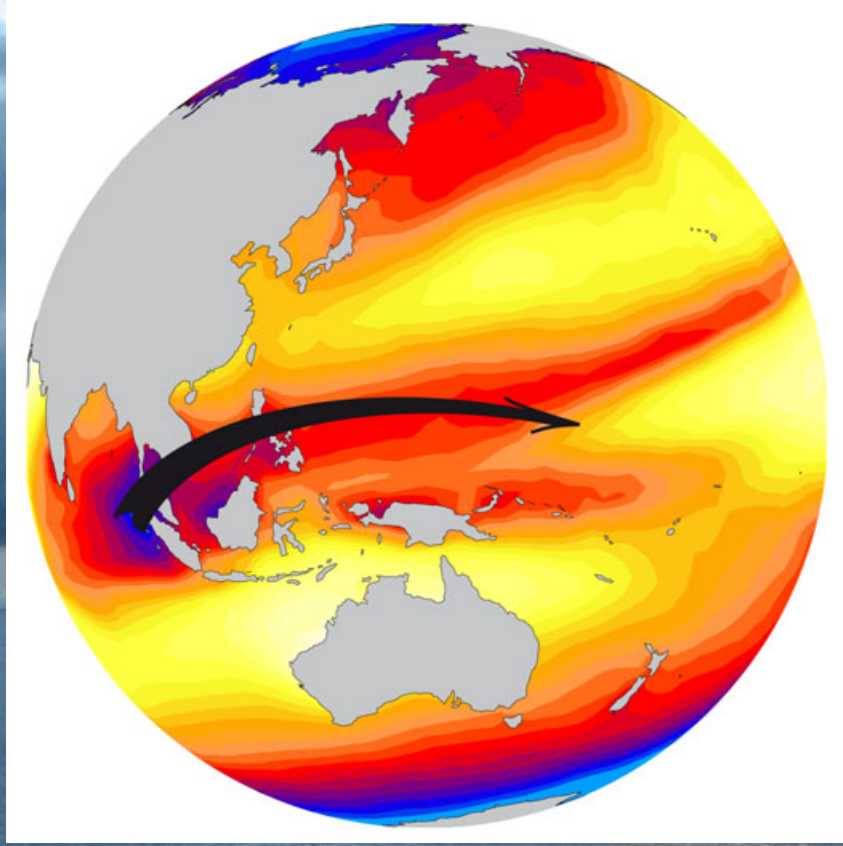
El Niño and the Indian Ocean



Jérôme Vialard - jerome.vialard@ird.fr

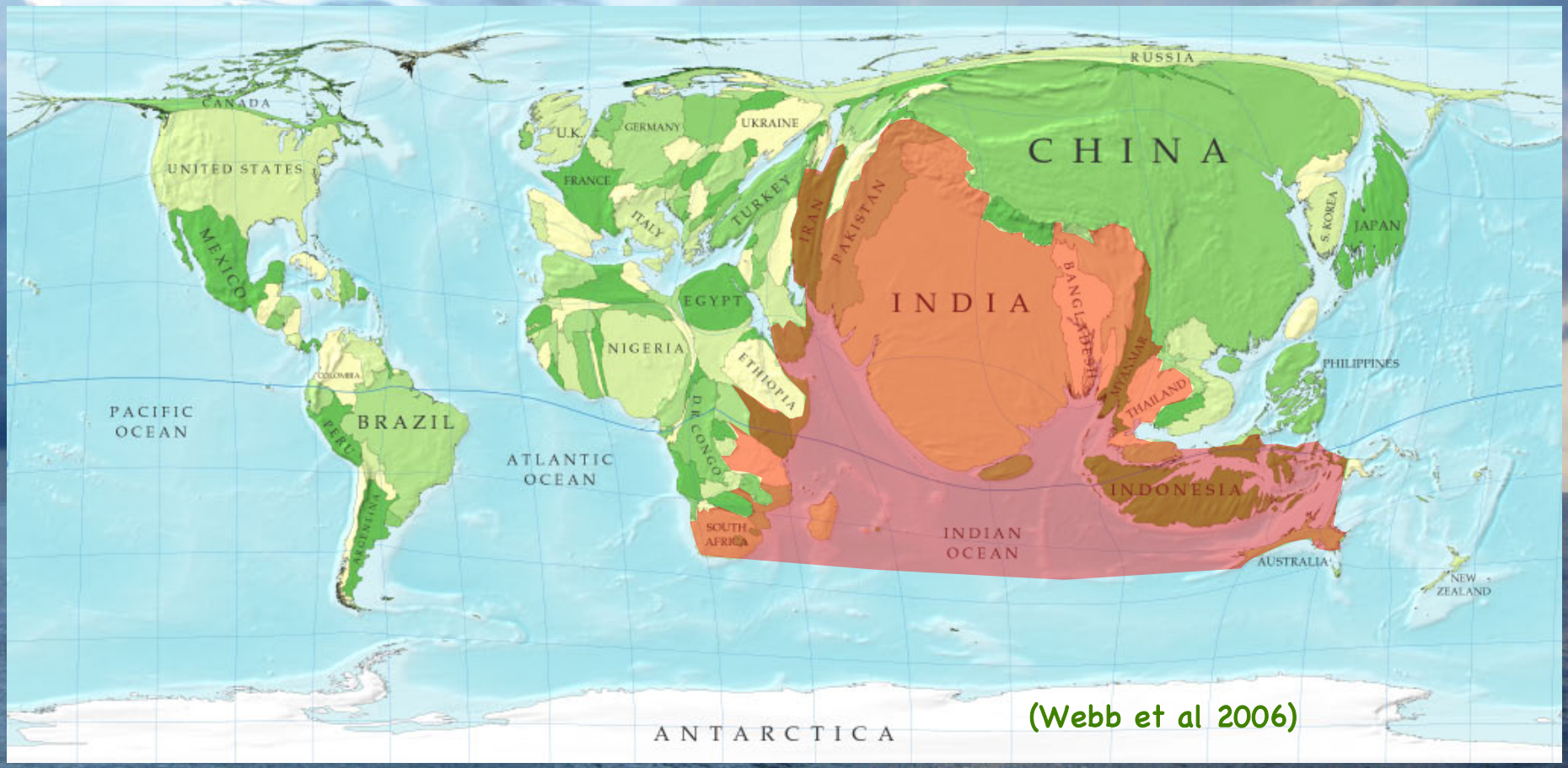
Disadvantages of speaking last

- Keep you awake after three days of workshop
- Convince you that there is some ENSO variance left to explain!

Advantages of speaking last

- No more wine or dessert to earn.

Why study the Indian Ocean ?



(Webb et al 2006)

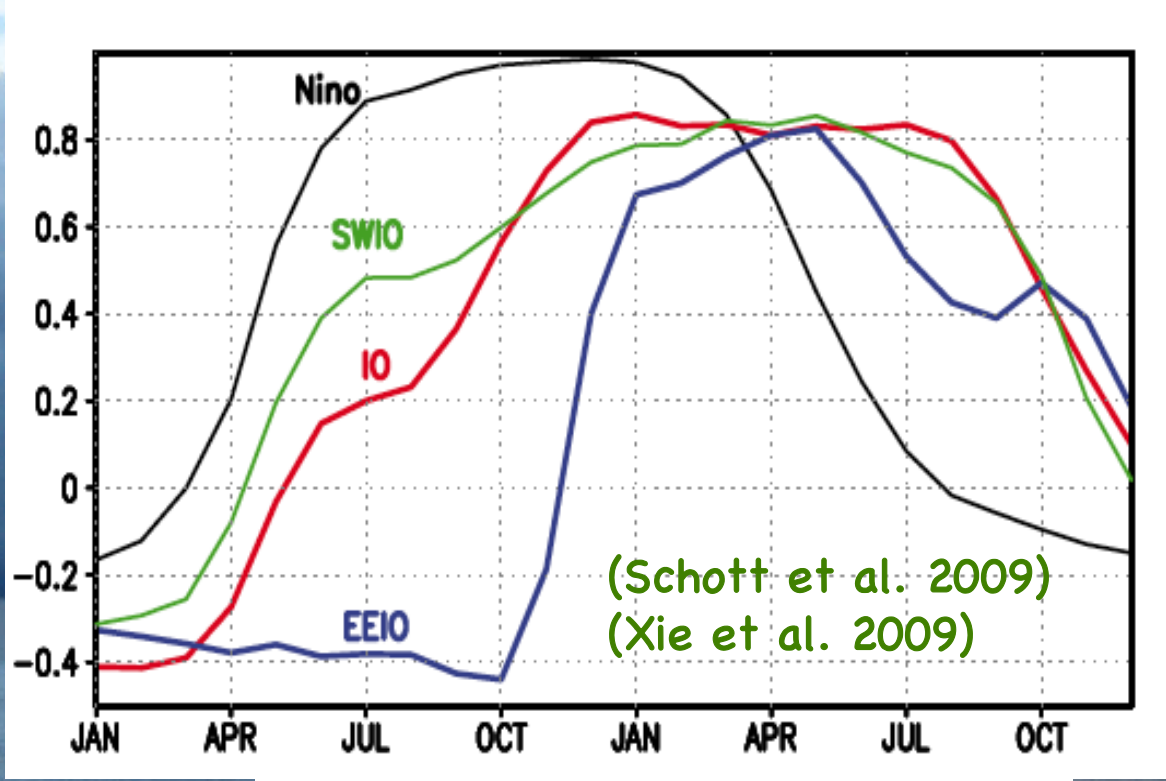
1/3 of world population (23 countries)

Outline

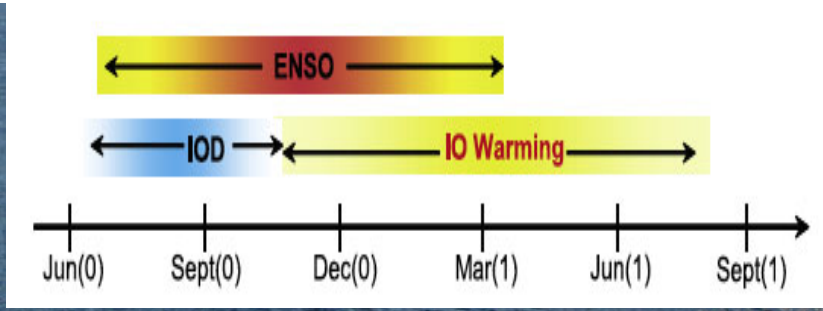
- The Pacific impacts the Indian Ocean!
- Does the Indian Ocean impacts the Pacific?
- An Indo-Pacific perspective

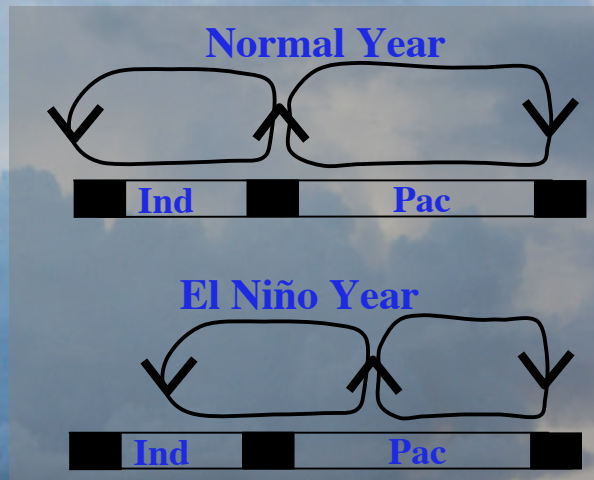
ENSO signature over Indian Ocean

Correlation with ENSO index



(Schott et al. 2009)
(Xie et al. 2009)

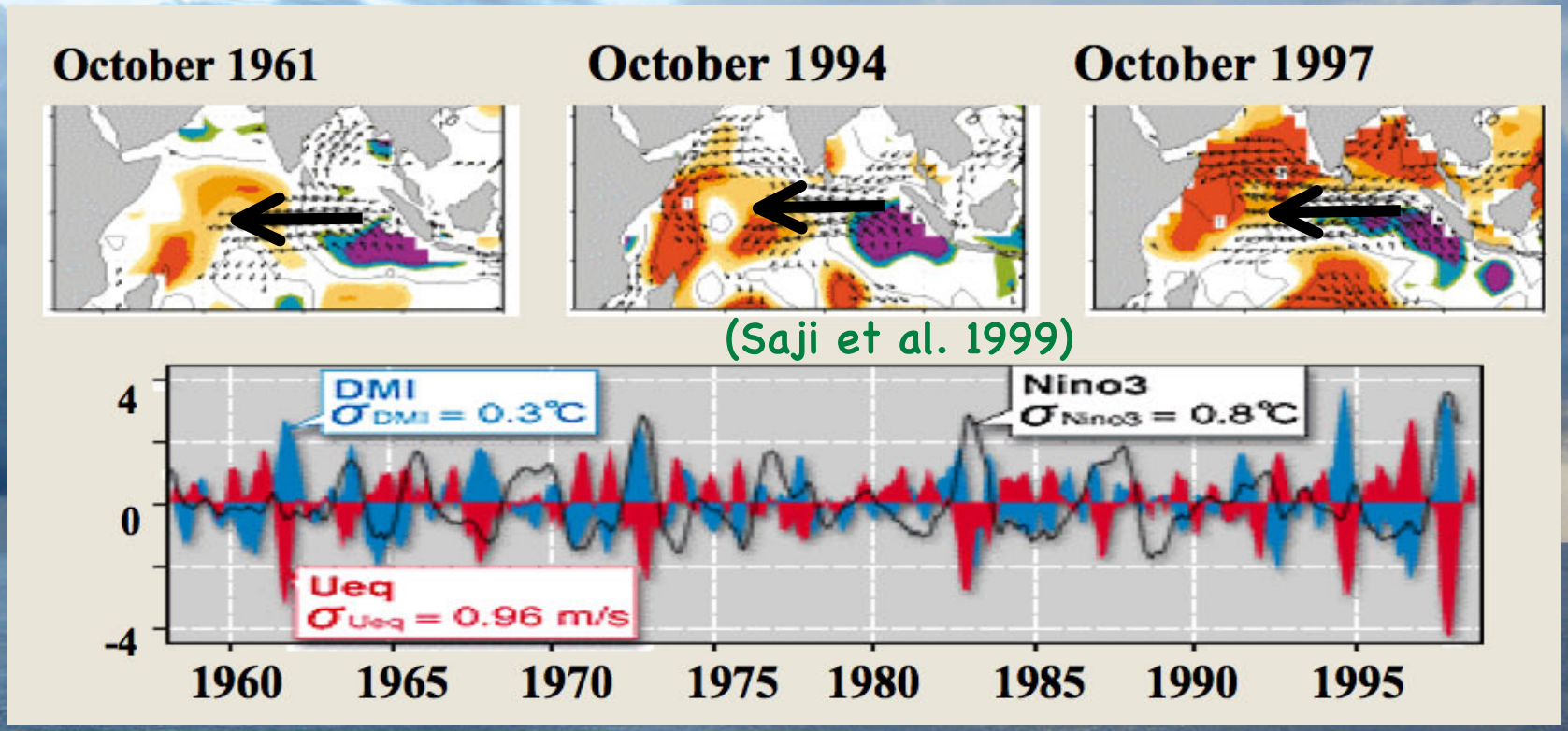




El Niño => Subsidence over Indian Ocean (Klein et al. 1999, Lau and Nath 2003)

The Indian Ocean Dipole

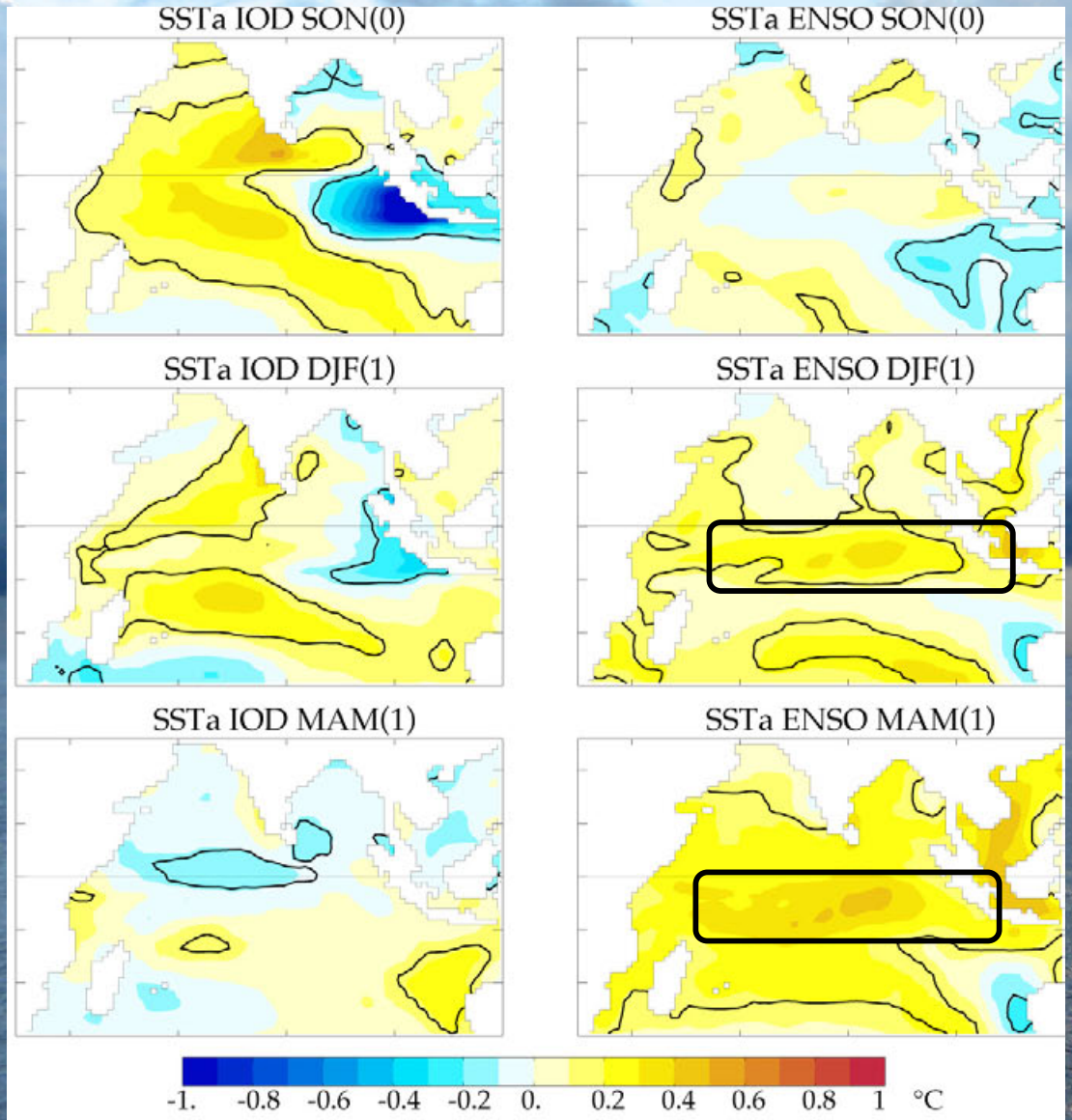
(Reverdin et al. 1986, Webster et al. 1999, Saji et al. 1999)



Bjerknes feedback (air-sea coupling essential)
Peaks in October-November
Partially independent from ENSO (but ENSO tend to induce IODs, $r_{SON} \approx 0.6$)
Clear climate impacts around the Indian Ocean

ENSO signature over Indian Ocean

Signature of IOD / ENSO on the Indian Ocean SST



Contrary to the IOD, ENSO induces a lasting SST anomaly in the southern Indian Ocean

Driven by air-sea fluxes and maintained by local air-sea interactions (Wu et al. 2008, Du et al. 2009, Xie et al. 2009)

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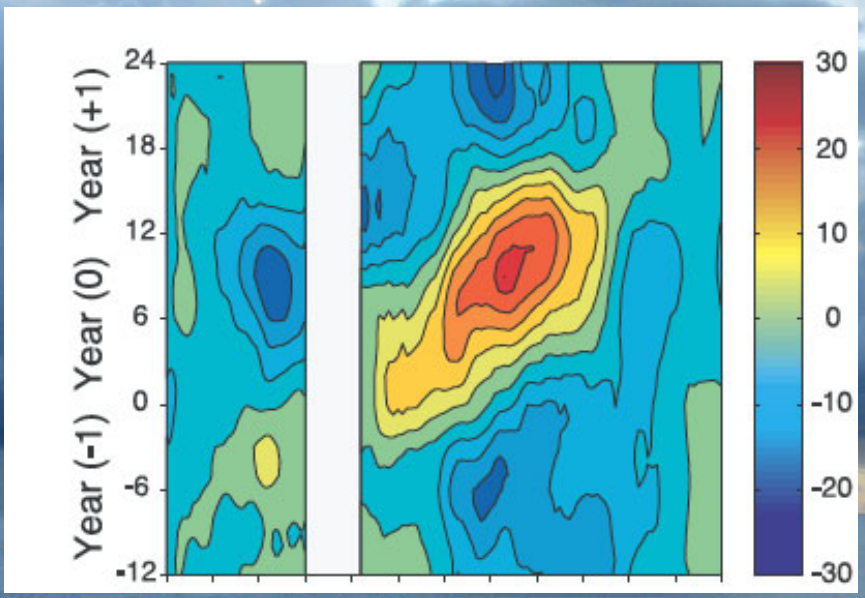
Observed influence of the Indian Ocean on El Niño



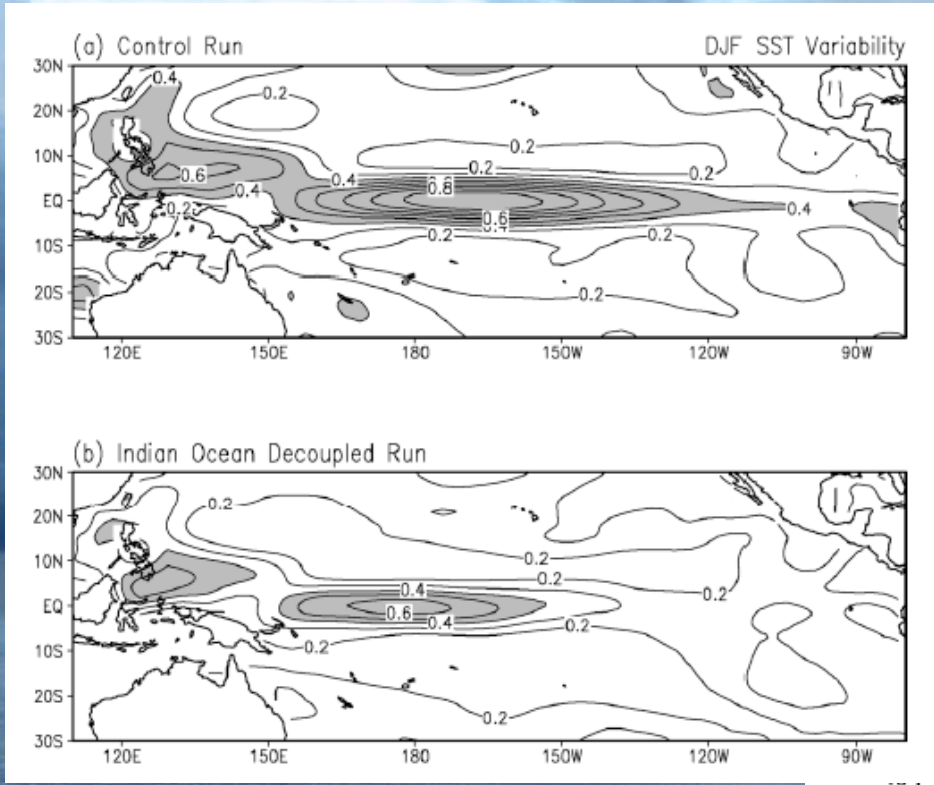
(Clarke and van Gorder, 2003)

Precursors of El Niño in the Indian Ocean (e.g. Meehl and Arblaster 2003, Clarke and van Gorder 2003, Terray and Dominiak 2005)

Uniform warming of the IO during El Niño favours the phase shift to La Niña (Kug and Kang 2006)

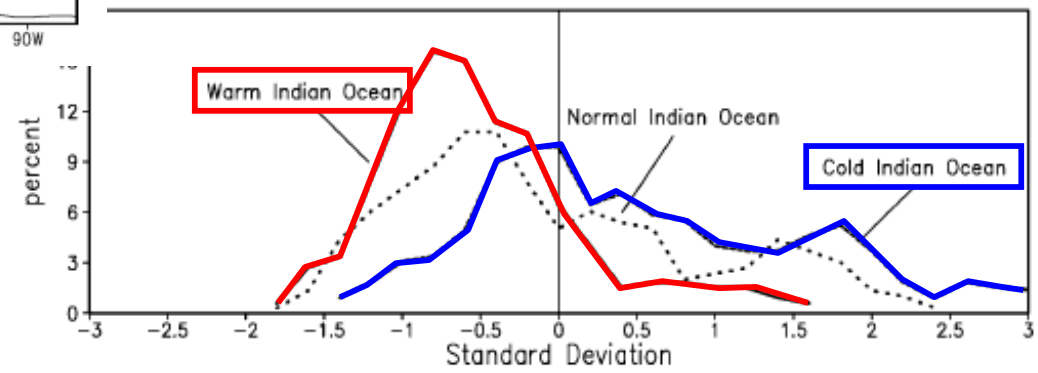
Indian ocean contributes to asymetries in El Niño / La Niña duration (Okomura and Deser 2010)

Indian ocean influence on the Pacific in CGCMs



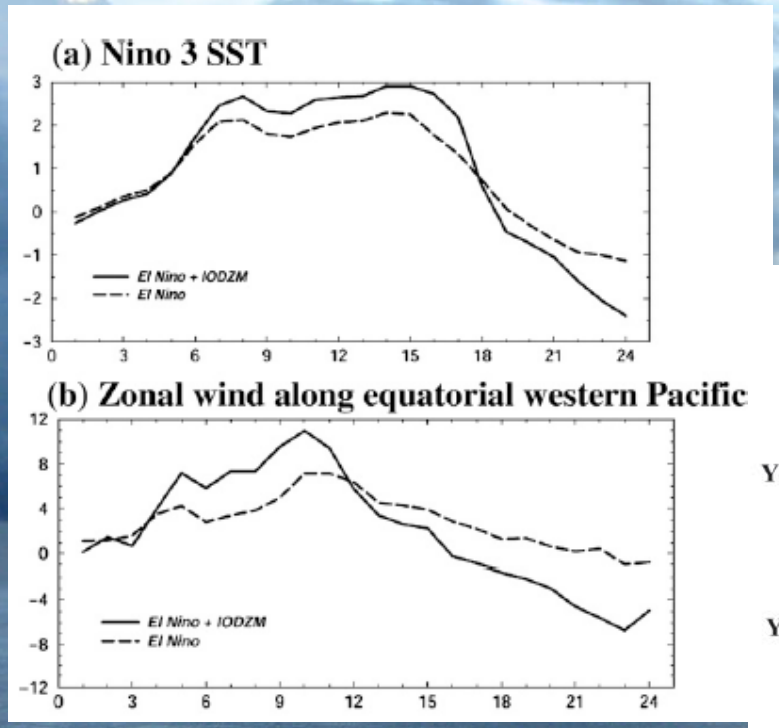
(Wu and Kirtman 2004)

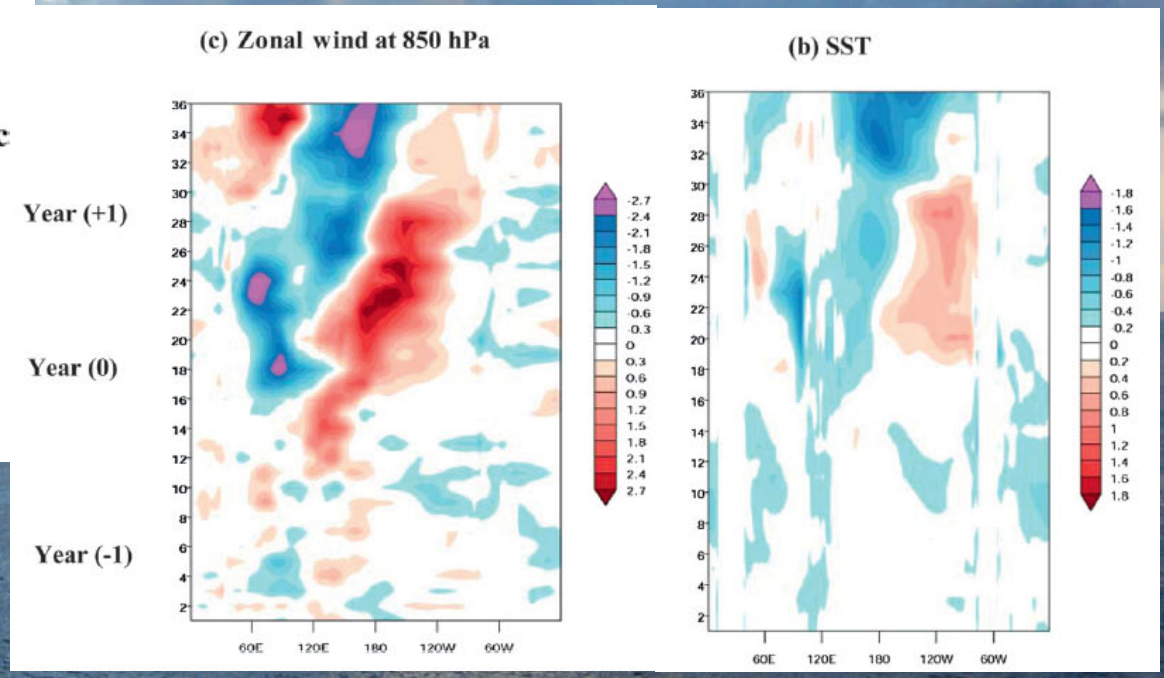
Based on JJAS SST anomalies over 60°-90°E, 5°N-5°S



Indian ocean influence on the Pacific in CGCMs

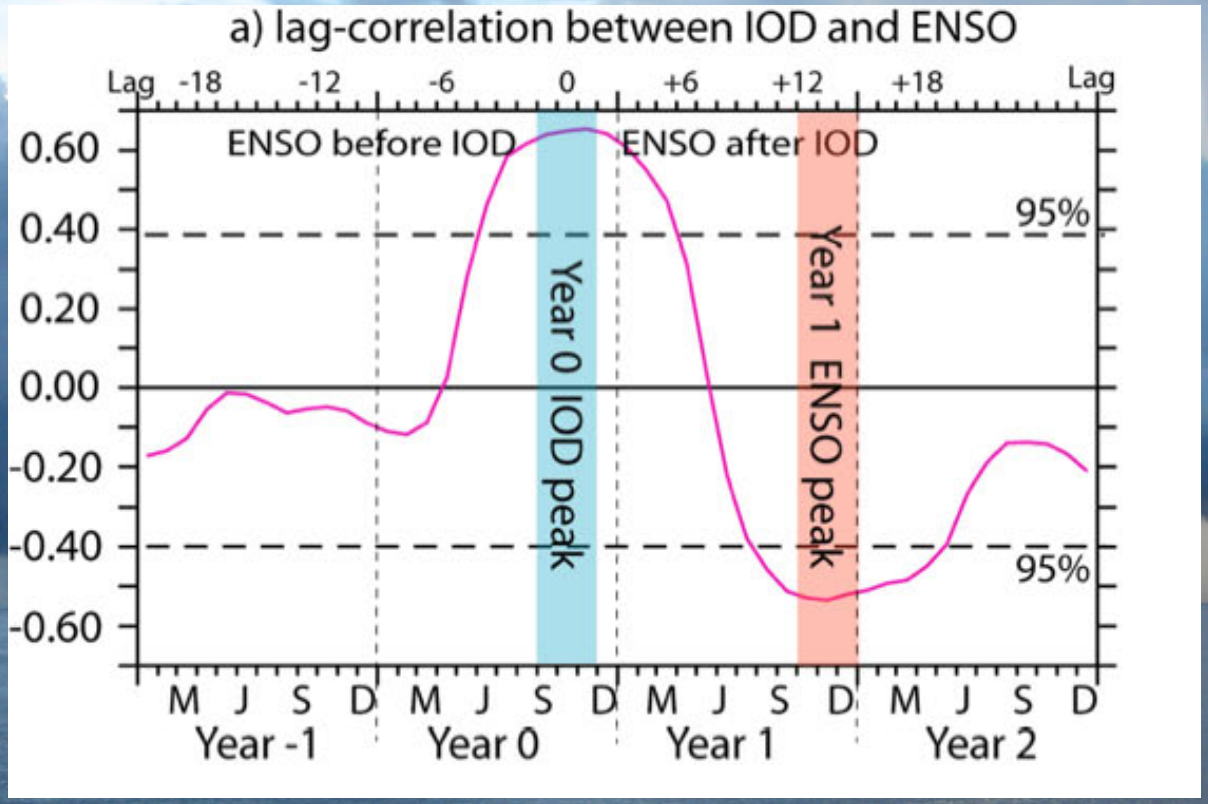
(Annamalai et al. 2010)





IOD, a precursor of following year's ENSO state

(Izumo et al. 2010)



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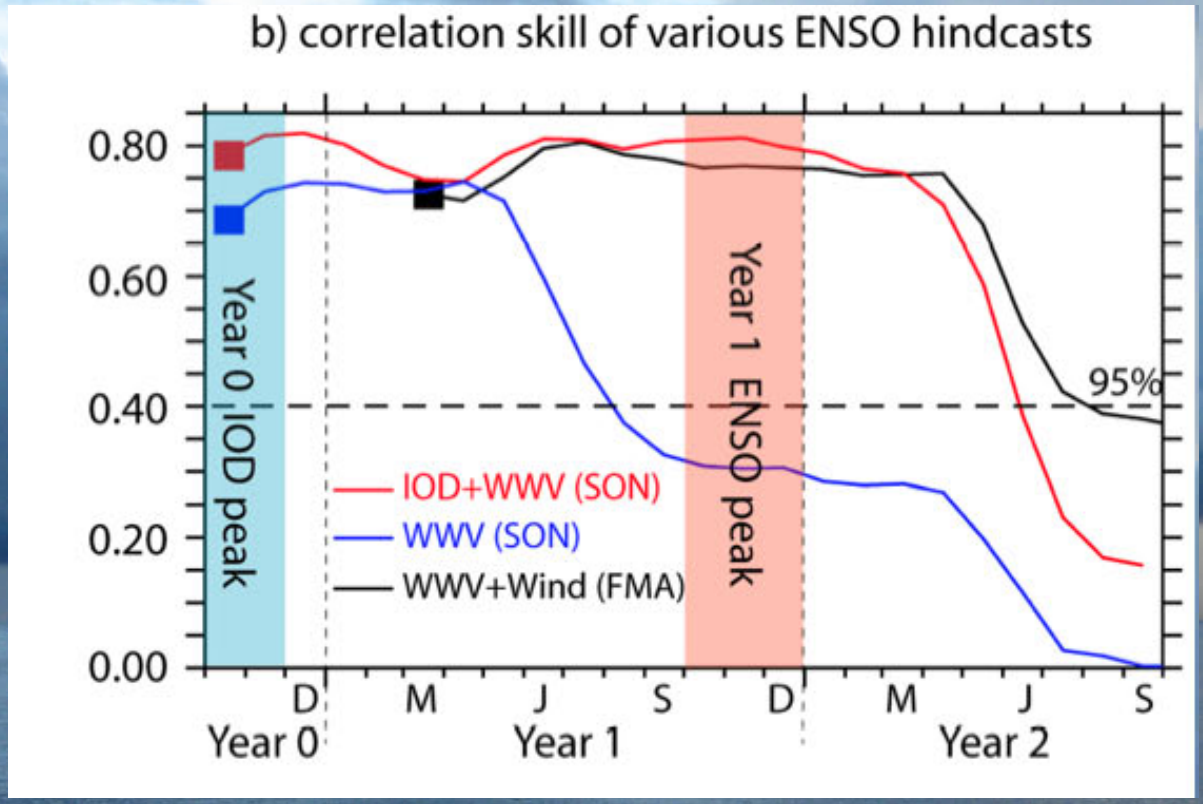


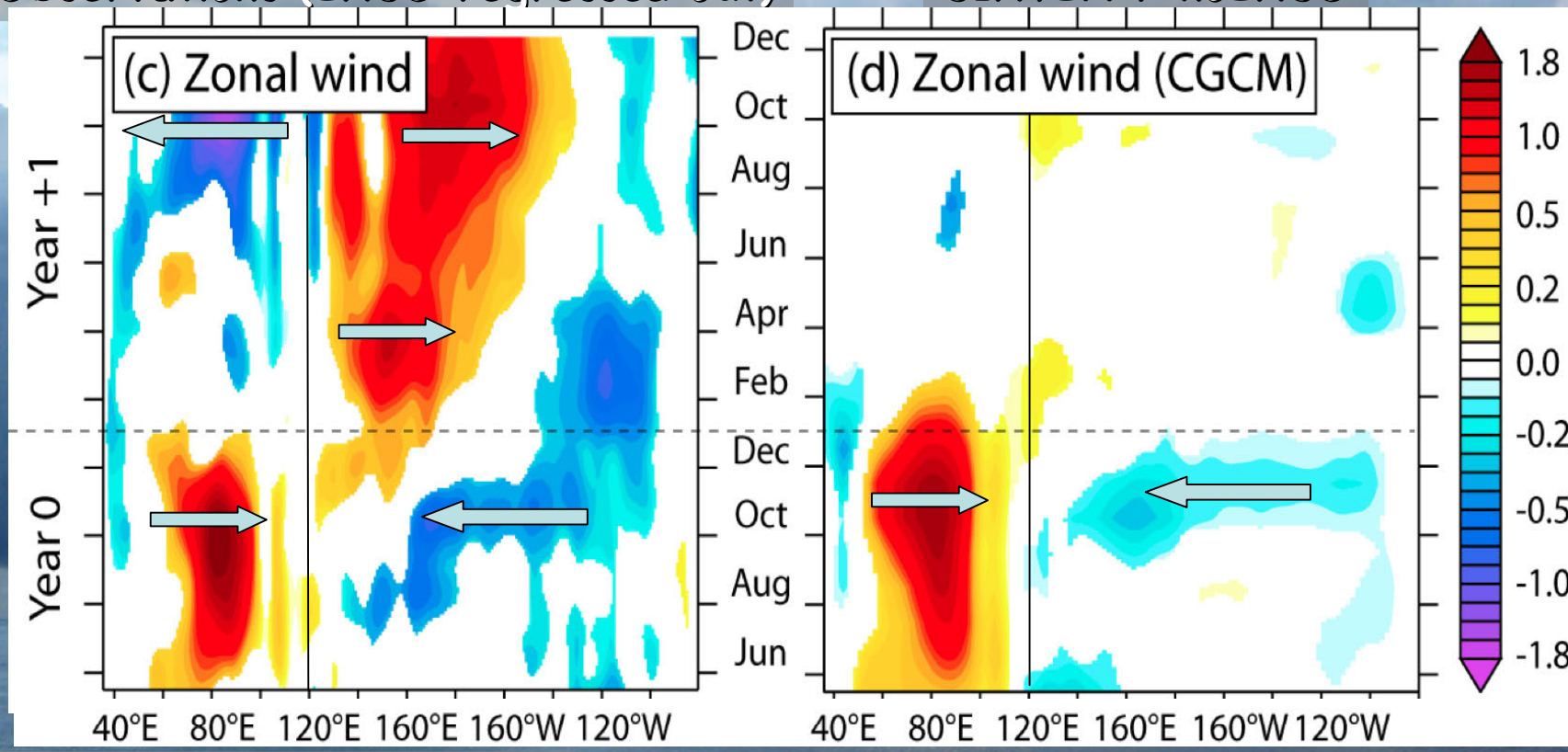
Using an IOD index results in a large and statistically significant improvement of linear hindcasts of ENSO peak 14 months in advance

improvement of forecasts of 1997 El Niño and 1998 La Niña
Equivalent contribution from WWV and IOD

Influence of the IOD on ENSO trigerring: *mechanism?*

Indo-Pacific anomalies associated with a negative IOD:

Observations (ENSO regressed out) | SINTEX-F noENSO

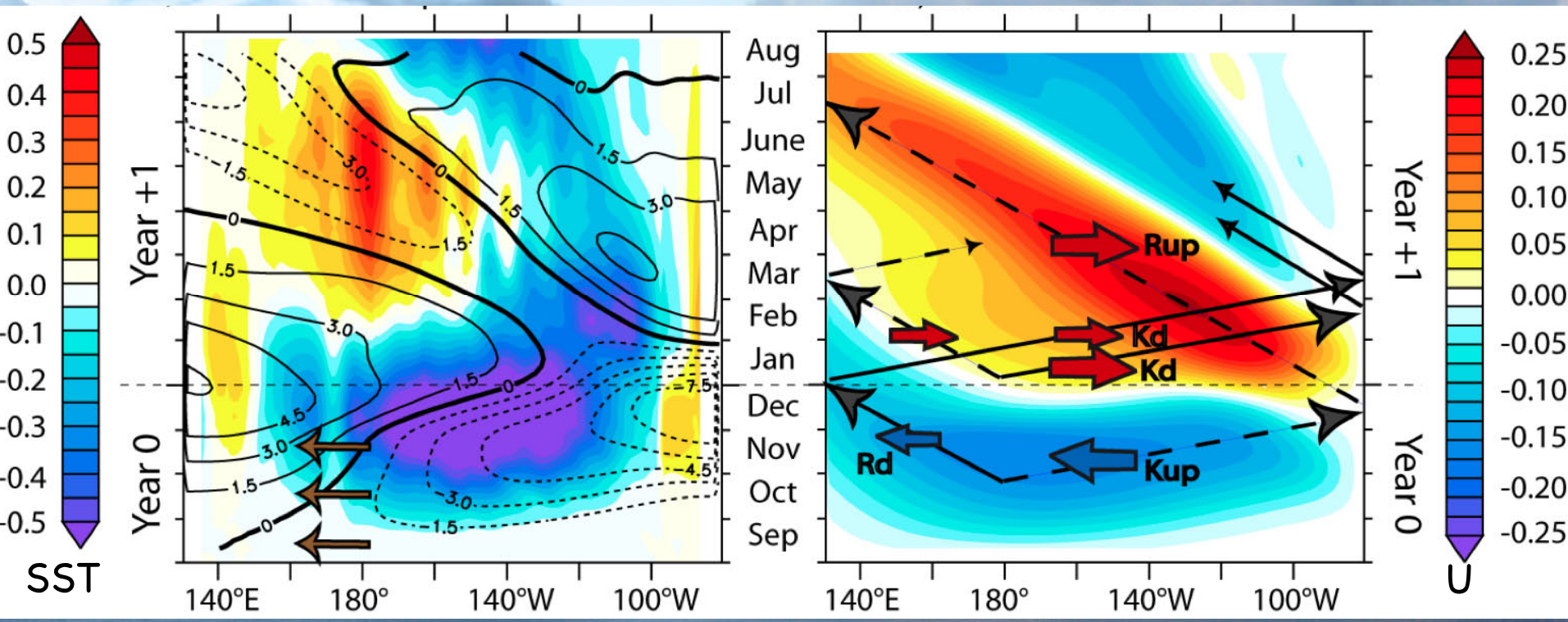


(Izumo et al. 2010)

This regression analysis suggests that the negative IOD enhances the Walker circulation, with anomalous easterlies over the Pacific that brutally disappear with the IOD demise in Nov-Dec.

Equatorial Pacific response to the negative IOD external forcing in a shallow water model

(Izumo et al. 2010)



Wave reflection at both boundaries => as in the delayed oscillator and advective-reflective paradigms, but in association with IOD-induced external forcing

SST anomaly in the central Pacific is the result of zonal advection of climatological SST (Picaut et al. 1996; Vialard et al., 2001) => triggers the Bjerknes feedback

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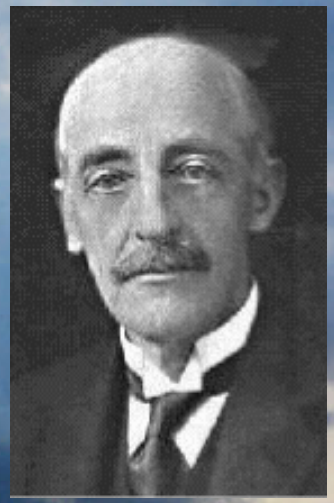
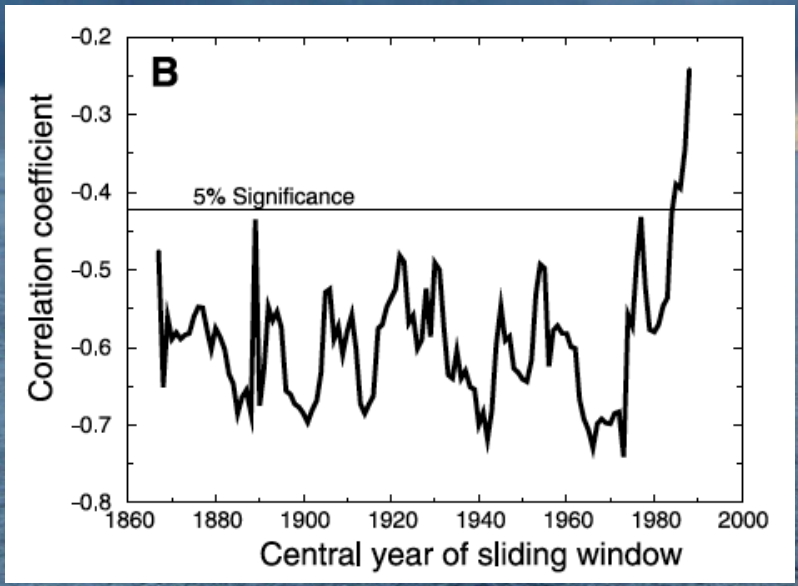
El Niño - Southern Oscillation

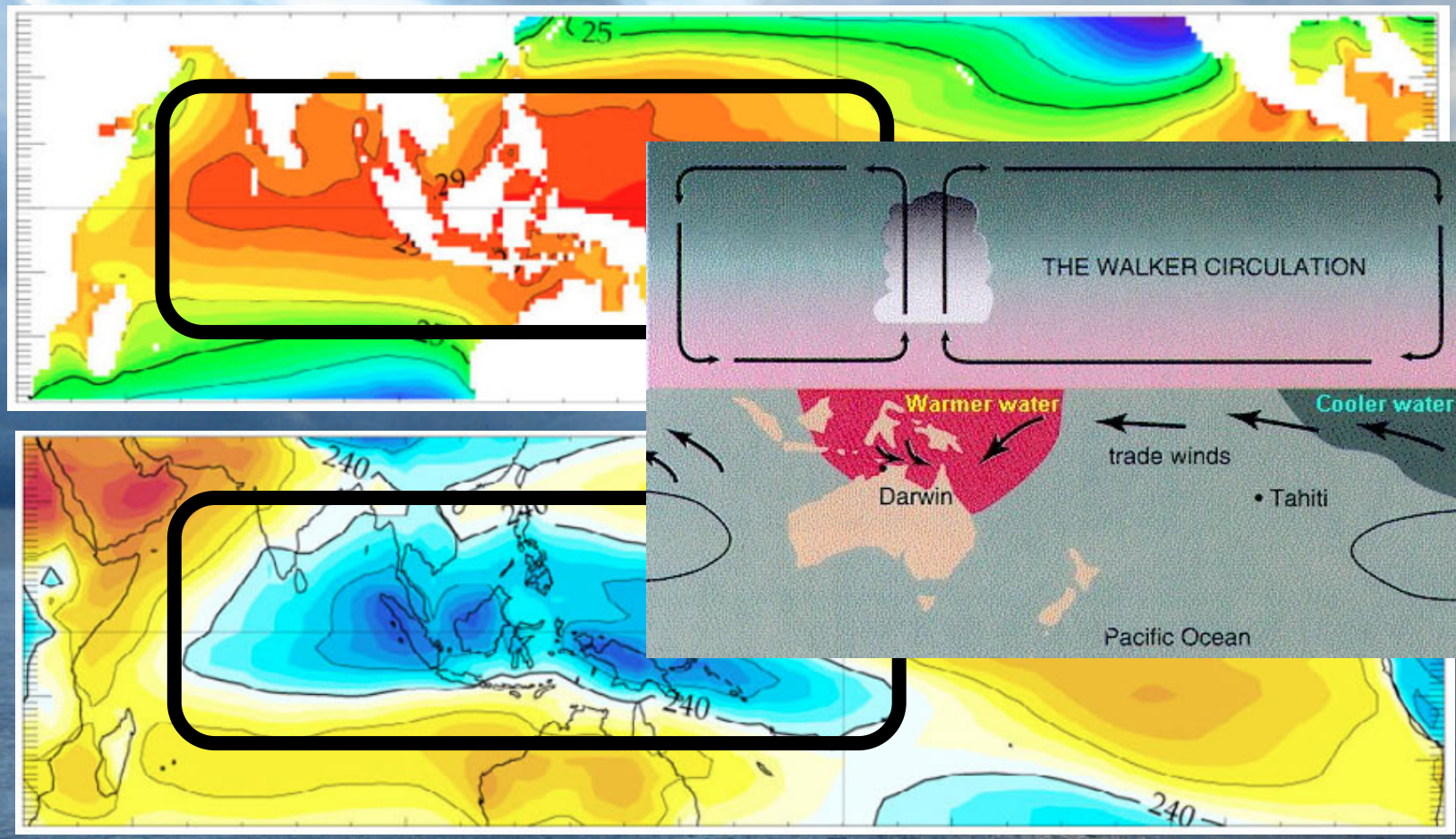
Sir Gilbert Walker, in a 1924 paper in the Memoirs of the Indian Meteorological department wrote: "By the Southern Oscillation it is implied the tendency of pressure at stations in the Pacific (…), and of rainfall in India and Java (…) to increase while pressure in the region of the Indian Ocean (…) decreases". He identified the eastern Pacific as a driving region but underlined clearly the near-global nature of ENSO.





(Krishna Kumar et al., 1999)
The link between ENSO and the Indian monsoon has weakened during recent decades…
And the scientific community has focussed a lot on the Pacific!

Let's go back to Walker's legacy

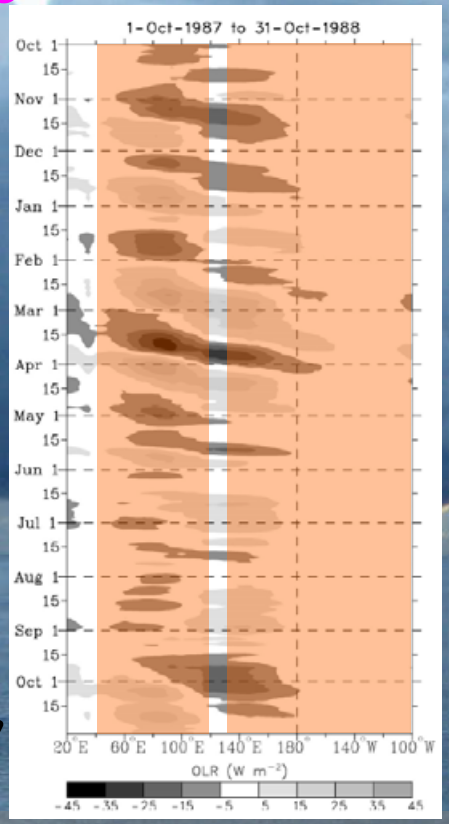


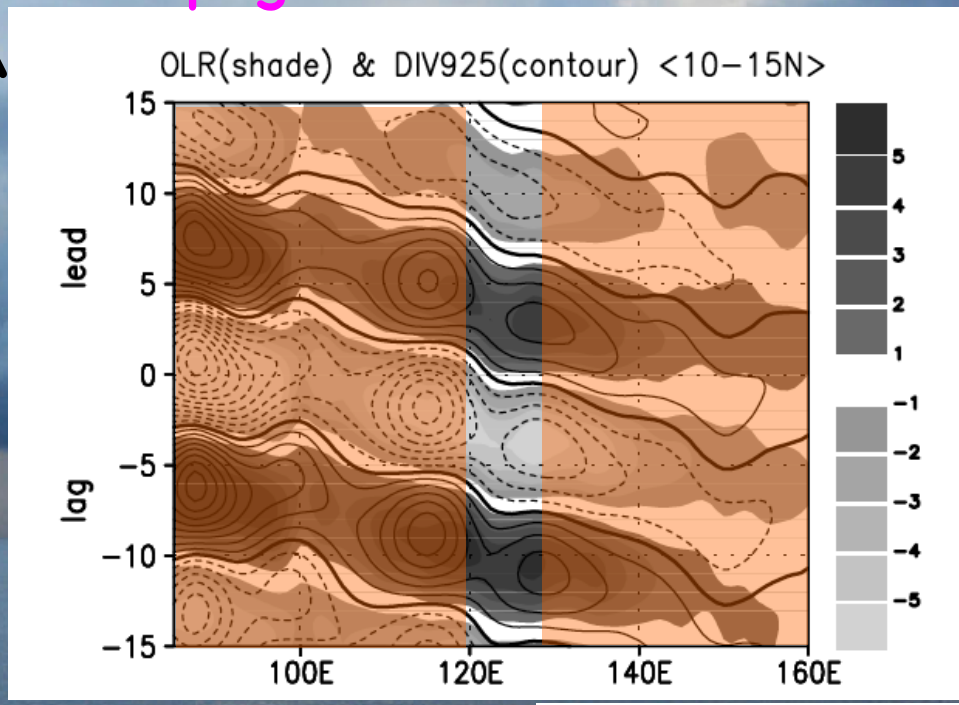
An Indo-Pacific perspective

MJO and Quasi-biweekly variability

Propagates from IO to PO

Propagates from PO to IO



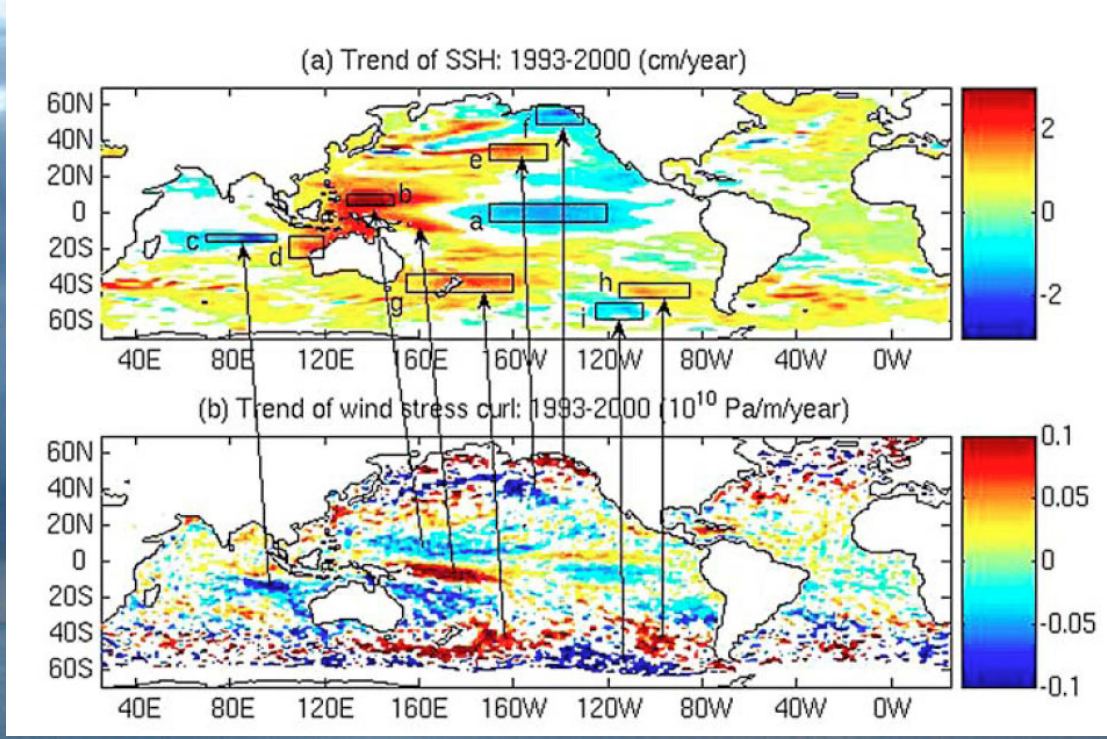


(Goswami 2005)

The Pacific and Indian oceans are highly interactive systems at intraseasonal timescales

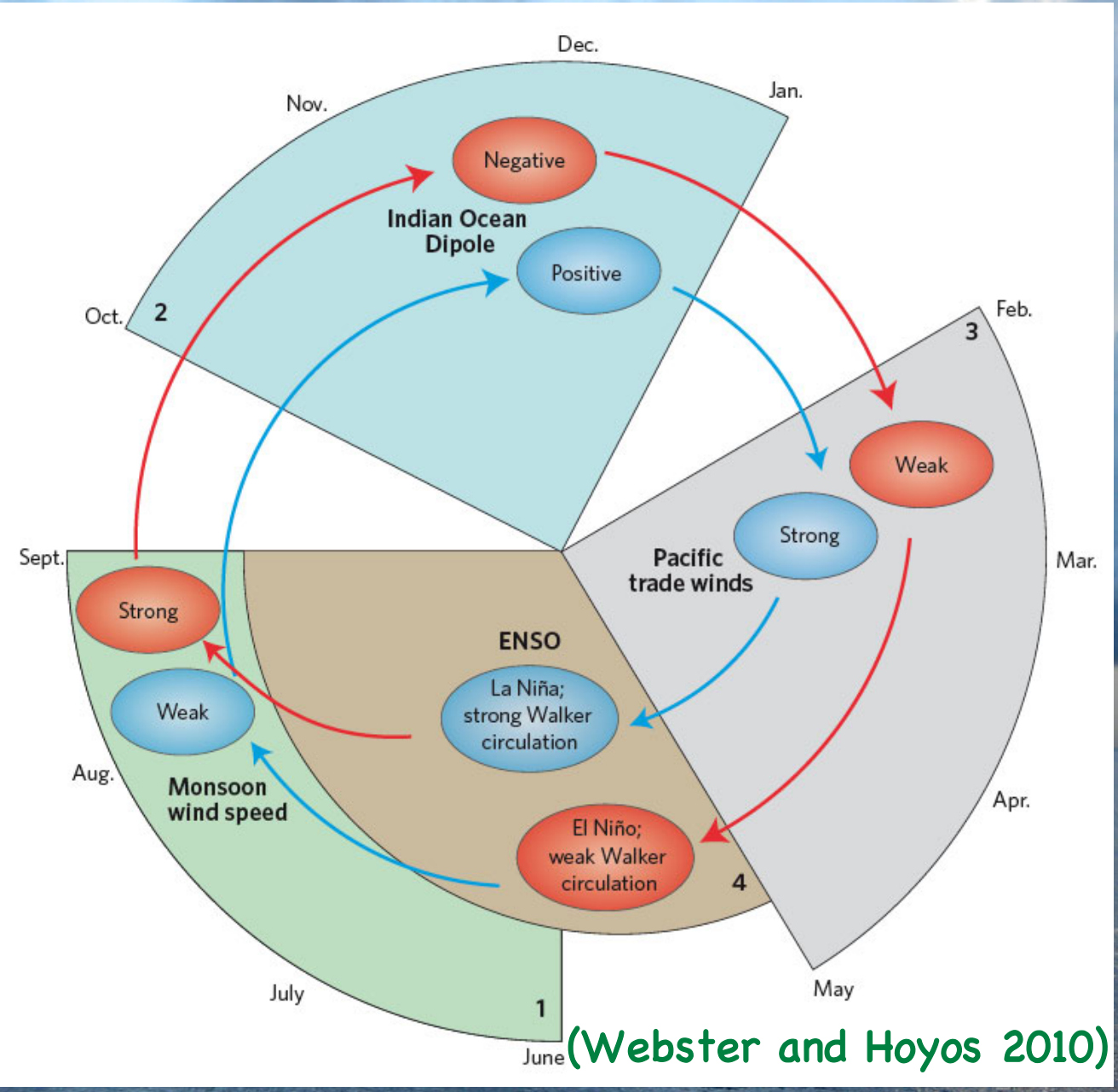
An Indo-Pacific perspective

Decadal variability



(Lee and McPhaden 2008)

The Pacific seems to drive the Indian Ocean at decadal timescales



(Webster and Hoyos 2010)

Is there a real effect of the IO on El Niño?

Is it a statistical artefact of the "biennial nature of El Niño"

Issues to resolve

Is there a real effect of the IO on El Niño ? (data issues!)

Is it due to ENSO-induced IO SST warming or to the IOD?

Exact mechanism? Synchronous or delayed influence?

Hugo Dayan's PhD (consistency accross models and datasets)

Homework (views from an outsider)

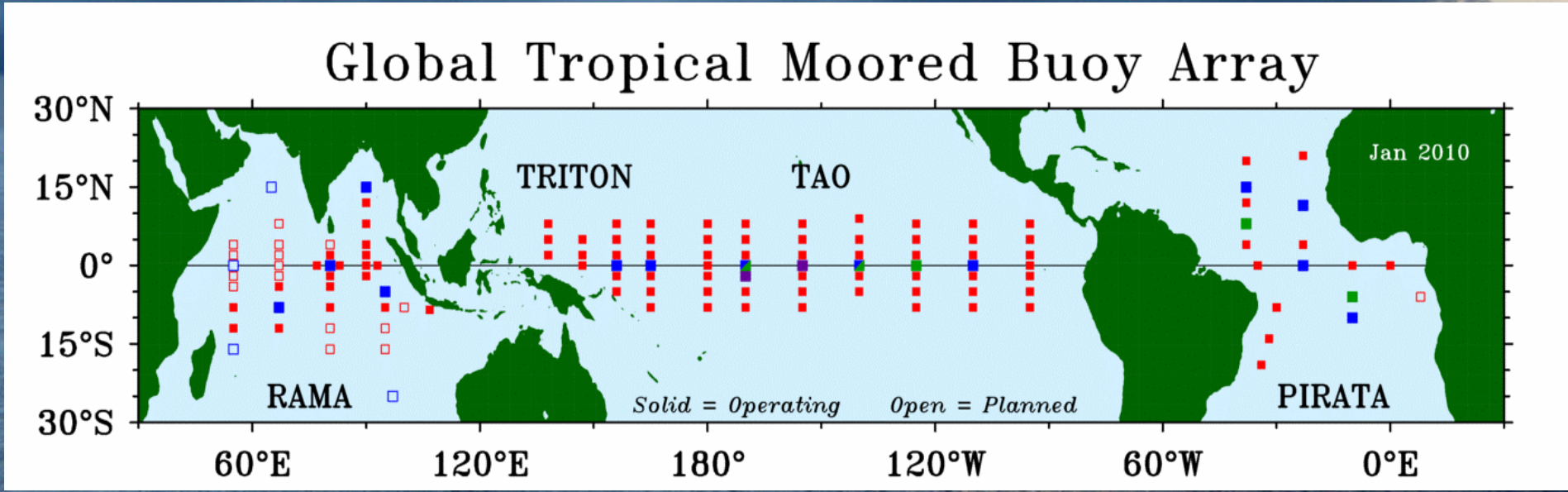
We now have a good understanding of the mechanisms of the El Niño cycle

We begin to have some understanding of the causes of some model errors (or at least have encouraging ways to follow)

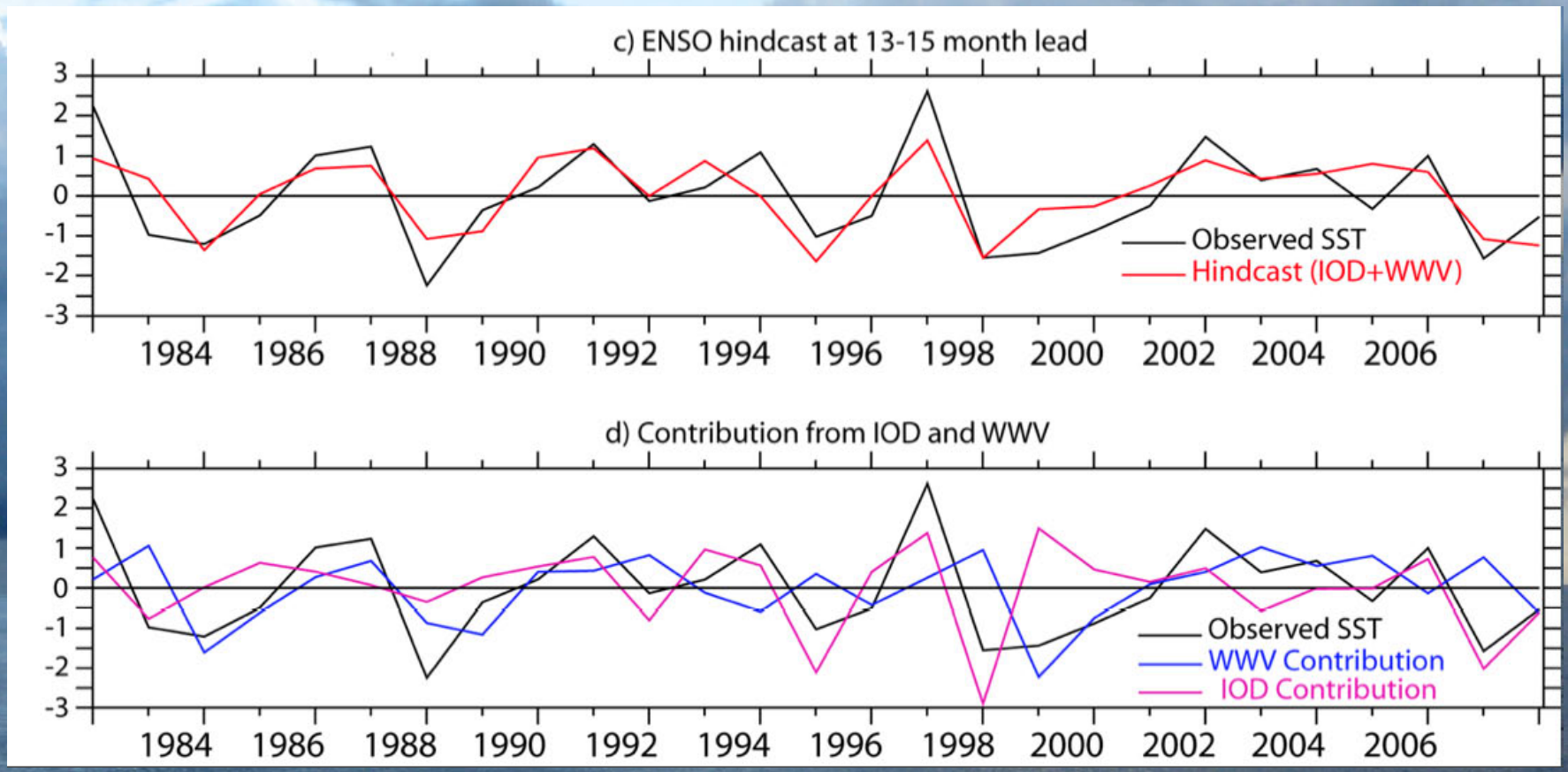
We don't know what triggers El Niño: WWBs, the MJO, seasonal footprinting, the Atlantic ocean, the Indian ocean? Or is there a bigger picture that we miss.

Why study the Indian Ocean ?

If the Indian Ocean impact on El Niño is confirmed, there is a (additional) huge incentive to better observe the Indian Ocean

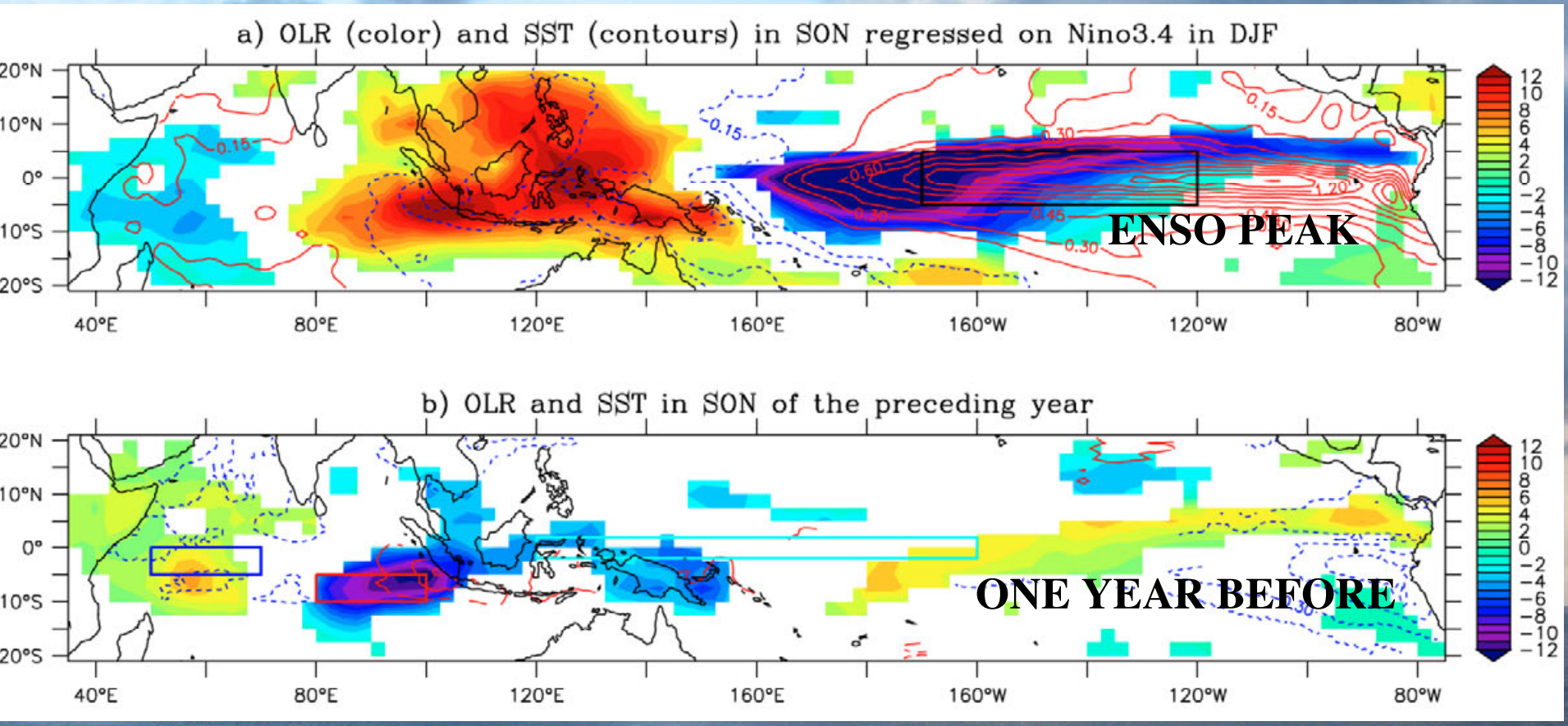


IOD, a precursor of following year's ENSO state



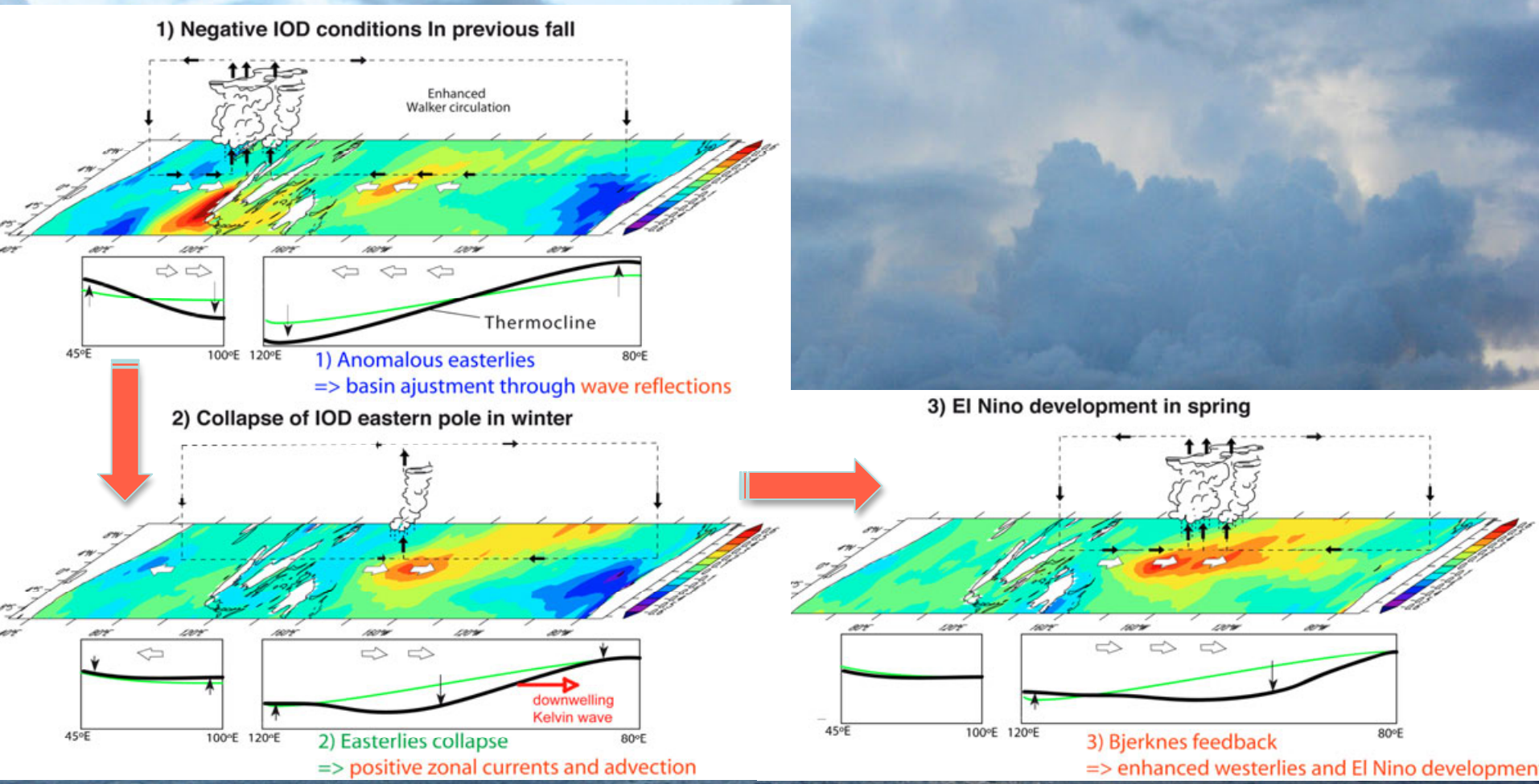
improvement of forecasts of 1997 El Niño and 1998 La Niña
Equivalent contribution from WWV and IOD

Can the IOD trigger an El Niño?



There is a tendency of a negative IOD to lead ENSO 14 months in advance (at the 99% confidence level, and with several different indices of the IOD)

El Niño triggering by the IOD

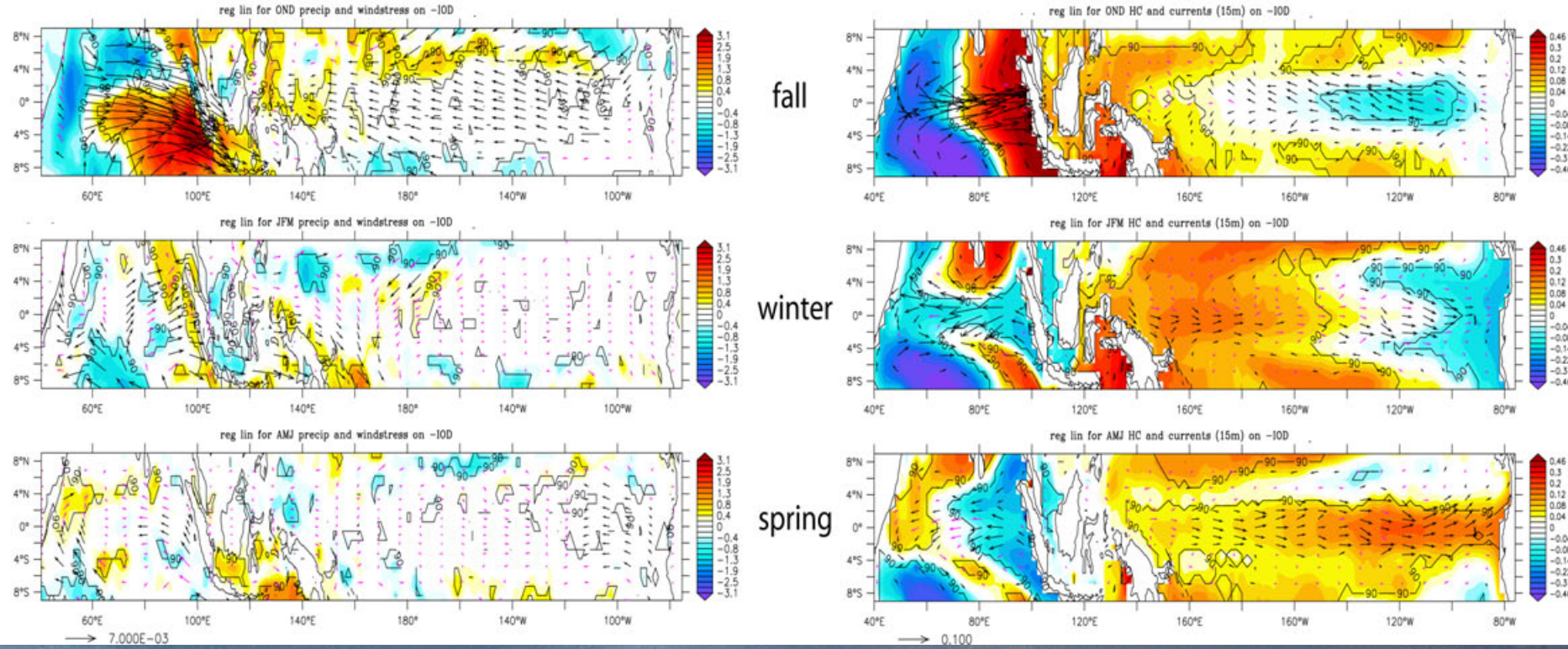


Mechanism confirmed by the SINTEX-F noENSO experiment

During and after a negative IOD in the noENSO experiment:

Precip and windstress

Oceanic heat content and currents



1) **Fall:** negative IOD => increased Walker circulation and easterlies *(possibly reinforced by the Bjerknes feedback in the real world)*

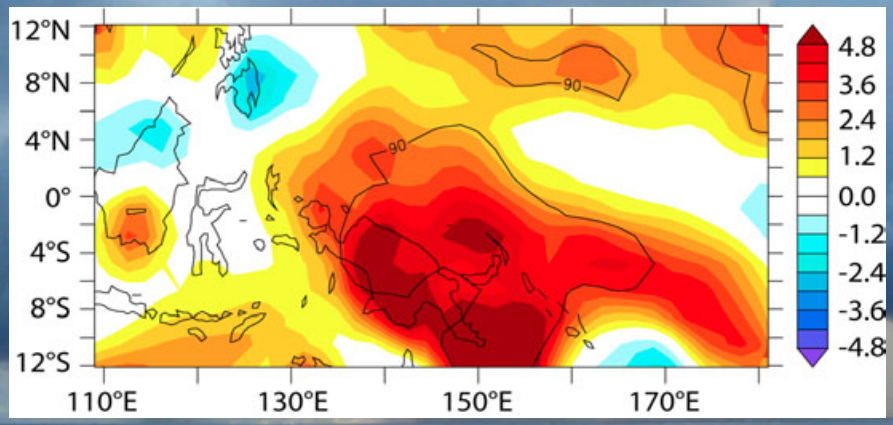
2) **Winter:** *IOD eastern pole collapses (seasonal phase-locking)* => wave adjustment favouring downwelling and eastward current

3) **Spring :** *Bjerknes feedback*

The MJO activity, an additional player?

Many studies suggest a strong role of atmospheric stochastic forcing (MJO, WWBs) on El Niño: then why such a high predictability at long lags?

Regression of zonal wind stress on –IOD of winter intraseasonal activity :



Negative IODs tend to be followed by more intense MJO activity in the Indian Ocean (Izumo et al., Clim. Dyn., 2010) and western Pacific => may also favour El Nino through Kessler et al. (1995) mechanism, or is alternatively just a "passive" consequence.