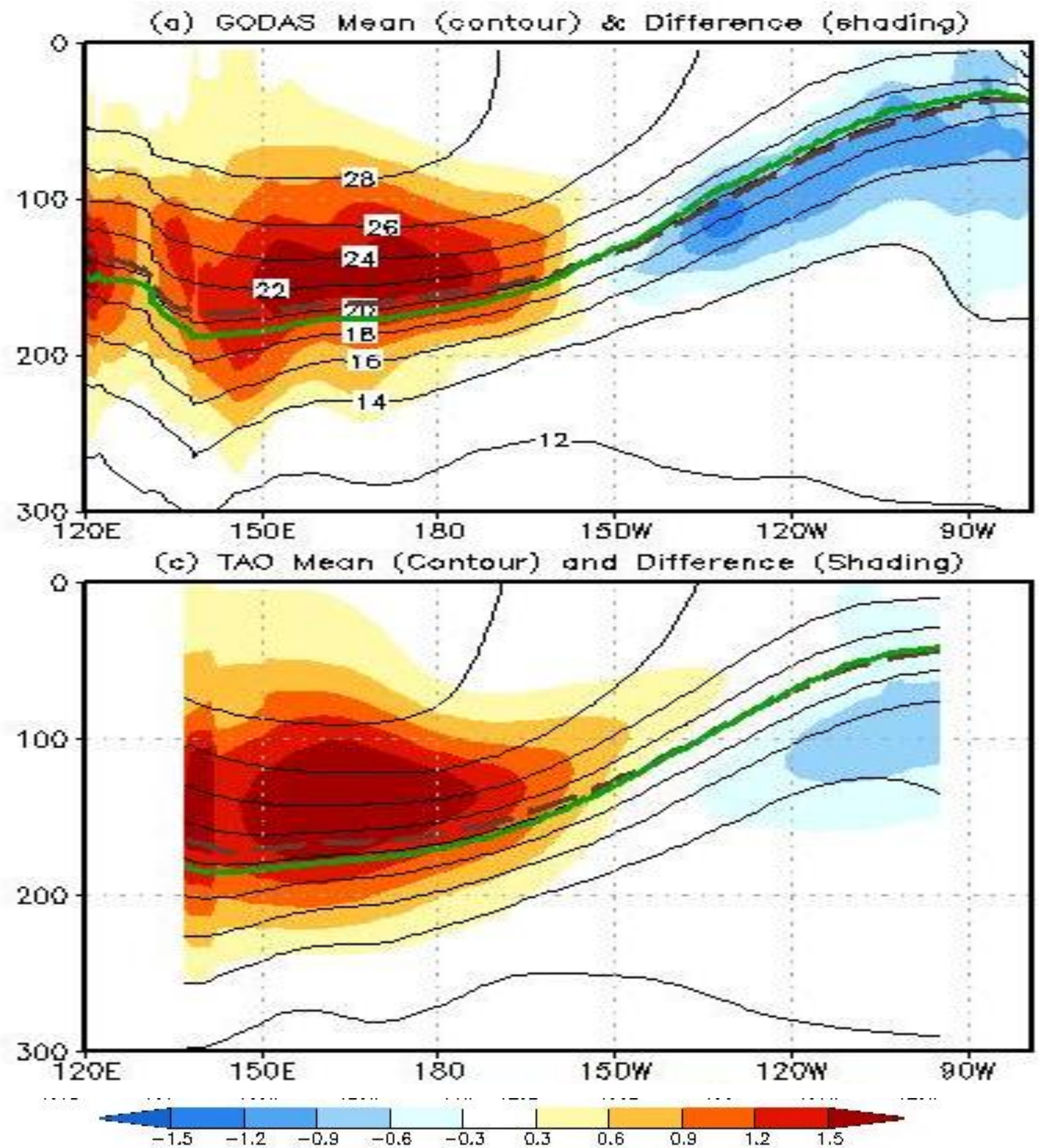
Intensified (suppressed) precipitation and deep convection in the western (eastern) tropical Pacific, consisting with the intensified trade winds and zonal SST gradient, as well as thermocline tilt



Walker circulation and W changes: <2000-2011>-<1979-1999>

Walker cell strengthened since 2000

Overall, the Walker circulation tendency is consistent among the different reanalyses



Mean: mean (contour) and long-term difference (shading) for GODAS (top) & TAO (bottom)

Mean state:
Sharpening tendency of the thermocline tilt in both GODAS (1979-2011) and TAO (1993-2011) (see dark lines in <a, b>)

Variance decreased:

We saw a coherent decrease of variability of SST, WWV, thermocline slope, OLR, and precipitation in the tropical Pacific.

The mean states also shanged:

SST warming in the western and cooling in the eastern Pacific;
Convection and precipitation enhanced (suppressed) in the west (east);
Wind stress became stronger;
Walker circulation was strengthened;
and thermocline slope was sharpened.

We hypothesize that the mean state changes cause the variance decrease.

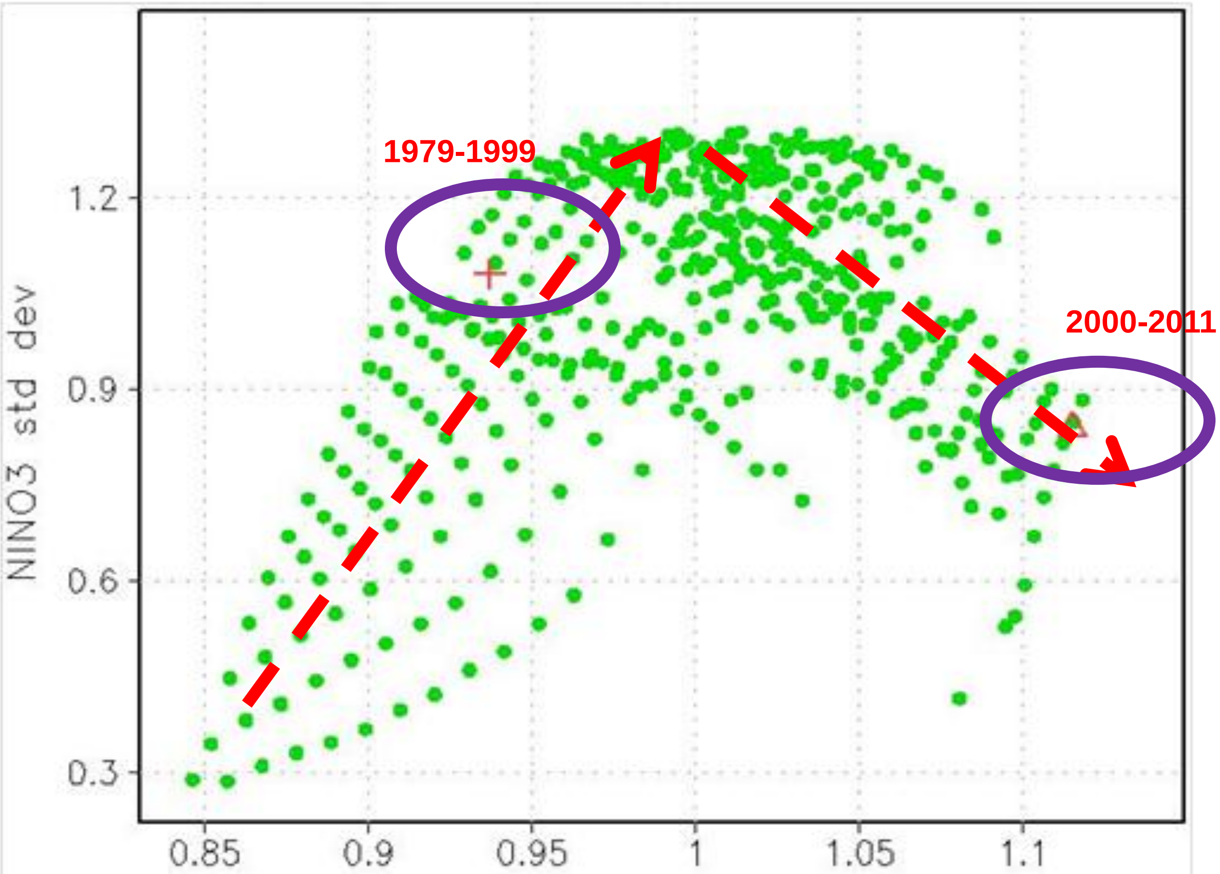
Zebiak and Cane Model Verification

The Zebiak and Cane Model (ZCM) was integrated with the different mean states which are generated by perturbing the model parameters (S and H, which represent effects of wind stress and thermocline depth), following the approach of Bejarano and Jin (2008).

Using these mean states, integrate the model for each parameter pair of S and H which corresponds to a certain thermocline slope. **Totally, 451 runs (41S x 11H) of 500 yrs were conducted.**

Following figure collects all of results of these runs. Y-axis is 500yr-averaged relative Nino3 index standard deviation and X-axis is relative thermocline slope. Thermocline slope is defined simply by the slope of equatorial thermocline depth at [125˚E, 85˚W]. Each dot is for one run.

Relative NINO3 standard deviation and relative thermocline slope ratio in the model simulations and in observations. Plus mark (1.08 0.937) is the observed mean in 1979-1999 ; triangle (0.84, 1.115) is the observed mean in 2000-2011



Relative thermocline slope

Dependence of Nino3 SST variance on the thermocline slope (wind stress)

With thermocline slope increasing, the ENSO variance becomes enhanced first and then weakened after the peak,

supporting the hypothesis that too large or too small thermocline slope (too strong or too weak wind stress) suppresses the ENSO variability.

The ZCM was integrated with the different mean states which are generated by perturbing the model parameters (S and H, which represent effects of wind stress and thermocline depth), following the approach of Bejarano and Jin (2008). Using these mean states, integrate the model for each parameter pair of S and H which corresponds to a certain thermocline slope. Totally, 451 runs (41S x 11H) of 500 yrs were conducted. This figure collects all of results of these runs. Y-axis (X-axis) is 500yr-averaged relative Nino3 index standard deviation (relative thermocline slope). Thermocline slope is defined simply by the slope of equatorial thermocline depth at [125˚E, 85˚W]. Each dot is for one run.

Seesaw and Oscillation

Variance decreased:

We saw a coherent decrease of variability of SST, WWV, thermocline slope, OLR, and precipitation in the tropical Pacific.

The mean states also changed:

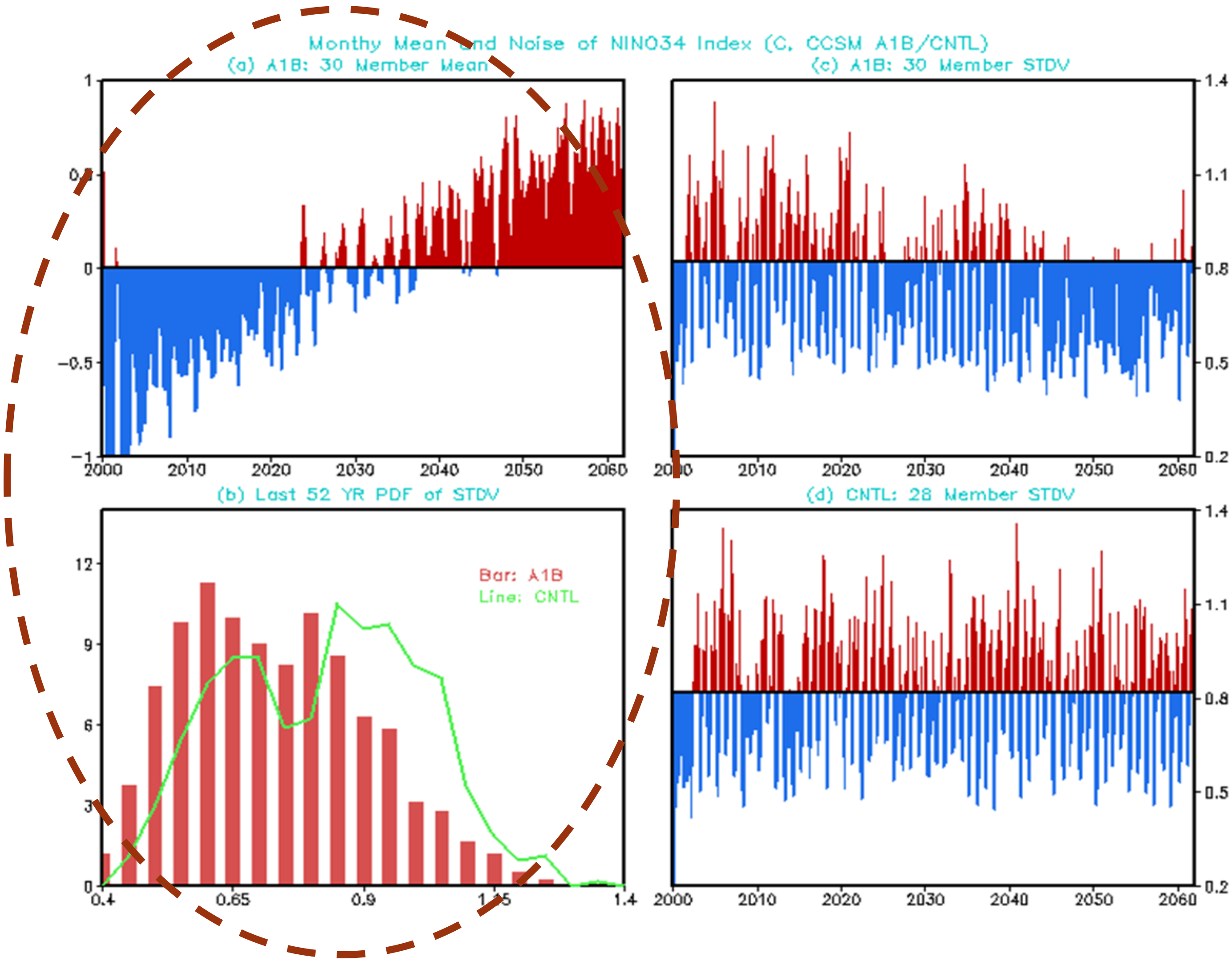
SST warming in the western and cooling in the eastern Pacific;
Convection and precipitation enhanced (suppressed) in the west (east);
Wind stress became stronger;
Walker circulation was strengthened;
and thermocline slope was sharpened.

We hypothesize that the mean state changes caused the variance decrease.

Both too large/small thermocline slope and too strong/weak wind stress do not favor large ENSO variability.

What cause the mean state changes?
Are they nature variability or human activity forced change?

Response of ENSO in CCSM3: Mean state and variability changes

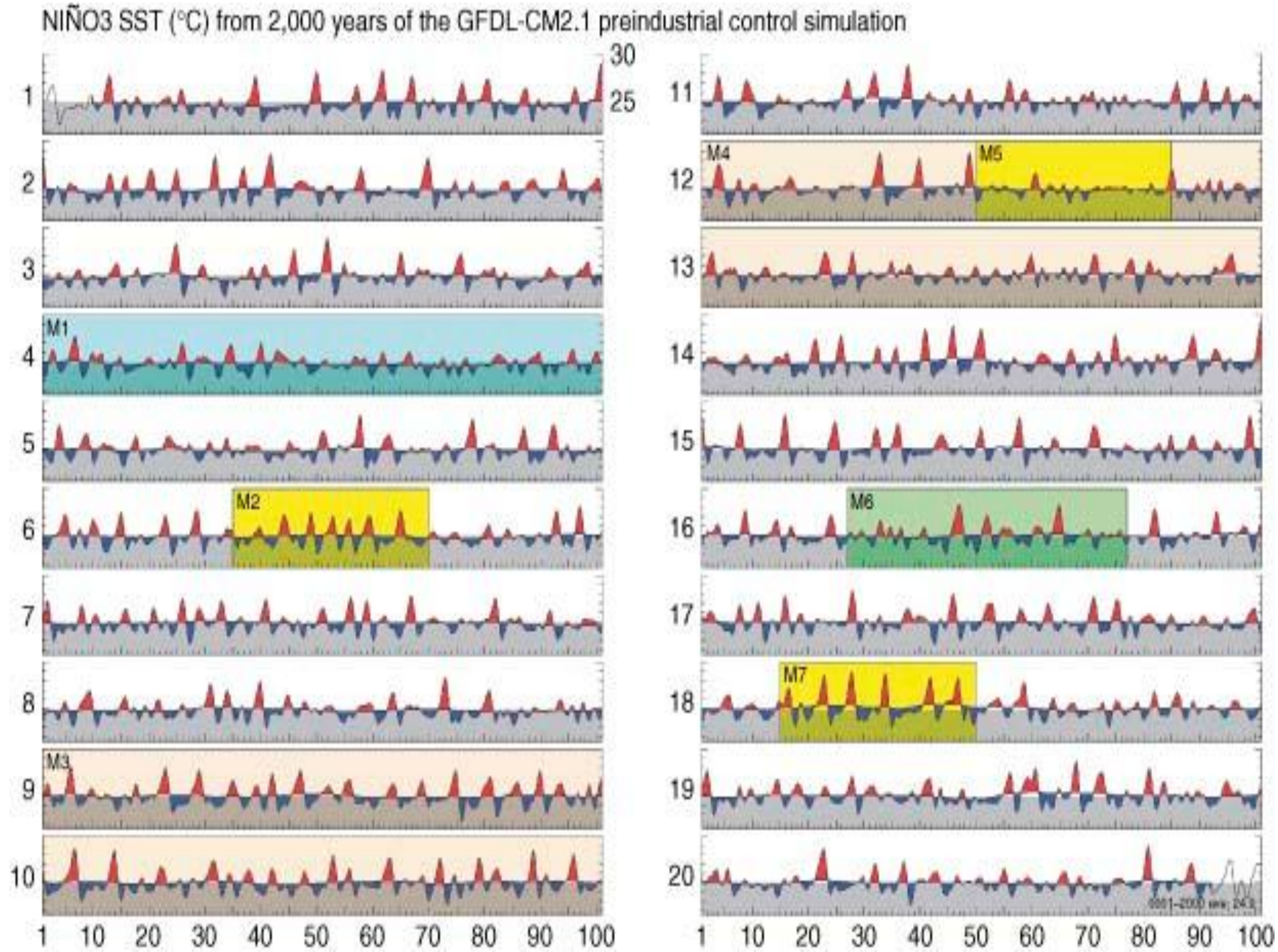


Significant warming trend in the tropical Pacific Ocean.

Suppression of internal variability of ENSO may be due to the increase of GHG concentrations

Hu, Z.-Z., A. Kumar, B. Jha, and B. Huang, 2012: An analysis of forced and internal variability in a warmer climate in CCSM3. *J. Climate*, **25 (7)**, 2356-2373.

Nature variation may also cause the similar ENSO variability changes.

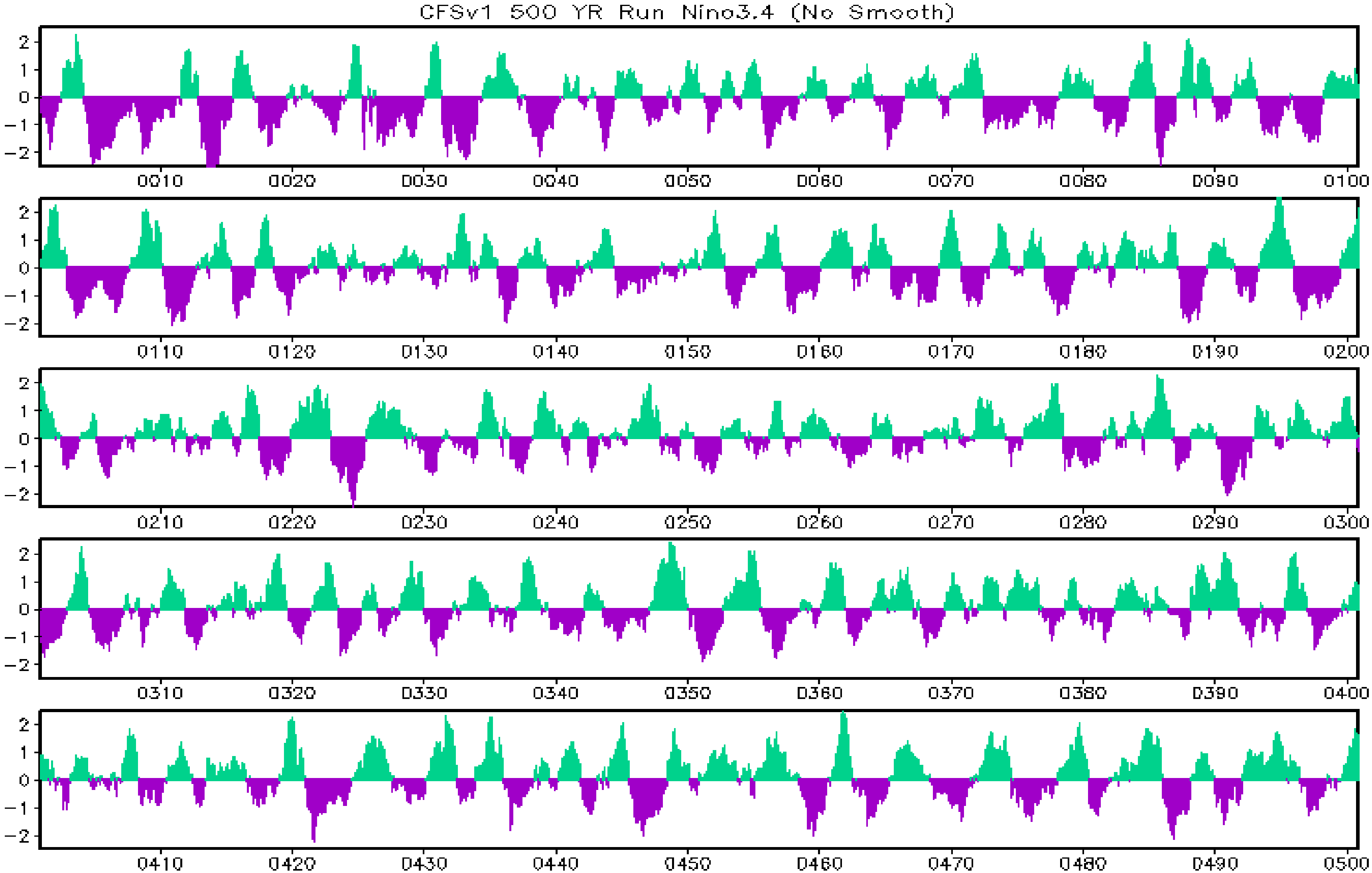


Nino3 SSTA in 2,000 year GFDL CM2.1 pre-industrial control run.

Wittenberg, A. T., 2009: Are historical records sufficient to constrain ENSO simulations? *GRL.,* 36, L12702.

The results may depend on models

NINO3.4 Index: CFSv1 500 year free run (not clear interdecadal amplitude modulation)



Main Results:

Compared with 1979-1999, during 2000-2011:

(1) Variability suppressed:

NINO3.4, WWV, thermocline slope indices

SST, precipitation, OLR, D20 in the tropical central-eastern Pacific.

OTA variability along the thermocline in the equatorial Pacific

(2) Mean state changed:

SST warming in the west and cooling in the east

Convection intensified in the w. equatorial Pacific and suppressed in the central

Trade wind enhanced

Walker circulation strengthened

Thermocline tilt sharpened

(3) Hypothesis:

Both too large/small thermocline slope and too strong/weak wind stress may not favor large ENSO variability

The observed mean state changes during 2000-2011 may be due to natural or human forcings, or both.

More Information

Hu, Z.-Z., A. Kumar, H.-L. Ren, H. Wang, M. L'Heureux, and F.-F. Jin, 2012: Weakened interannual variability in the tropical Pacific Ocean since 2000. *J. Climate* (in press).

Comments or ask PDF files, send mail or e-mail to

Dr. Zeng-Zhen Hu

Climate Prediction Center

NCEP/NWS/NOAA

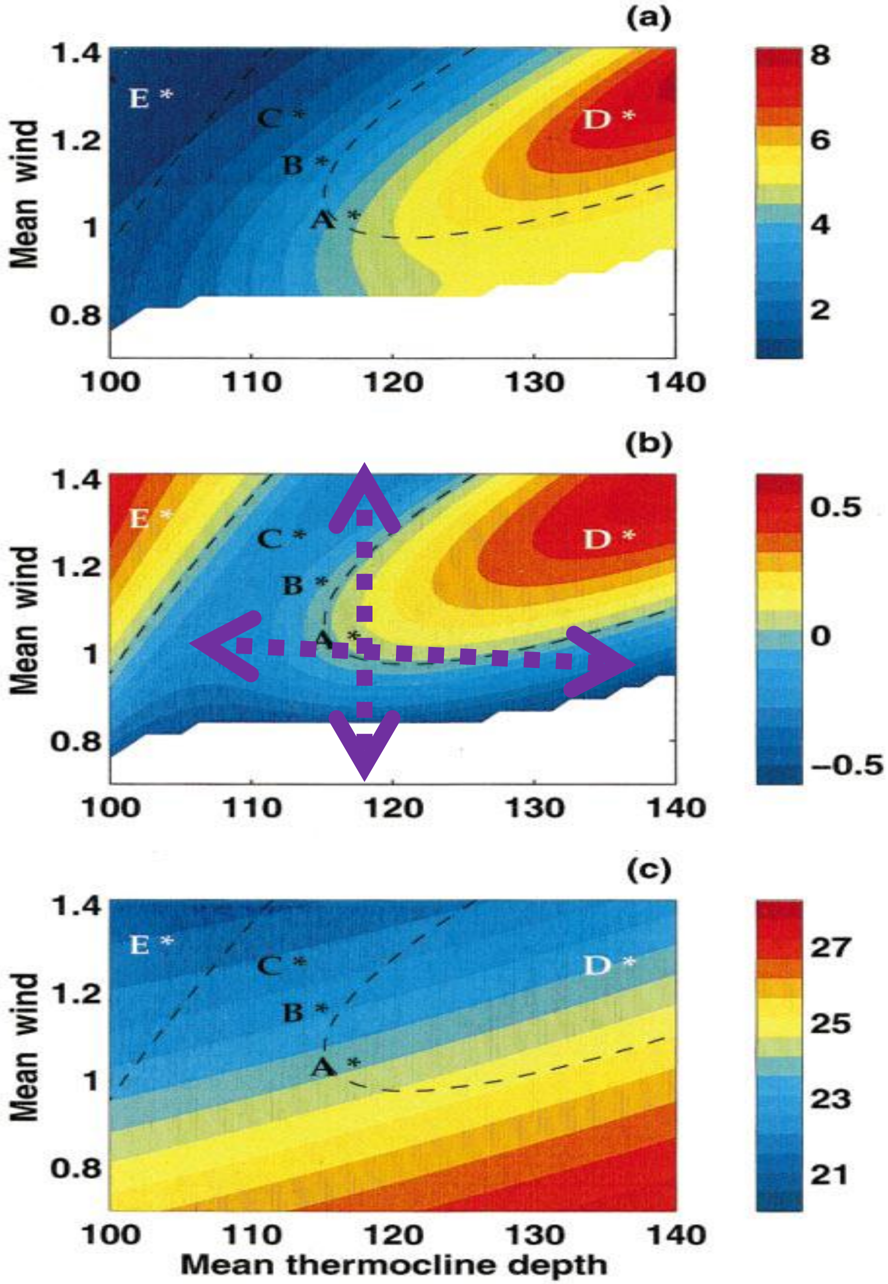
NOAA Center for Weather and Climate Prediction (#3130)

5830 University Research Court

College Park, Maryland 20740

Tel: +1-301-683-3441; Fax: 1-301-683-1557

Zeng-Zhen.Hu@NOAA.GOV

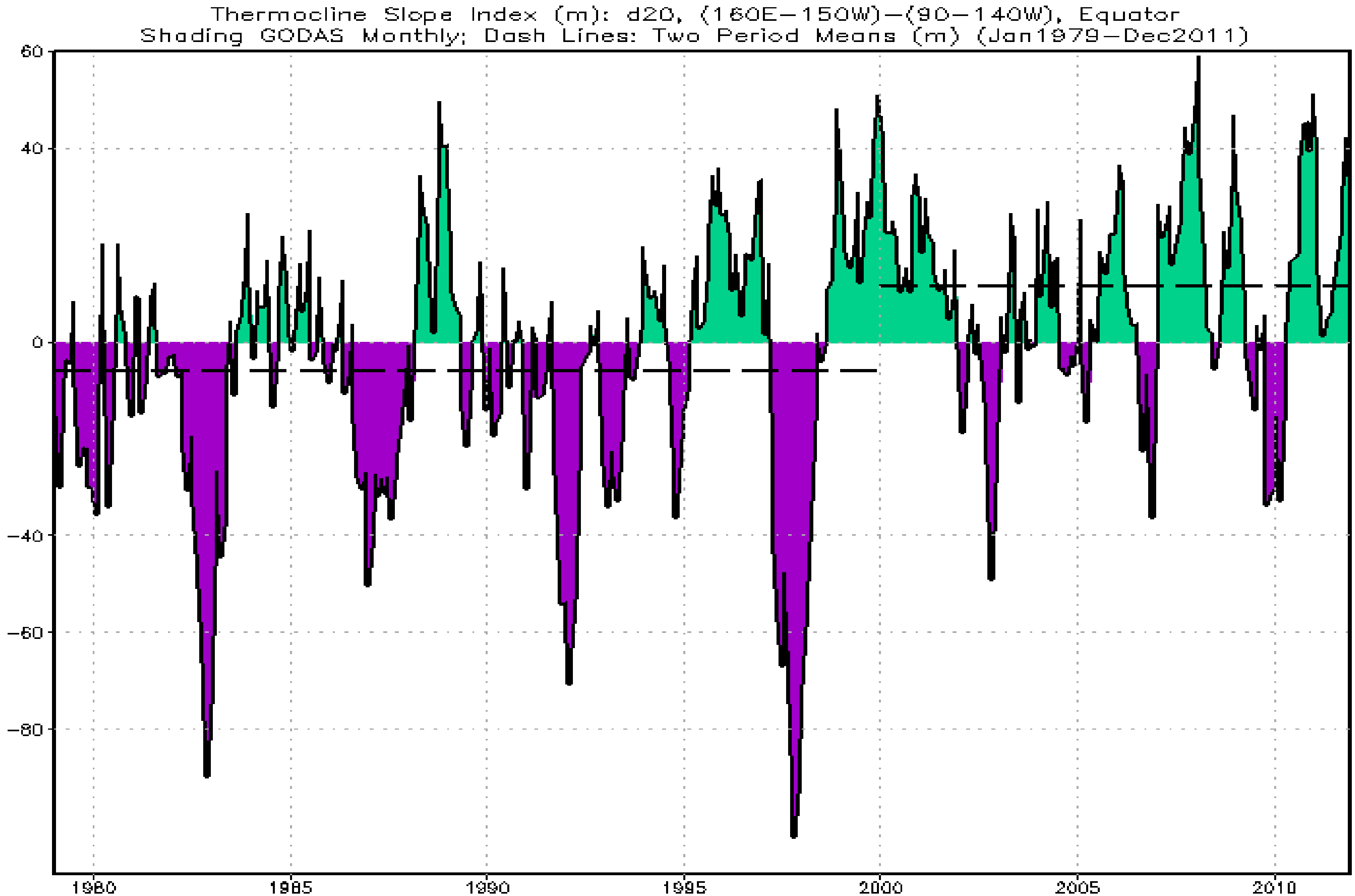


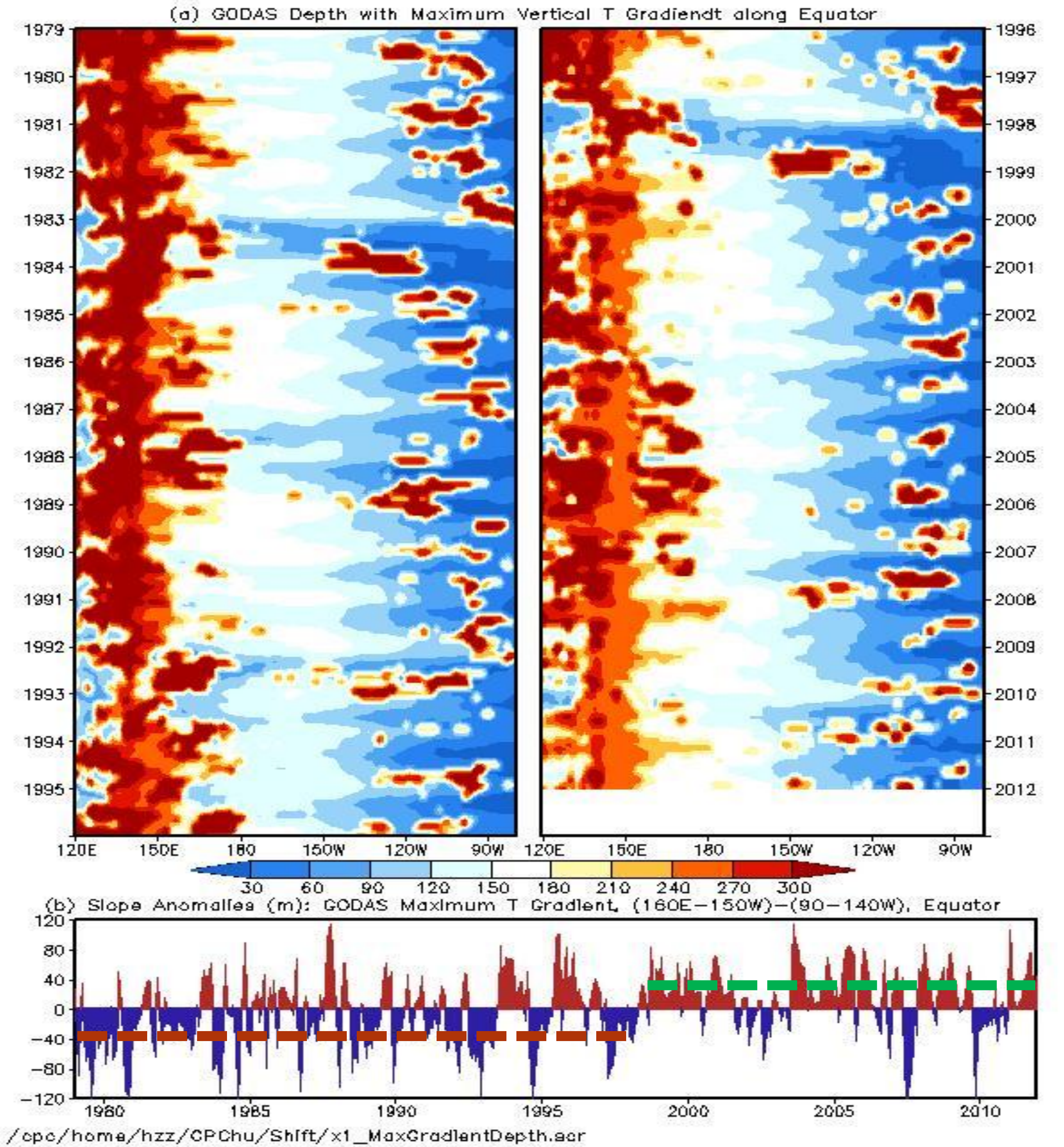
Both too strong and too weak wind stress and thermocline depth does not favor ENSO growth.

Fedorov & Philander, 2001:. J. Climate, 14, 3086-3101.

FIG. 4. Changes in (a) the period and (b) growth rates of the most unstable oscillations as a function of changes in the easterly winds along the equator (in the units of 0.5 dyn cm^{-2}), and in the depth of the equatorial thermocline (m). The value of DT measured over a 50-m depth variation is 78C. The dotted line corresponds to the line of zero growth rate; in the white area both amplifying and damped modes are absent. (c) The minimum SST (in 8C) of the basic state in the eastern Pacific Ocean.

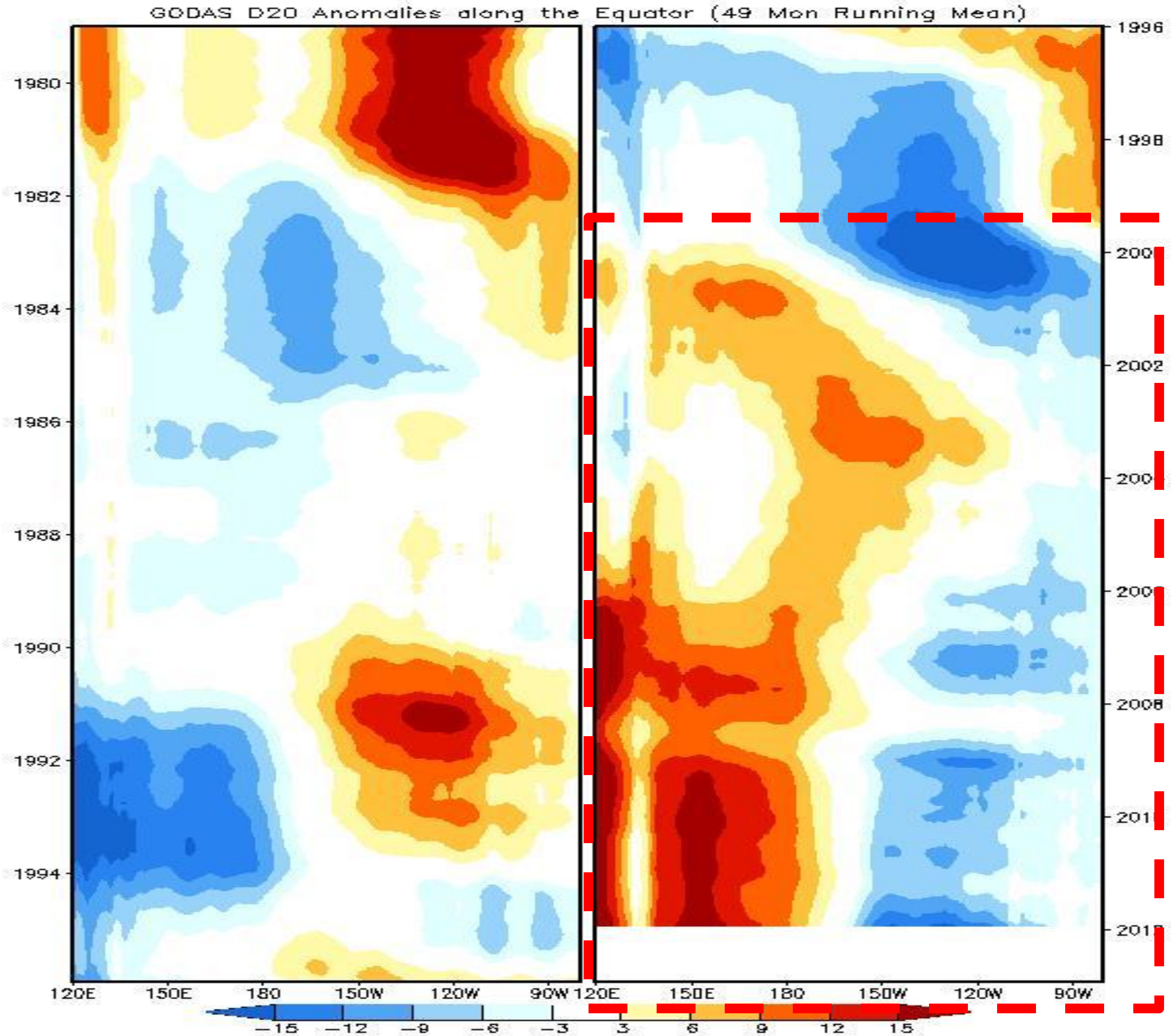
Sharpening trend of the thermocline tilt: Shifted from negative dominated in1979-1999 to positive dominated in 2000-2011



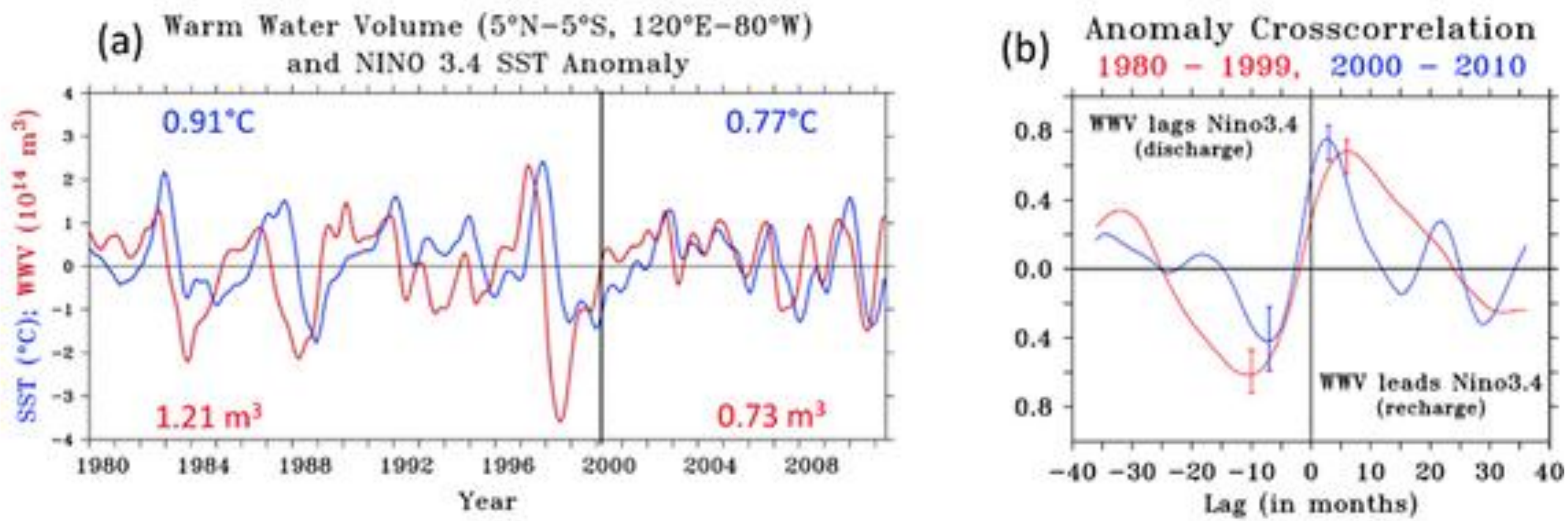


Sharpening trend of the thermocline tilt: Shifted from negative dominated in1979-1999 to positive dominated in 2000-2011

Results are similar using maximum vertical T gradient along the equator



It is a shift, instead of gradually increase

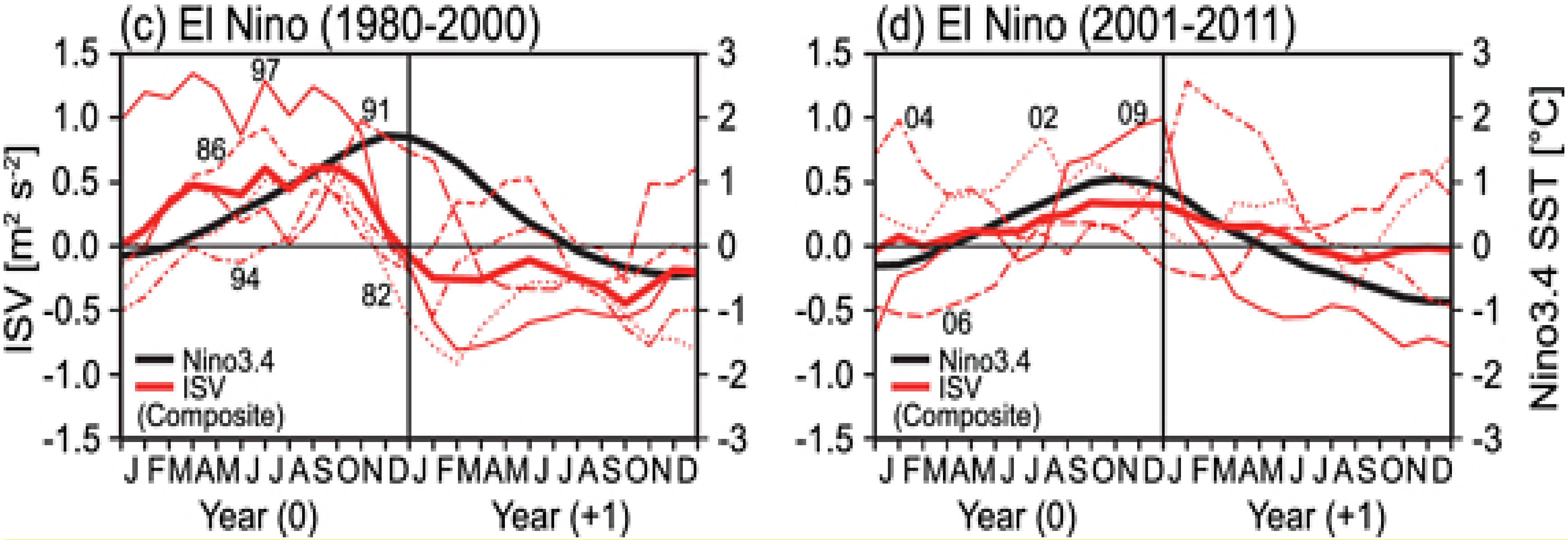


<u>Cross correlation of monthly WWV and NINO3.4 SST anomalies for 1980–99 (red) and 2000–2010 (blue).</u>

McPhaden (2012): WWV integrated along the equator leads ENSO SST anomalies by 2–3 seasons during the 1980s and 1990s. For the first decade of the 21st century however, WWV variations decreased and lead time was reduced to only one season, mainly due to the diminished persistence of WWV anomalies early in the calendar year. These changes are linked to a shift towards more central Pacific (CP) versus eastern Pacific (EP) El Niños in the past decade. The results are consistent with a reduced impact of thermocline feedbacks on ENSO SST development and potentially imply reduced seasonal time scale predictability during periods dominated by CP El Niños."

But, it is unclear what caused this change.

McPhaden, M. J., 2012: A 21st century shift in the relationship between ENSO SST and warm water volume anomalies. *Geophys. Res. Lett.*, 39, L09706, doi: 10.1029/2012GL051826.



(c) Composite time series of Niño-3.4 (bold black) and ISV (bold red) for five El Niño events during 1980–2000. The time axis is from January of the onset year (0) to December of the following year (+1). The thin red line shows the ISV in each year. (d) As in Figure 1c, but for four El Niño events during 2001–2011.
ISV: surface wind, 20-100 days, 5S-5N, 120E-180

Horii et al. (2012) said" During 1981–2000, the recharge (discharge) of the WWV and strong (weak) ISV forcing preceded El Niño (La Niña) by two to three seasons. However, in the 2000s, the interrelationship between the WWV/ISV and following ENSO became weak, especially for the El Niño/La Niña events after 2005."

But, it is also unclear what caused this change.

Horii, T., I. Ueki, and K. Hanawa, 2012: Breakdown of ENSO predictors in the 2000s: Decadal changes of recharge/discharge-SST phase relation and atmospheric intraseasonal forcing. Geophys. Res. Lett., 39, L10707, doi: 10.1029/2012GL051740.

Anomalous upward movement in C&W Pacific, and anomalous downward movement in C&E Pacific. That may prevent the subsurface warm water stored in the w Pacific propagating to E Pacific. That is consistent with the evidence of frequent occurrence of C Pacific El Nino in the recent decades.