Initialized decadal prediction for transition to positive phase of the Interdecadal Pacific Oscillation: What's the mechanism?

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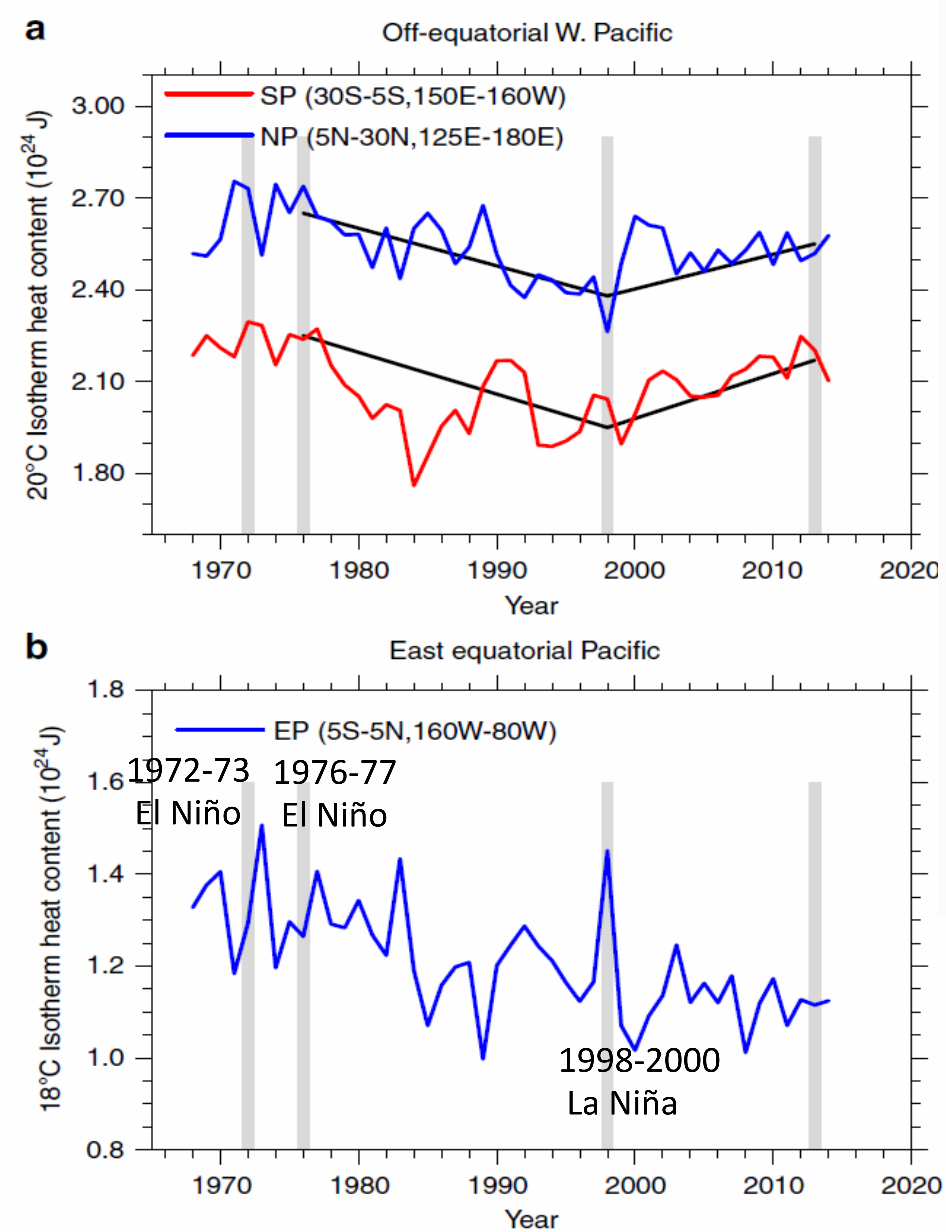
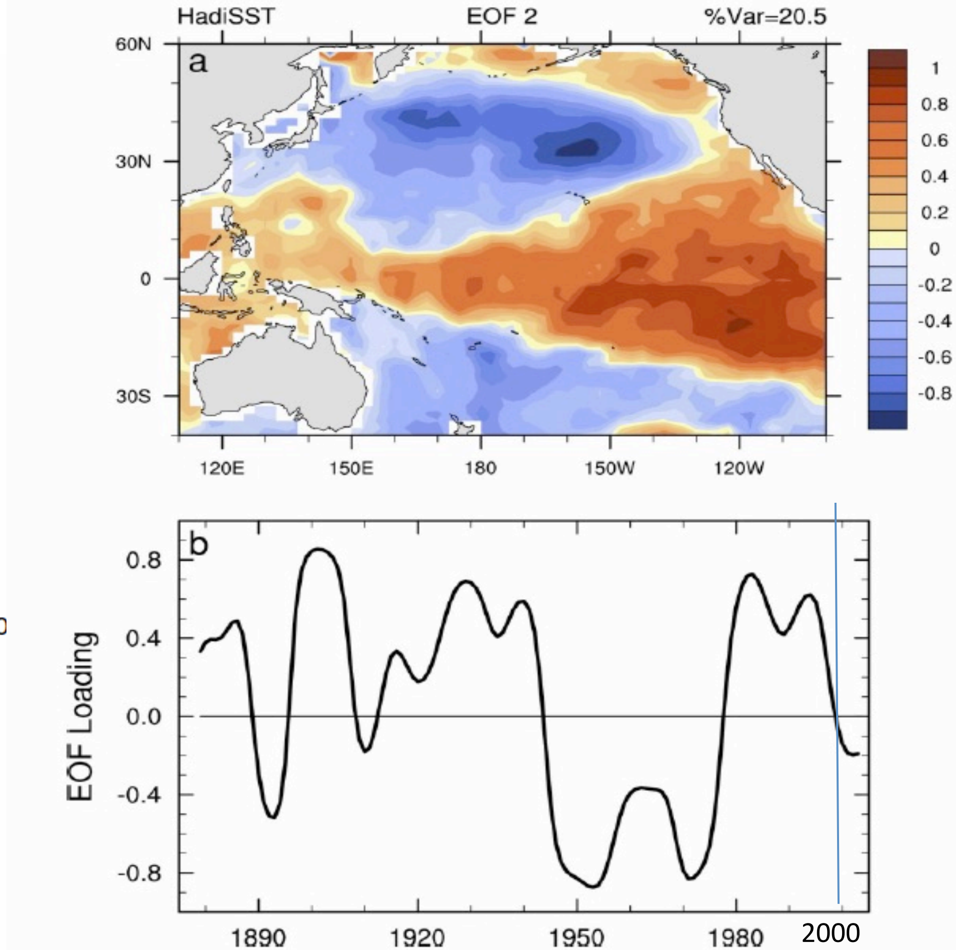
Regional and Global Model Analysis

Could ENSO events on the interannual timescale trigger decadal shifts of the IPO?

It is important to understand processes and mechanisms to identify sources of decadal timescale predictability

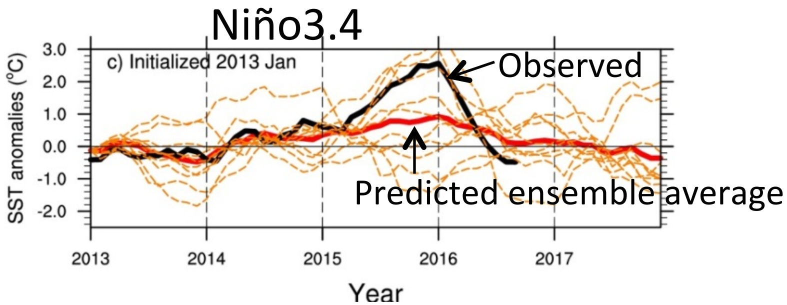




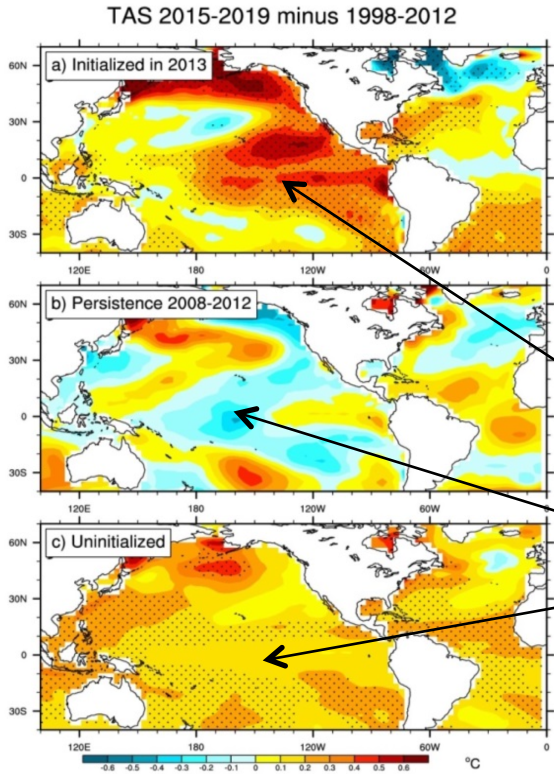
Off-equatorial ocean heat content in the tropical western Pacific could provide the conditions for ENSO events to trigger an IPO transition

(Meehl, Hu, Teng, 2016, *Nature Communications*)

Initialized prediction

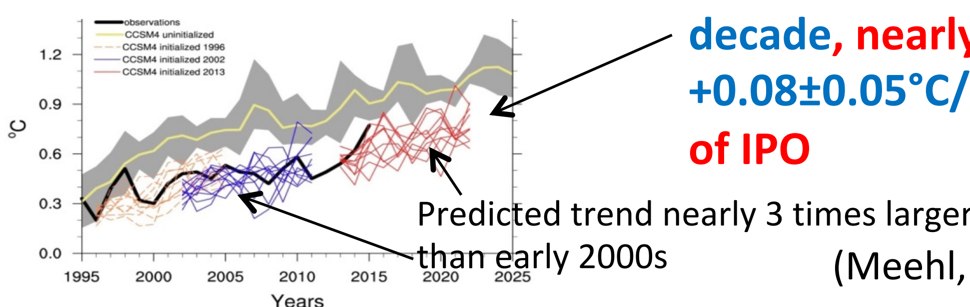


Model initialized in 2013 predicted small warming in 2014 followed by larger El Niño in 2015-2016



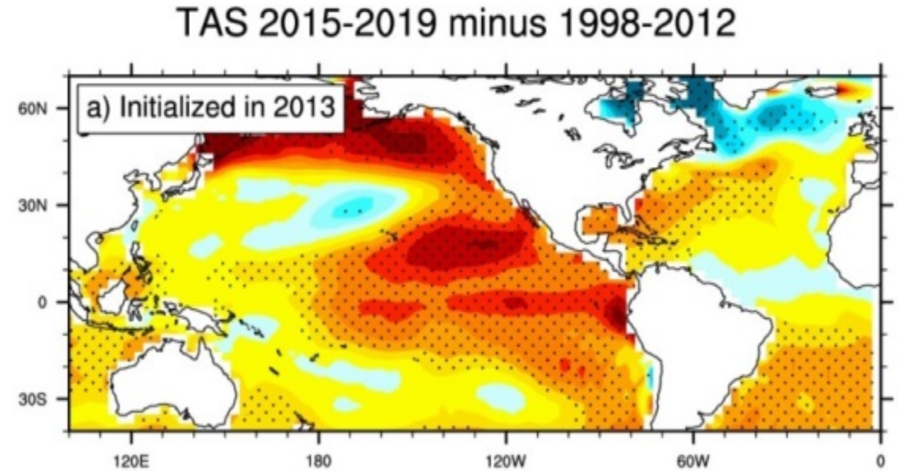
Physical basis for prediction skill: Initialized hindcasts show model qualitatively captures ENSO evolution in eastern equatorial Pacific that triggers decadal timescale IPO transitions associated with off-equatorial western Pacific ocean heat content anomalies

Prediction (initialized in 2013) for years 3-7 (2015-2019) shows transition to positive phase of the IPO different from persistence or uninitialized

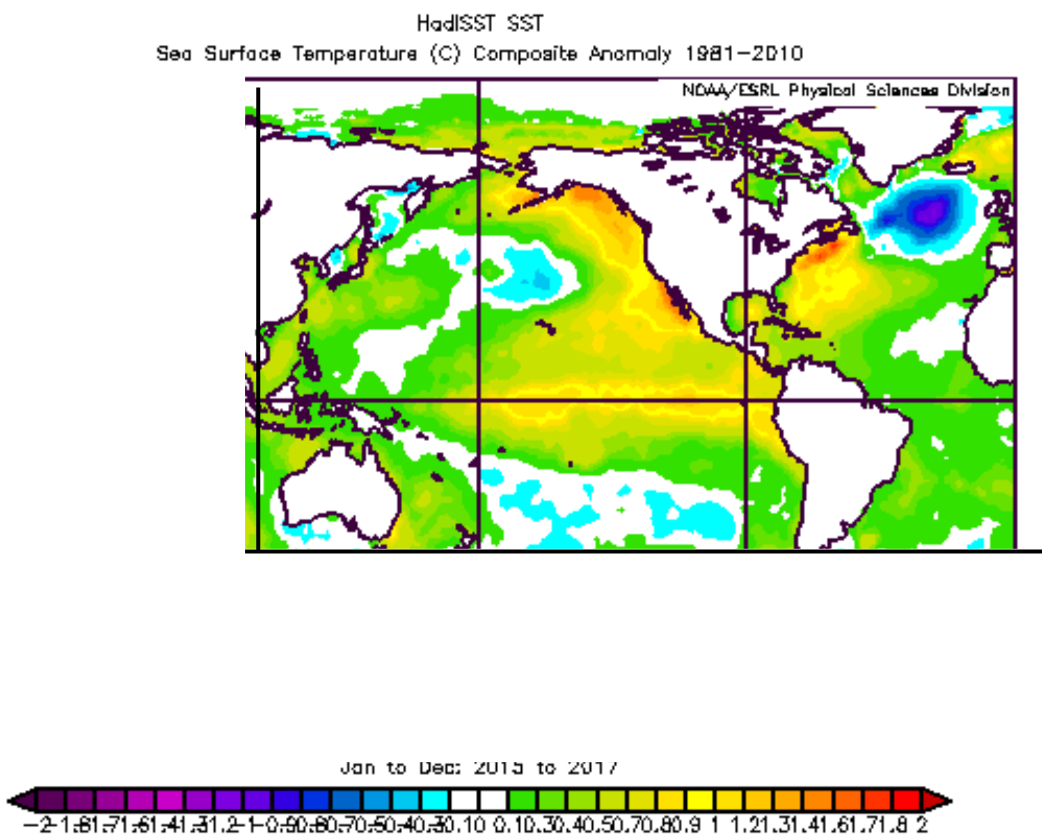


Predicted transition to positive IPO produces global temperature trend for 2013-2022 of +0.22±0.13°C/decade, nearly 3 times larger than 2001-2014 trend of +0.08±0.05°C/decade during previous negative phase of IPO

(Meehl, G.A., A. Hu, and H. Teng, 2016, *Nature Comms.*)



Prediction for
2015-2019 average



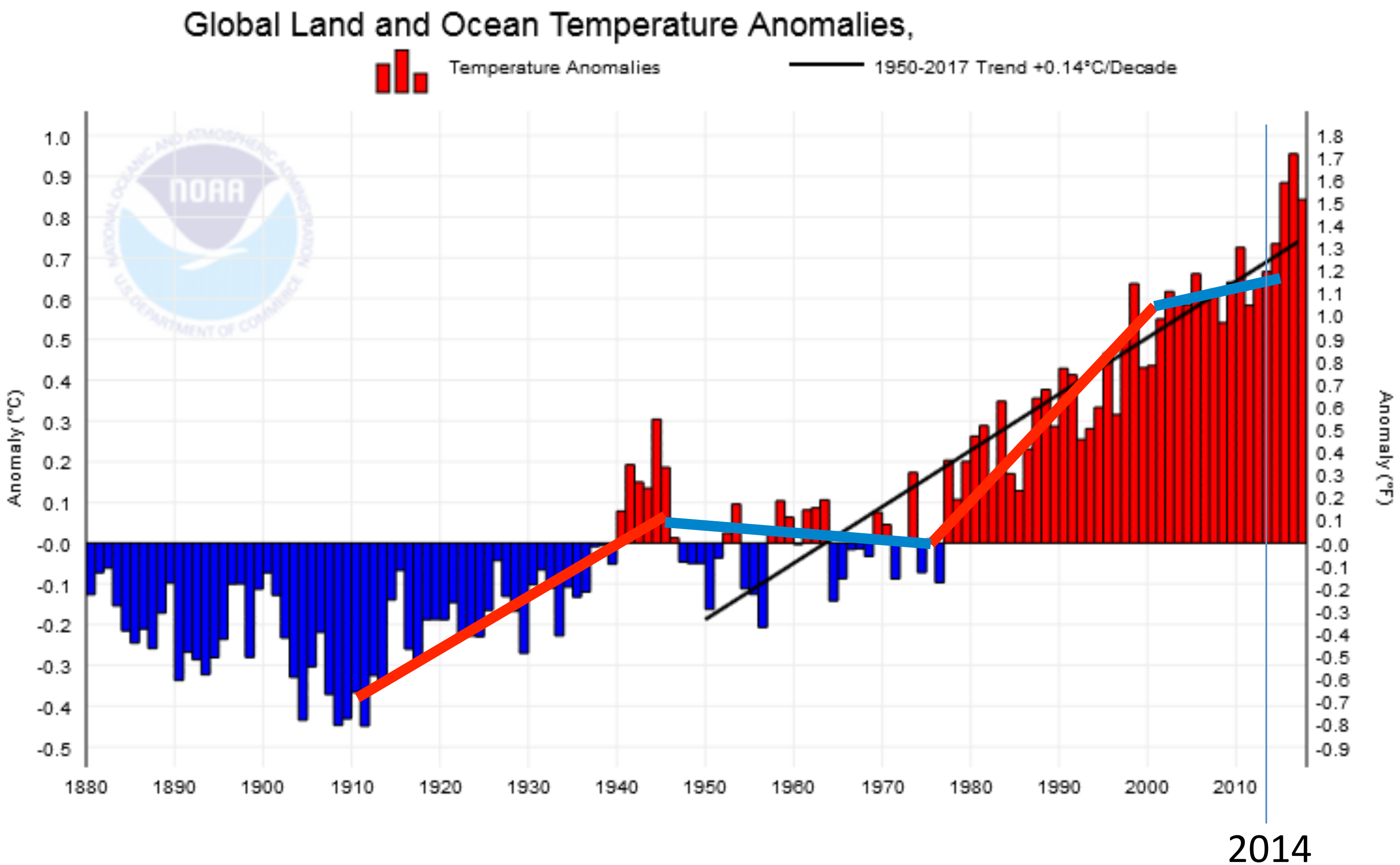
Observed for
2015-2017 average

IPO likely transitioned to positive in the 2014-2016 time frame:

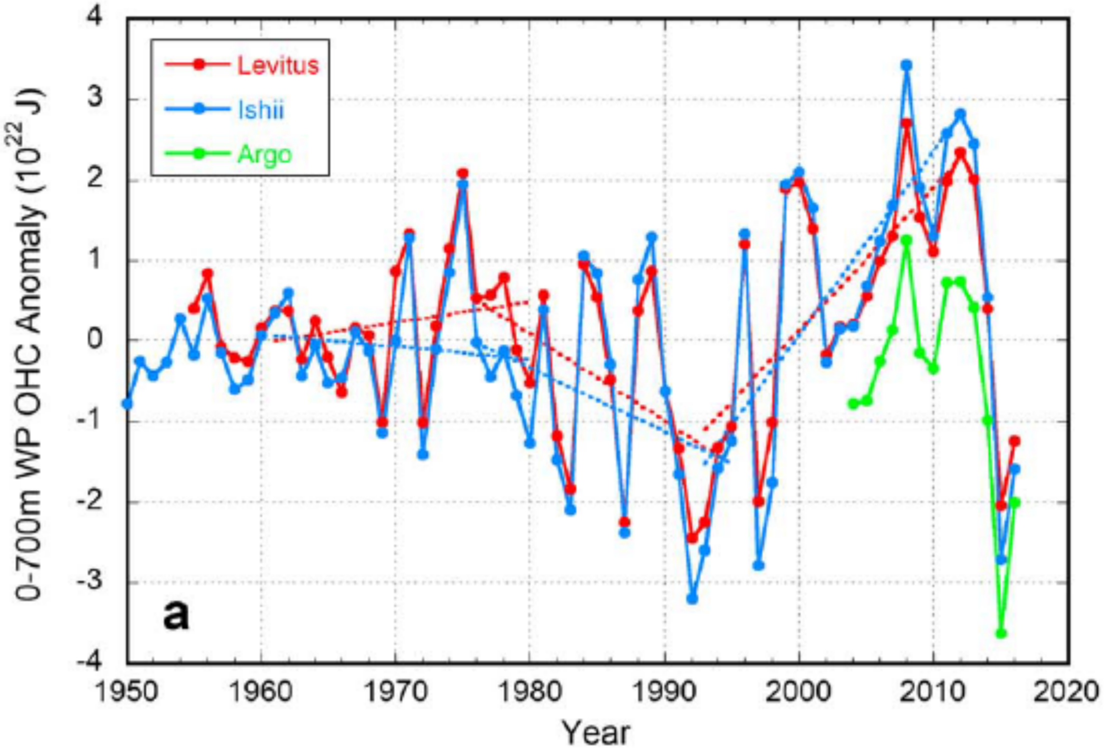
Su et al., 2017, Sci. Rep.

Hu and Federov, 2017, GRL

Transition to positive phase of IPO associated with an increased trend in the rate of global mean surface temperature



Recent ocean heat content observations from the western Pacific indicate a discharge of western Pacific heat content indicative of a possible transition of the IPO to a positive phase



(Yin et al., GRL, 2018)

1800 year CESM1 pre-industrial control run

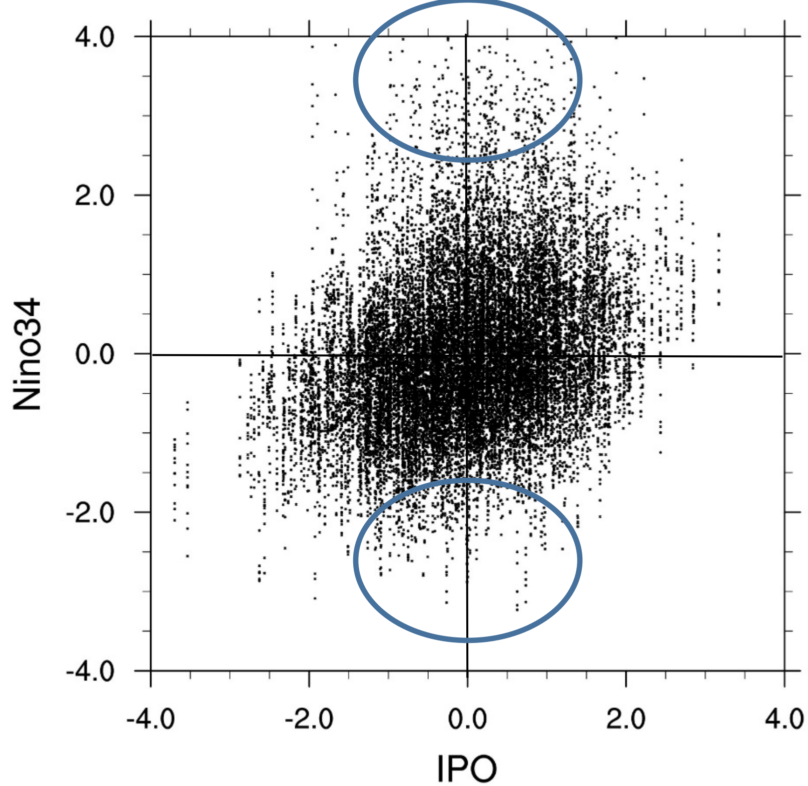
Compute IPO index as the first EOF of low pass filtered SSTs for the Pacific basin

Select IPO transitions from positive to negative (e.g. as in the late 1990s), and negative to positive (e.g. as in the mid-1970s and 2014-2016 time frame)

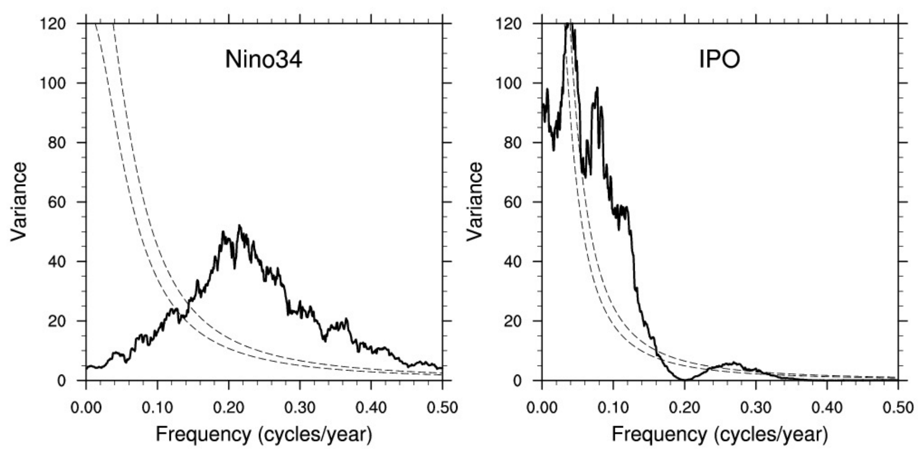
47 cases of IPO negative to positive transition
51 cases of IPO positive to negative transition

Composite conditions associated with those transitions

Here we show negative to positive transitions
(positive to negative are very similar but with opposite sign)

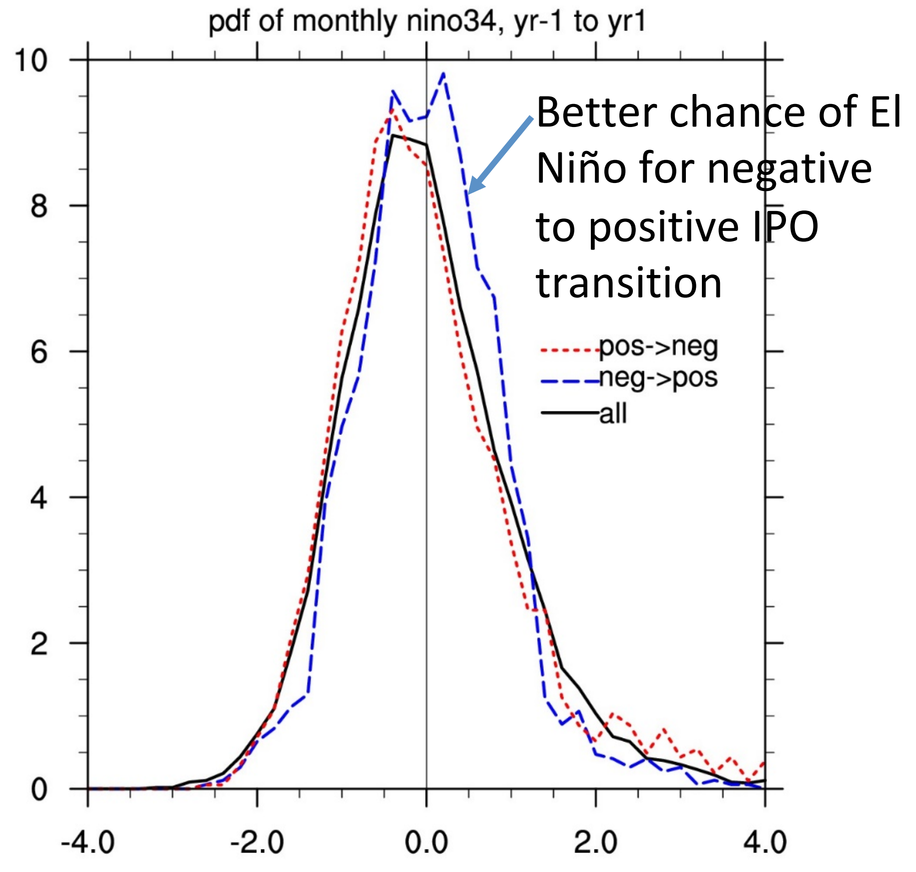


Large El Niño and La Niña events near zero values of IPO index suggest that the IPO is not simply amplitude modulation of ENSO

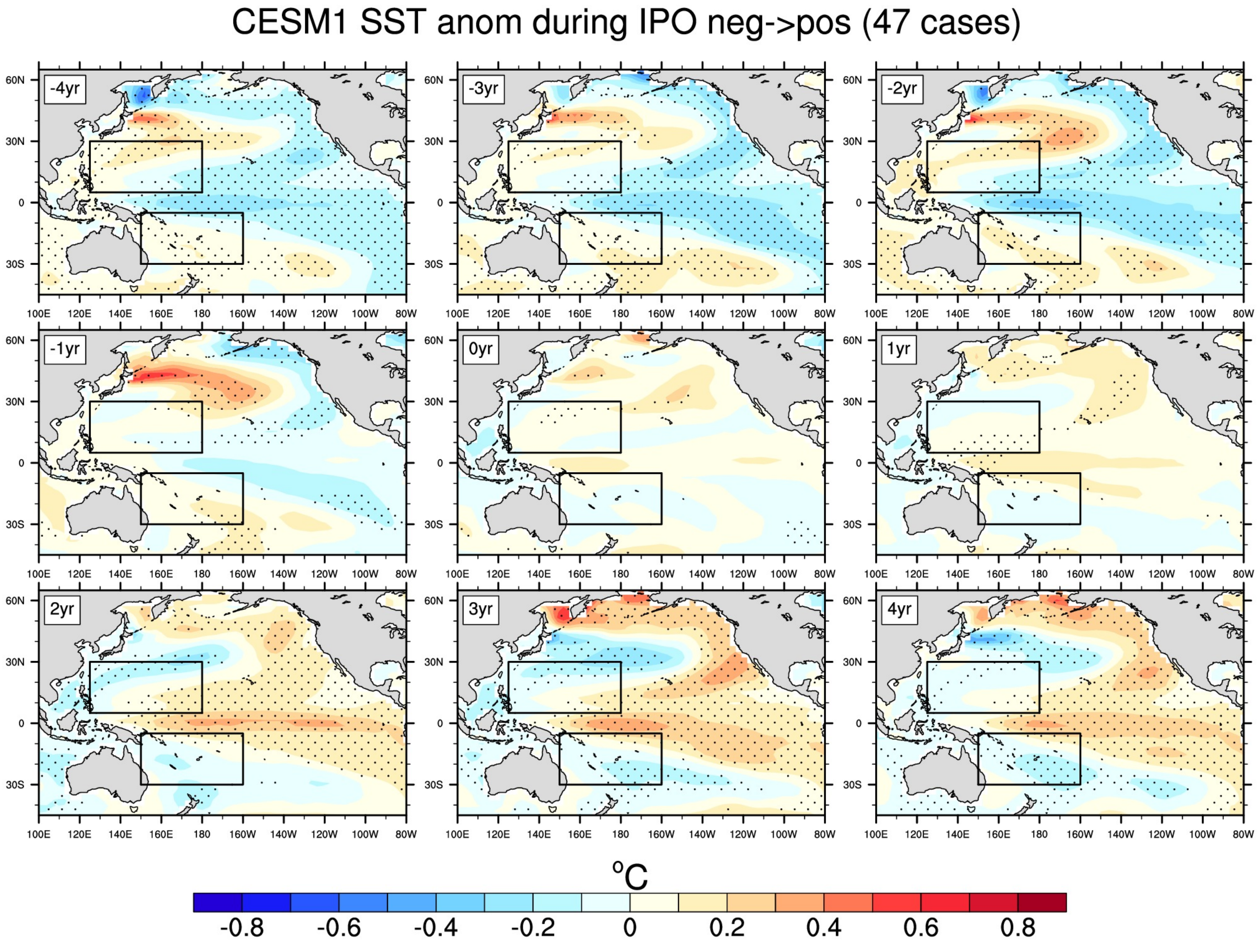


Within a year of an IPO transition from negative to positive, there is a better chance of an El Niño event

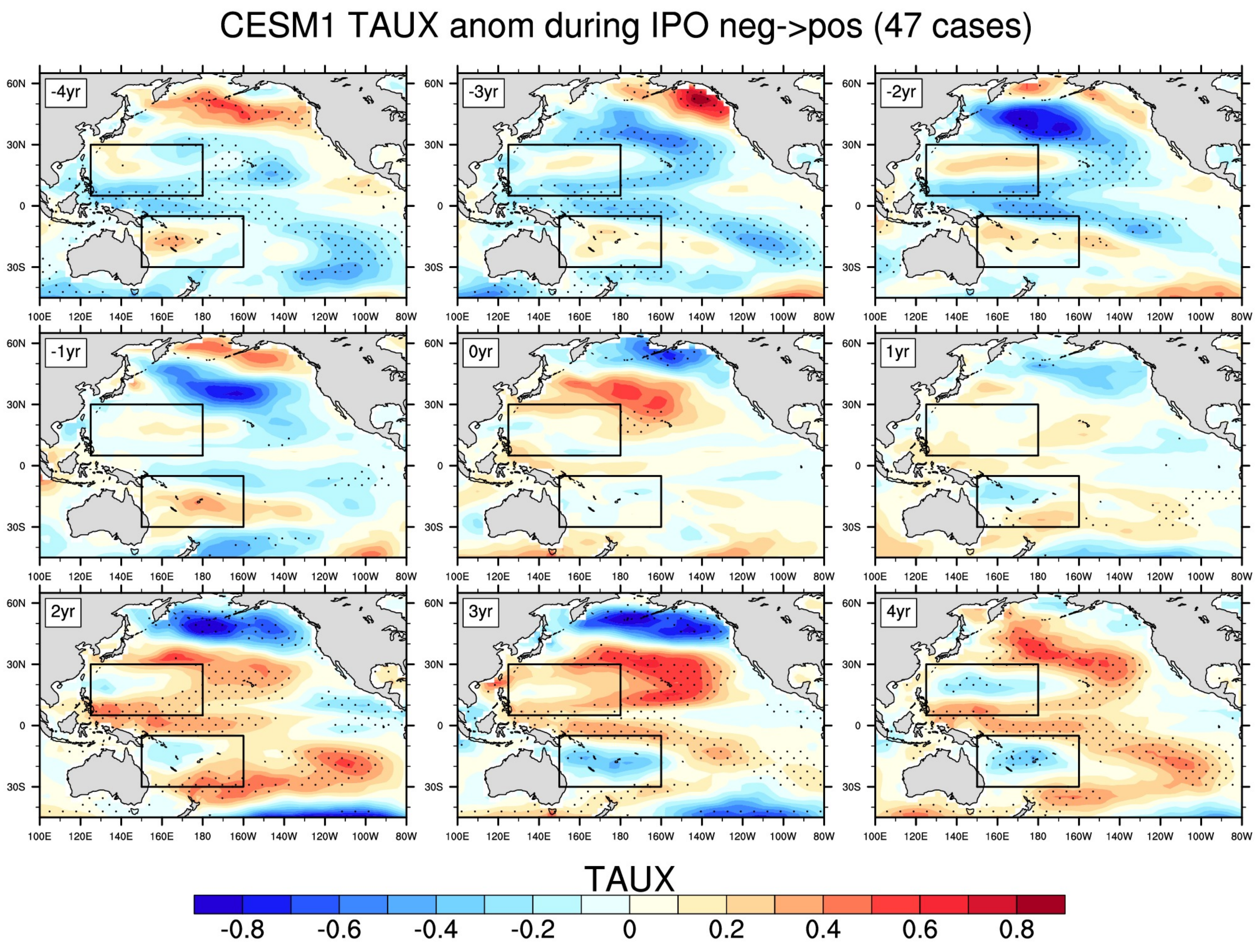
(and better chance of a La Niña event from positive to negative IPO)



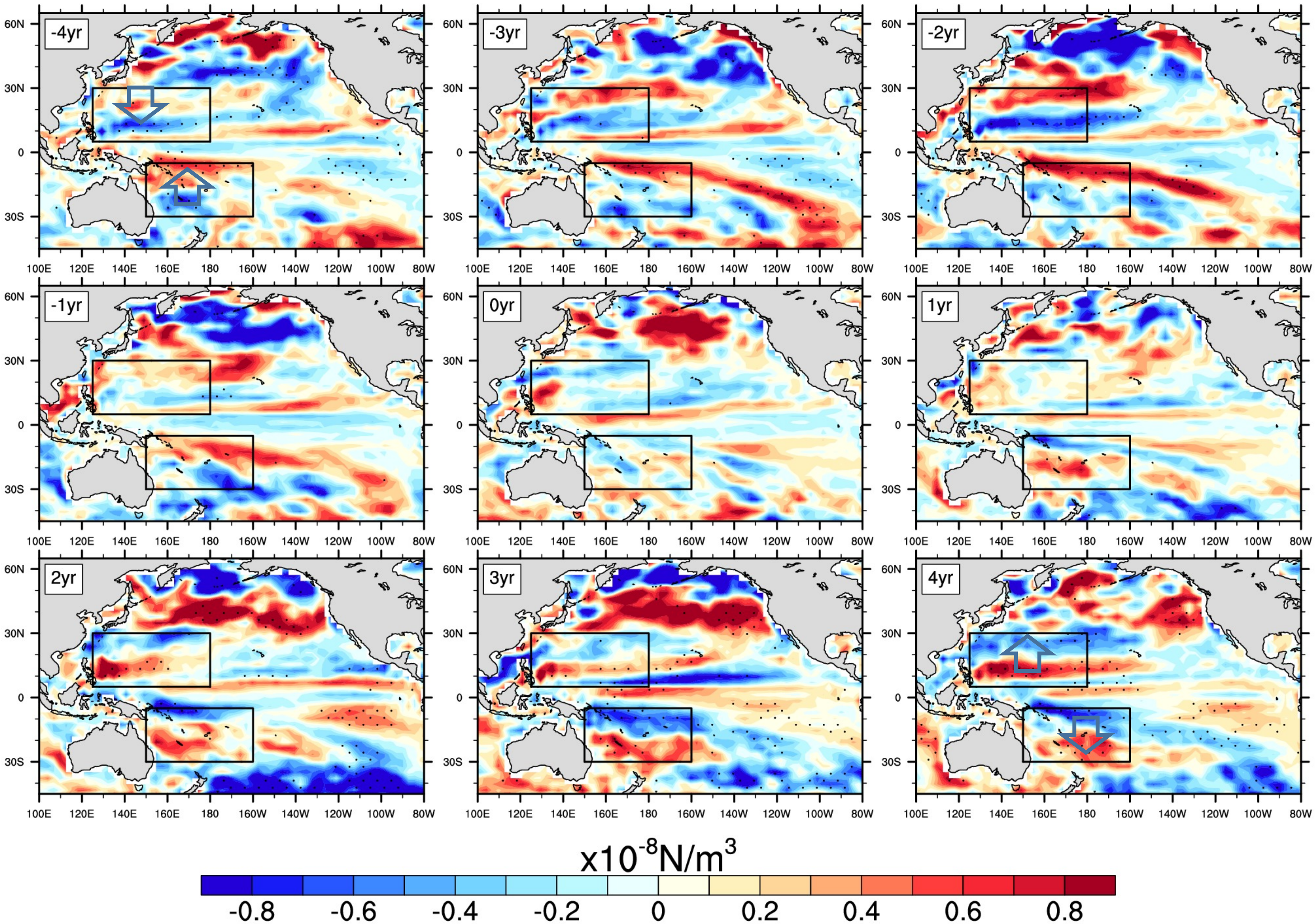
Nino3.4 standard deviation



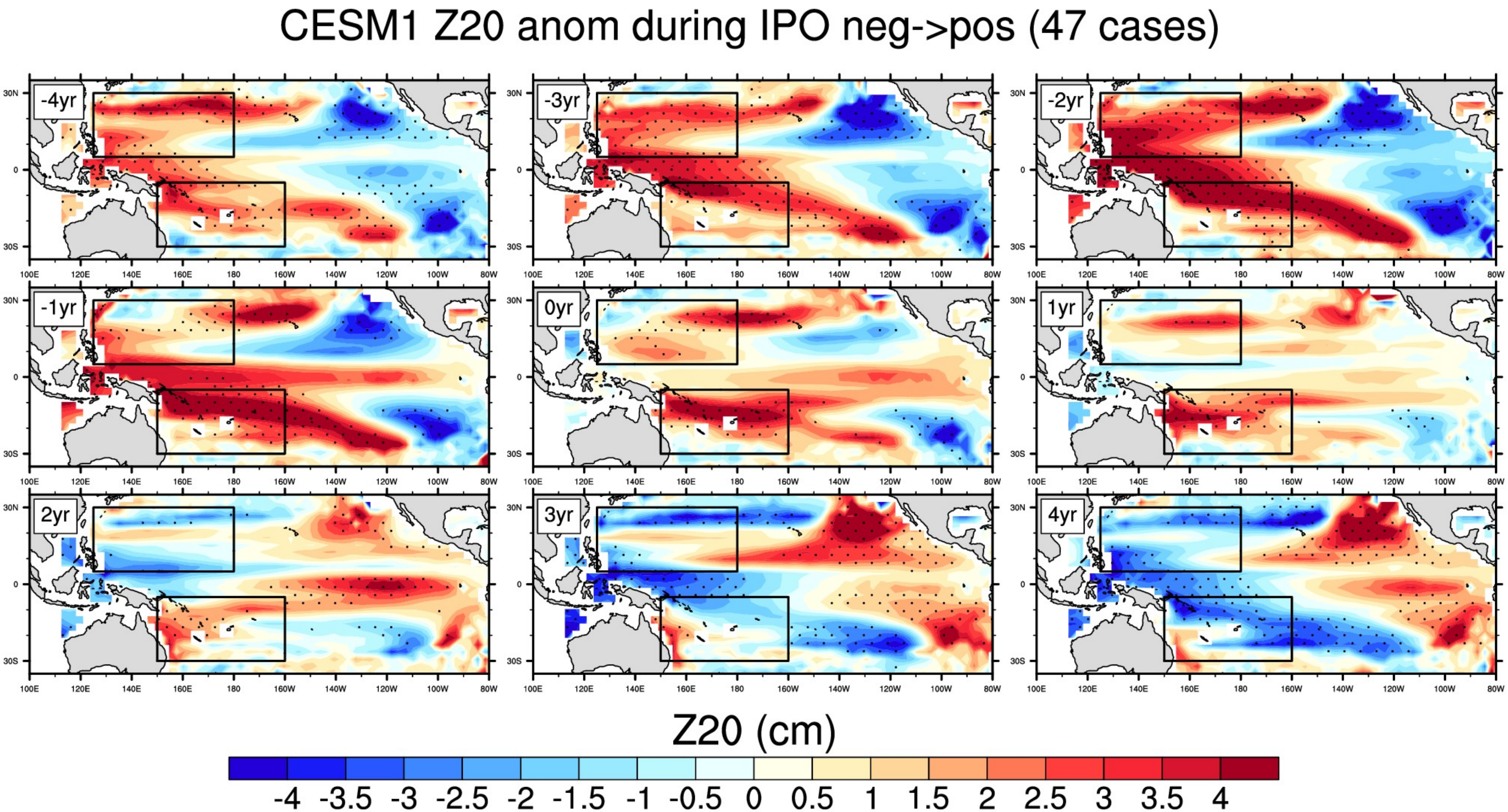
CESM1 SST anom during IPO neg->pos (47 cases)
-4yr
-3yr
-2yr
-1yr
0yr
1yr
2yr
3yr
4yr
60N
30N
0
30S
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
oC
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

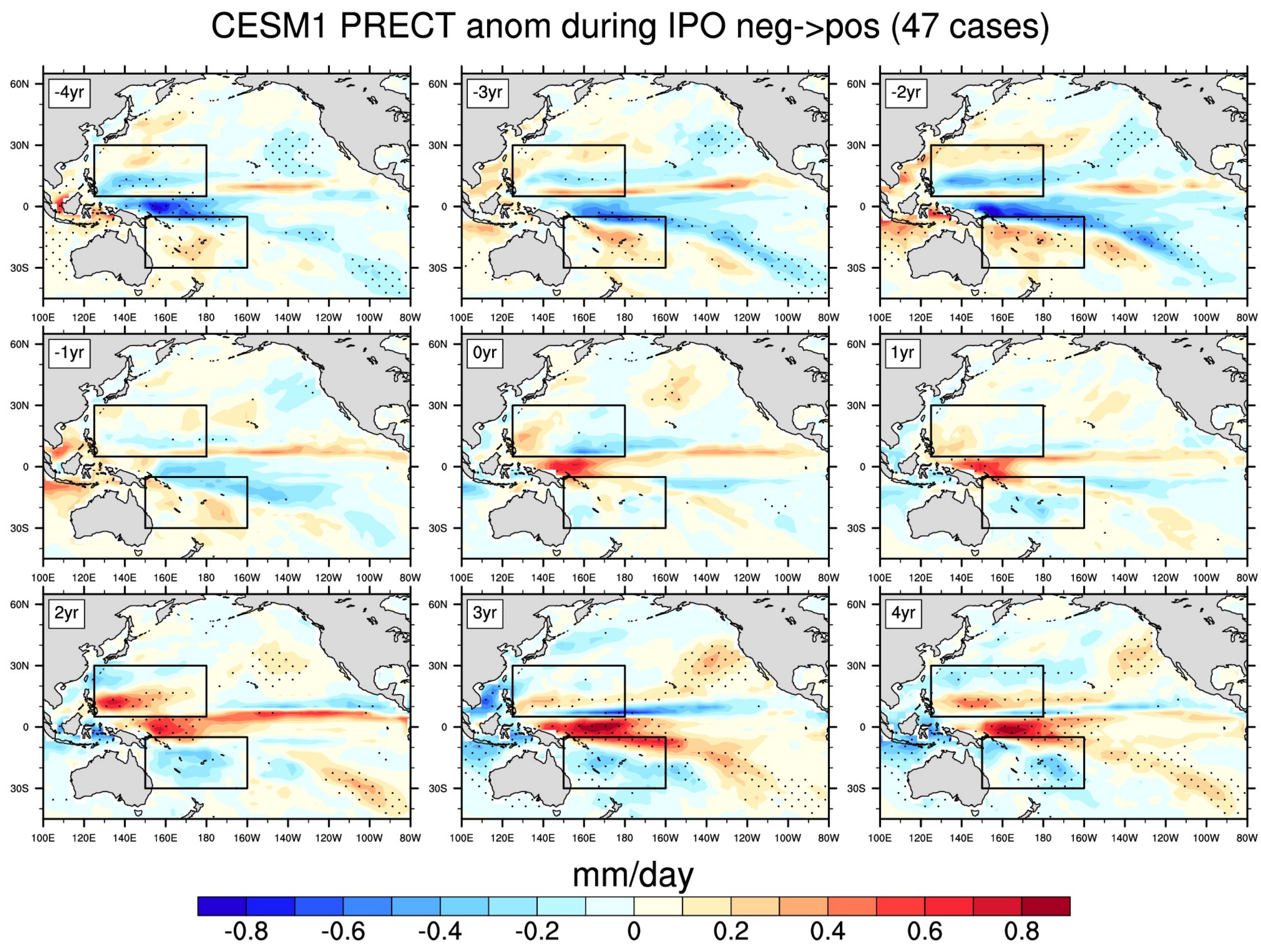

CESM1 TAUX anom during IPO neg->pos (47 cases)
-4yr
-3yr
-2yr
-1yr
0yr
1yr
2yr
3yr
4yr
60N
30N
0
30S
100E 120E 140E 160E 180 160W 140W 120W 100W 80W
TAUX
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8

CESM1 curl(tau) anom during IPO neg->pos (47 cases)



Ocean heat content (depth of 20˚C isotherm)

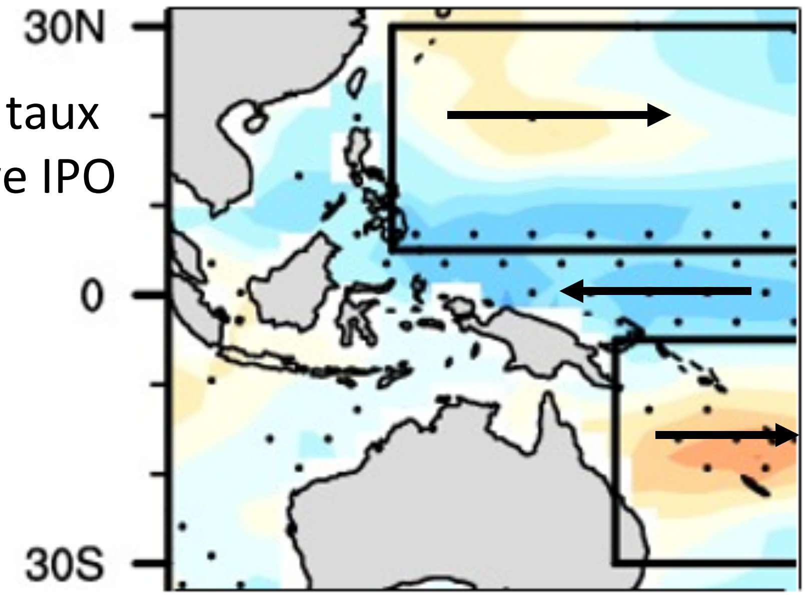




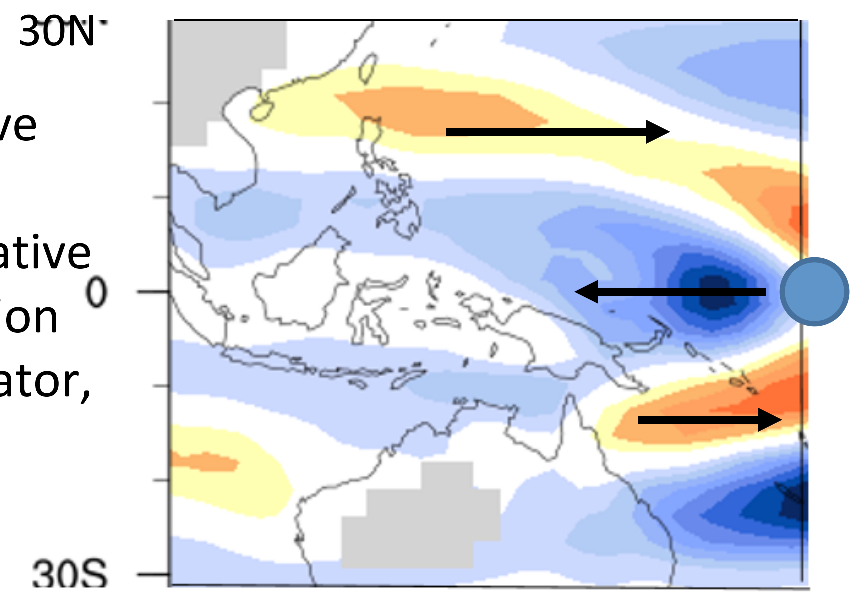
CESM1 PRECT anom during IPO neg->pos (47 cases)
-4yr
-3yr
-2yr
-1yr
0yr
1yr
2yr
3yr
4yr
60N
30N
0
30S
100E 120E 140E 160E 180 160W 140W 120W 100W 80W
mm/day
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8

Negative convective heating anomaly near 165E can produce u-component wind stress anomalies in off-equatorial western Pacific to sustain ocean heat content anomalies

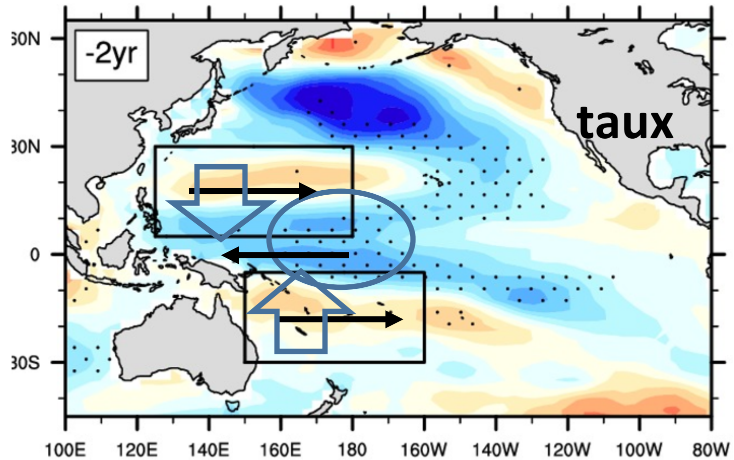
Year -4 composite taux negative to positive IPO transition



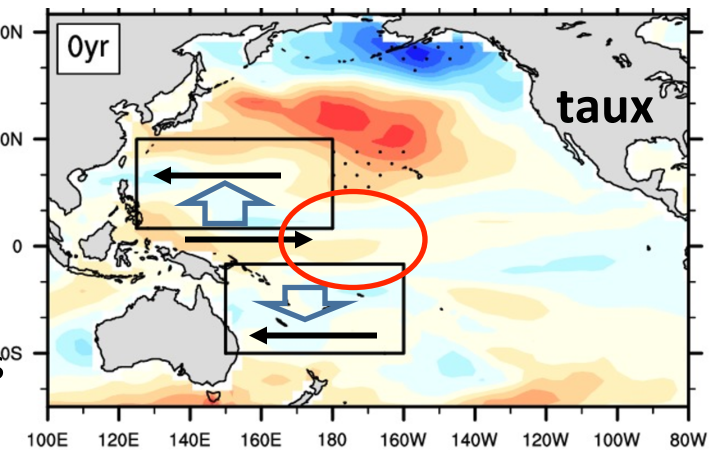
Negative convective heating anomaly (representing negative SST and precipitation anomalies) at equator, 165E

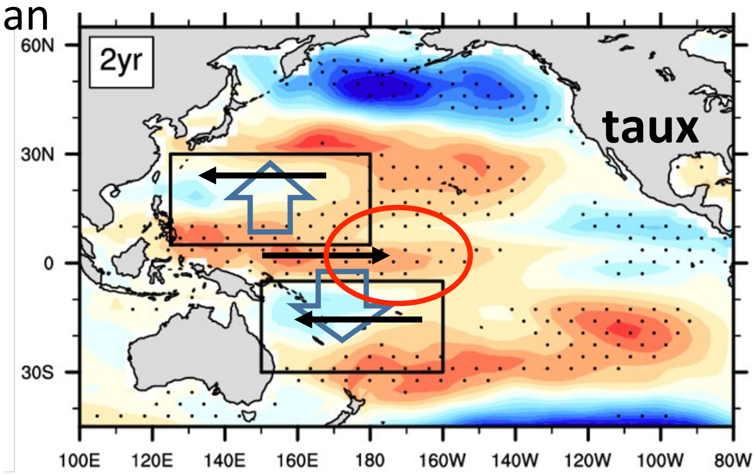


Westerly wind stress anomalies maintained by negative precip and convective heating anomalies near 165E produce equatorward Ekman transport and positive ocean heat content anomalies



El Niño brings westerly equatorial wind stress anomalies, warming SSTs to the east, positive precip and convective heating anomalies near 165E, easterly wind stress anomalies near 20N and 20S, and poleward Ekman transport





Easterly wind stress anomalies maintained by positive precip and convective heating anomalies near 165E produce poleward Ekman transport and negative off-equocean heat content anomalies

Summary:

An IPO transition from negative to positive (as was seen in the mid-1970s and the 2014-2016 time frame):

--build-up of off-equatorial western Pacific ocean heat content anomalies maintained by negative SST, precipitation and convective heating anomalies near 165E and associated positive wind stress anomalies near 25N and 25S

An El Niño event can trigger a transition if off-equatorial western Pacific ocean heat content anomalies are sufficiently large:

--onset of equatorial westerly wind anomalies, warming SSTs, positive precipitation and convective heating anomalies near 165E, and negative wind stress anomalies near 25N and 25S

The positive phase of the IPO will be maintained as ocean heat content anomalies in the western Pacific build up:

--onset of a La Niña event can trigger a transition to negative IPO with the opposite set of processes than for the transition from negative to positive IPO