Influences of Indian Ocean dipole and Pacific recharge on following year's El Niño: historical robustness

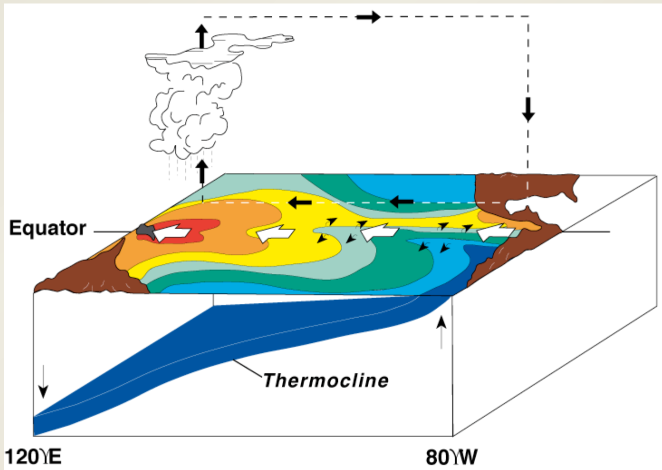
Takeshi Izumo[1, formerly at 2], Matthieu Lengaigne[1], Jérôme Vialard[1], Hugo Dayan[1], Jing-Jia Luo[3], Toshio Yamagata[2,3] and Gurvan Madec[1]

[1]IRD, LOCEAN/IPSL, France, [2]University of Tokyo, Japan, [3]JAMSTEC, Japan

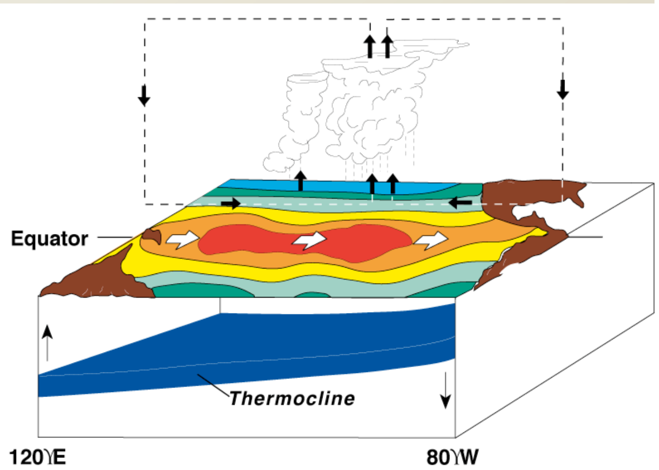
Droughts

Floods

Recharge of Warm Water Volume (WWV) during La Niña



Discharge of WWV during El Niño



Huge impacts of El Niño Southern Oscillation (ENSO)

Recharge-discharge mechanism [Jin 1997] of Warm Water Volume (WWV [Meinen and McPhaden 2000]) => ENSO predictability

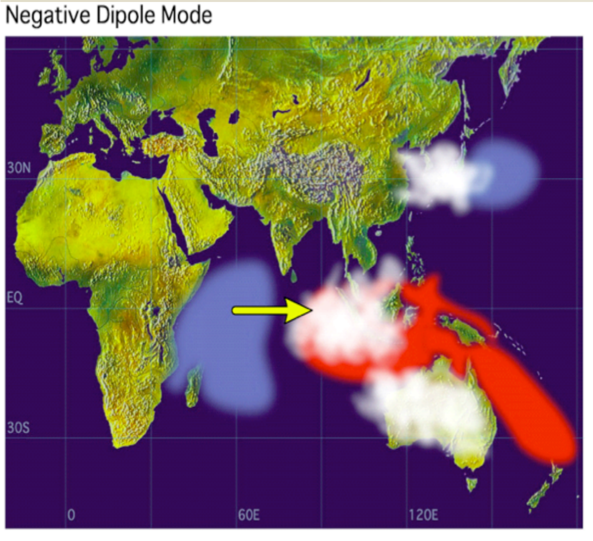
But still a « spring predictability barrier » =>Atmospheric noise, and/or something else?

Influences of Indian Ocean dipole and Pacific recharge on following year's El Niño: historical robustness

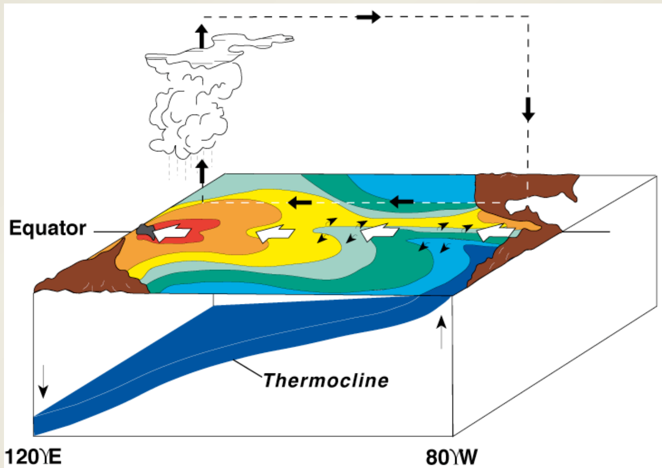
Takeshi Izumo[1, formerly at 2], Matthieu Lengaigne[1], Jérôme Vialard[1], Hugo Dayan[1], Jing-Jia Luo[3], Toshio Yamagata[2,3] and Gurvan Madec[1]

[1]IRD, LOCEAN/IPSL, France, [2]University of Tokyo, Japan, [3]JAMSTEC, Japan

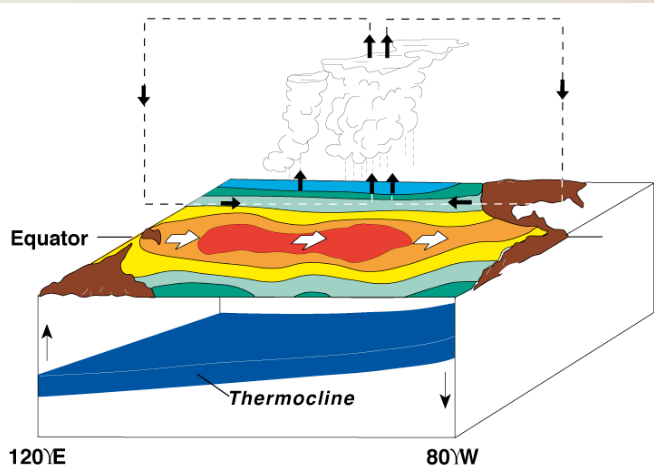
Indian Ocean dipole (IOD)



Recharge of Warm Water Volume (WWV) during La Niña



Discharge of WWV during El Niño



Huge impacts of El Niño Southern Oscillation (ENSO)

Recharge-discharge mechanism [Jin 1997] of Warm Water Volume (WWV [Meinen and McPhaden 2000]) => ENSO predictability

But still a « spring predictability barrier » =>Atmospheric noise, and/or something else?

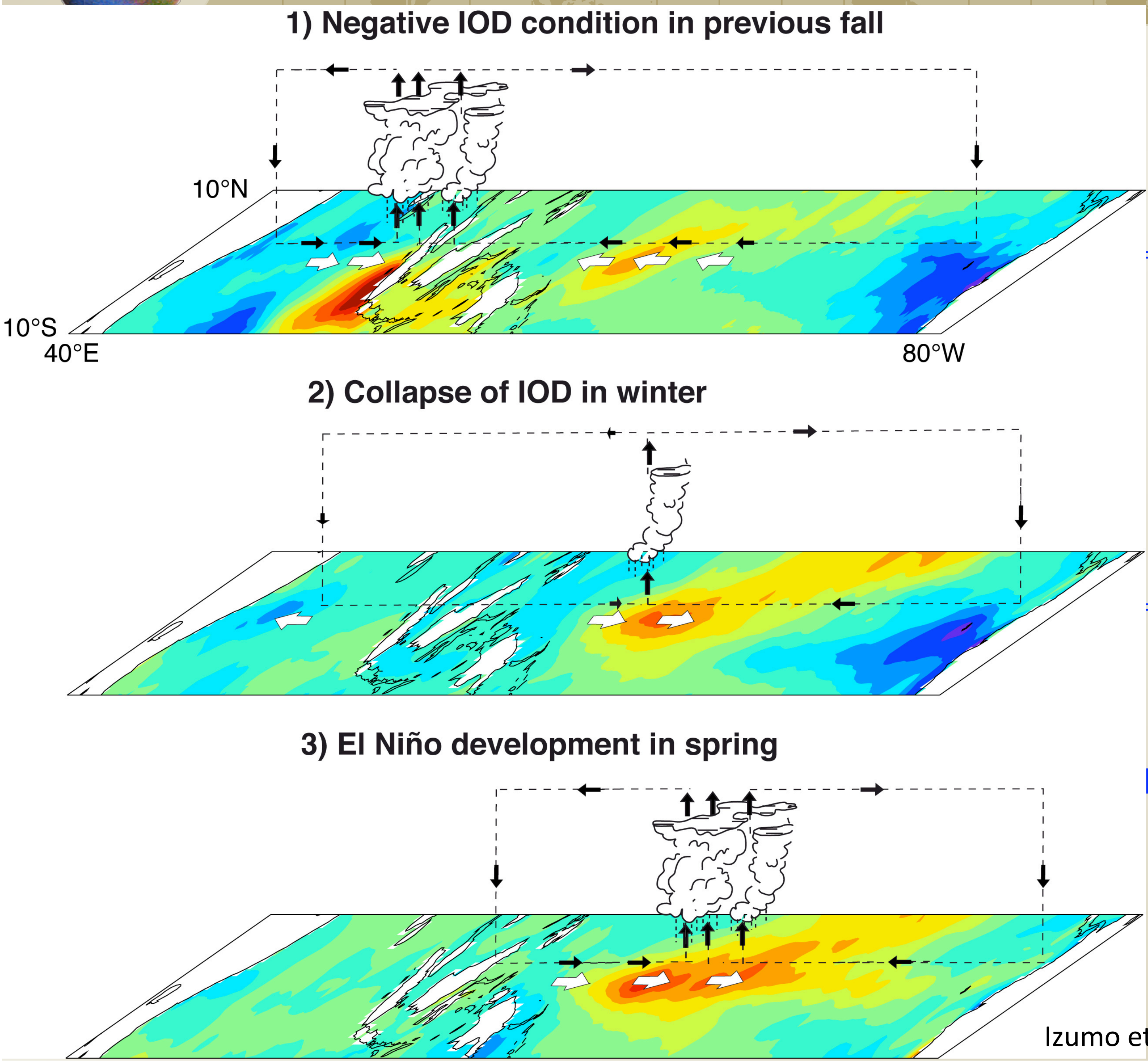
Outline

- 1) Introduction: IOD influence on following El Niño - mechanisms and issues

- 2) Construction of historical indices for IOD and WWV from the 1870s

- 3) Robustness and interdecadal stability of IOD and WWV influences on following El Niño

El Niño triggering by the IOD: suggested mechanism



⇒ IOD can, through variations in easterlies and related equatorial wave response in the Pacific, significantly influence next year's ENSO

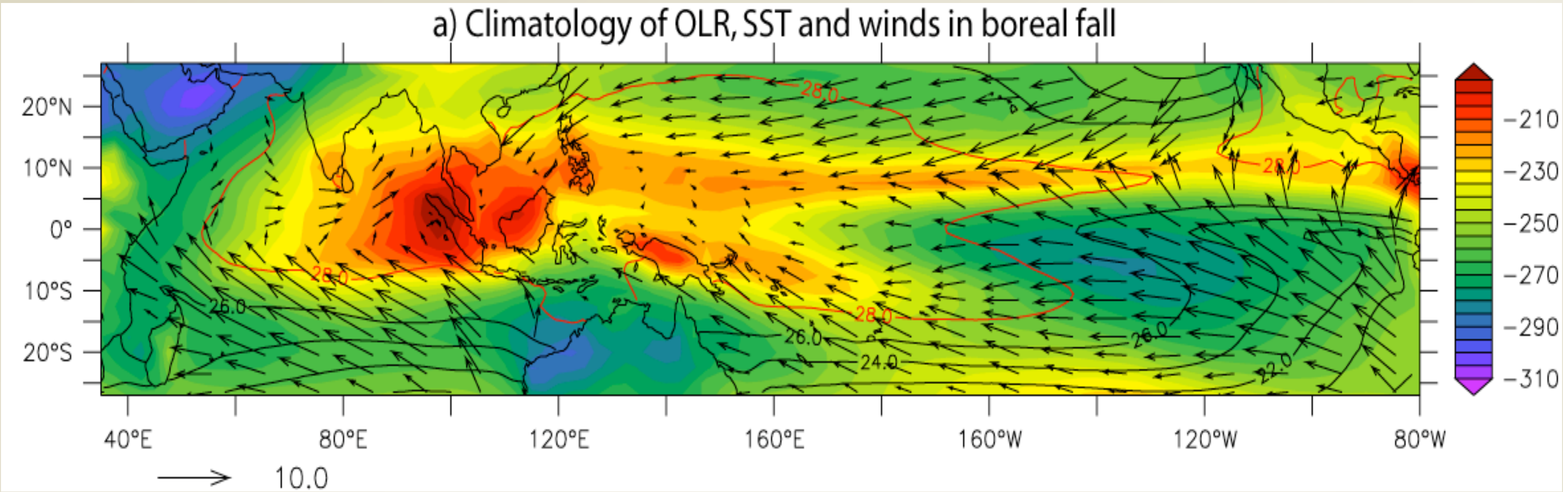
⇒ IOD is a good ENSO predictor, when combined to WWV in fall (yr0):

ENSO(yr+1)~ -IOD+ WWV

Skill of 0.8 at one year lead over 1981-2009.

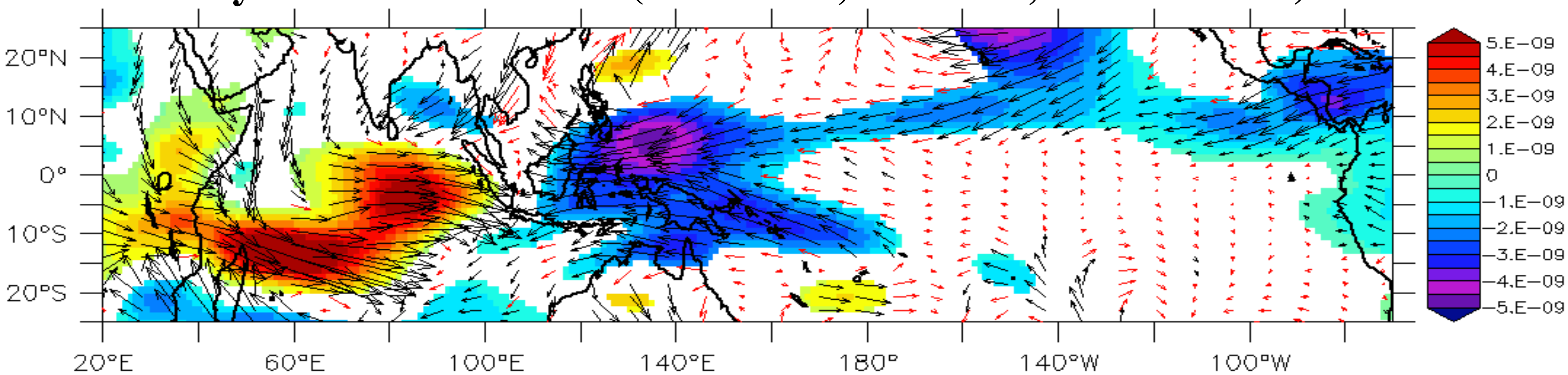
Izumo et al. 2010, *Nature Geoscience*

Mechanism for the IOD influence: atmospheric part



⇒deep convection, and so the ascending branch of the Walker circulation, is maximal over the eastern Indian Ocean in fall, the peak season for the IOD.

Windstress variations in December caused by IOD eastern pole collapse, in an AGCM forced by IOD observed SST (ECHAM5, T106L31, 40 ensembles):

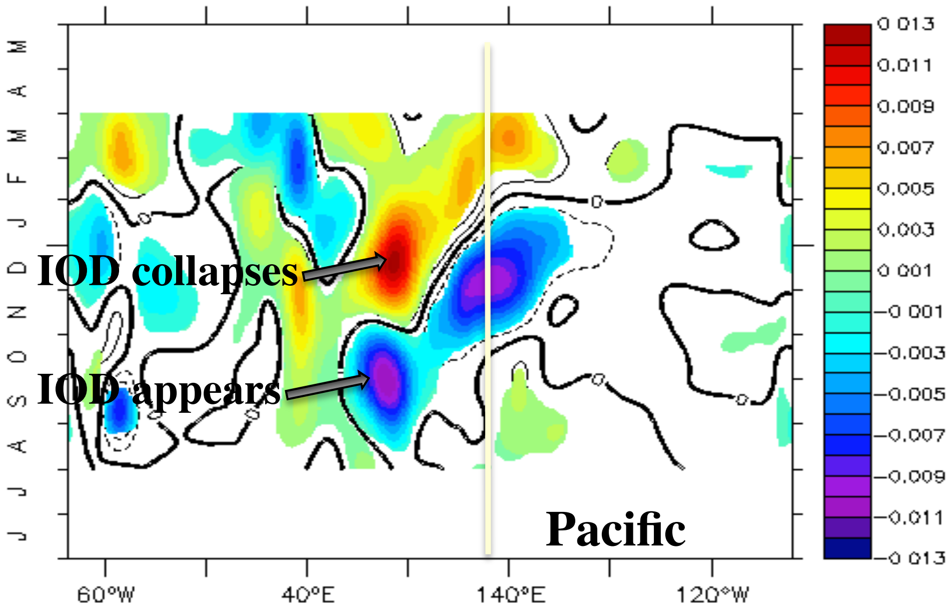


(agrees with Annamalai et al. 2010)

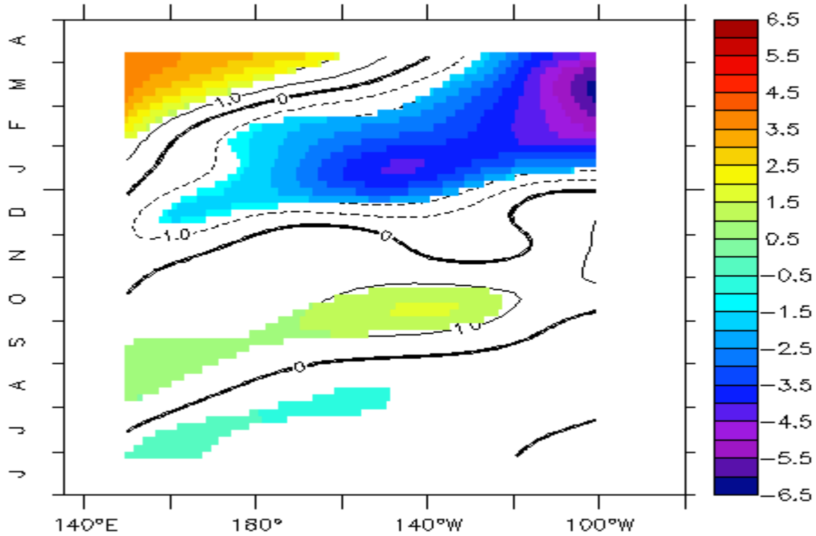
[Dayan et al., to be submitted]

Oceanic response to IOD-related wind forcing

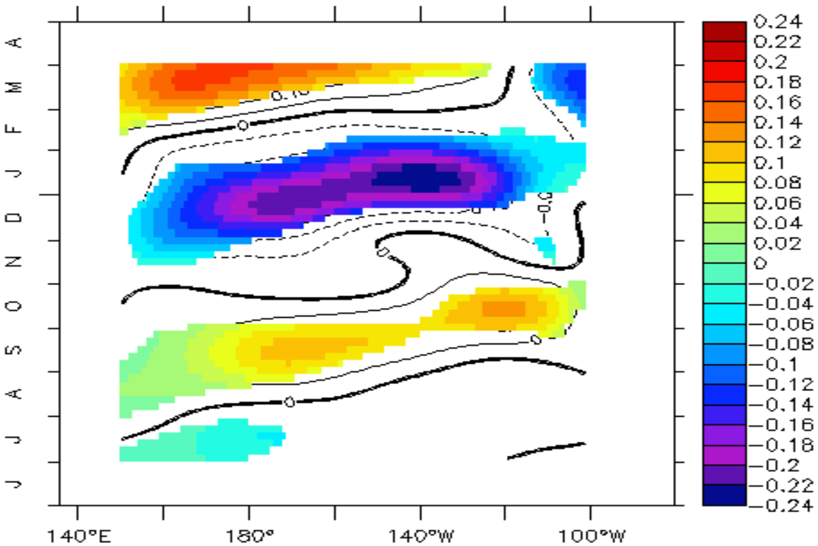
d(Taux)/dt of AGCM exp.



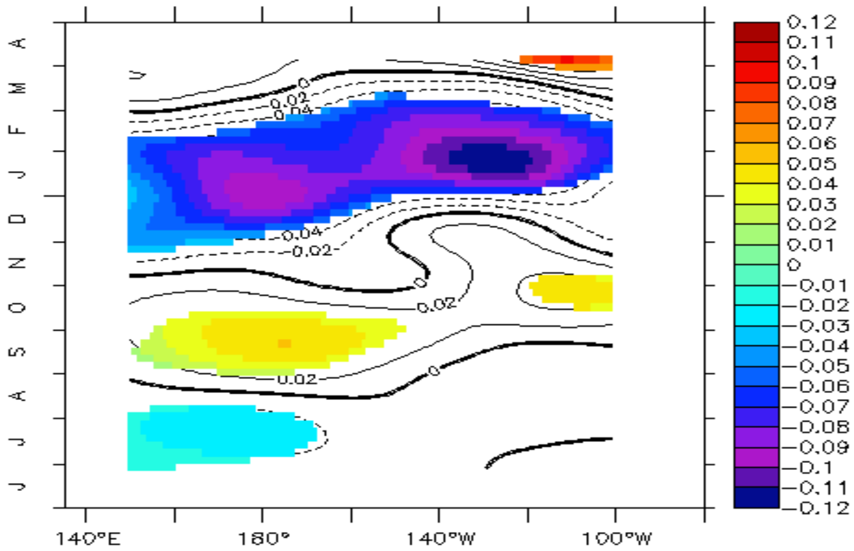
Thermocline depth of the shallow water Pacific



d(SST)/dt along the eq. Pacific



Zonal current

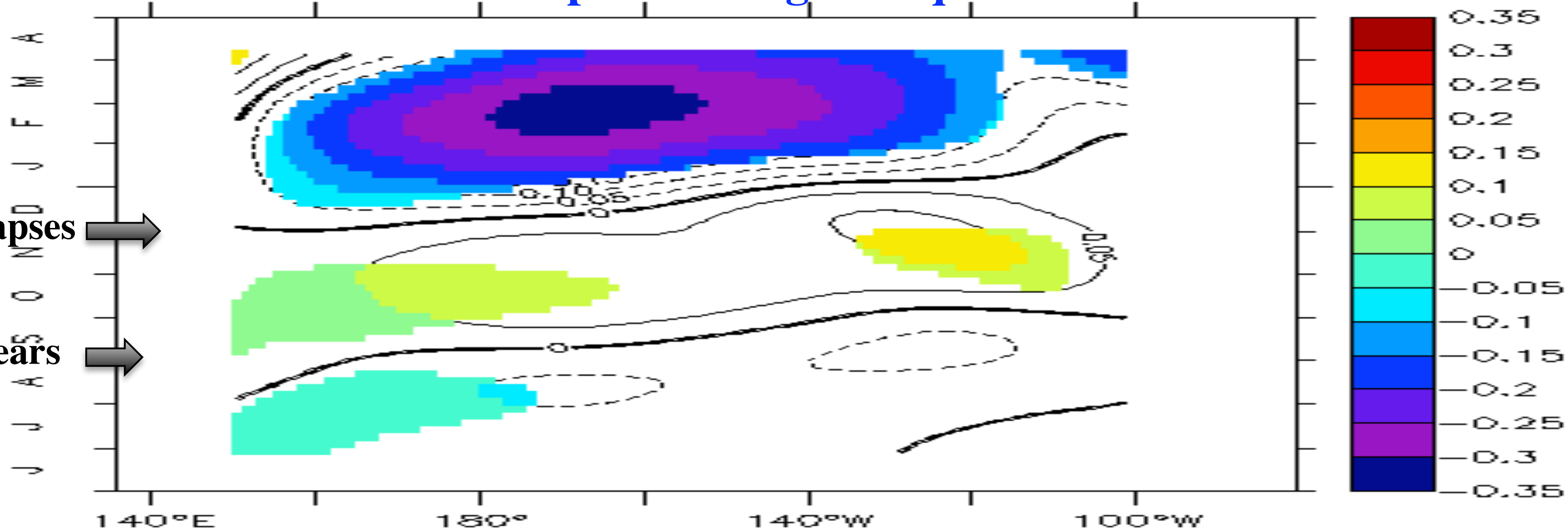


Oceanic response to IOD-related wind forcing

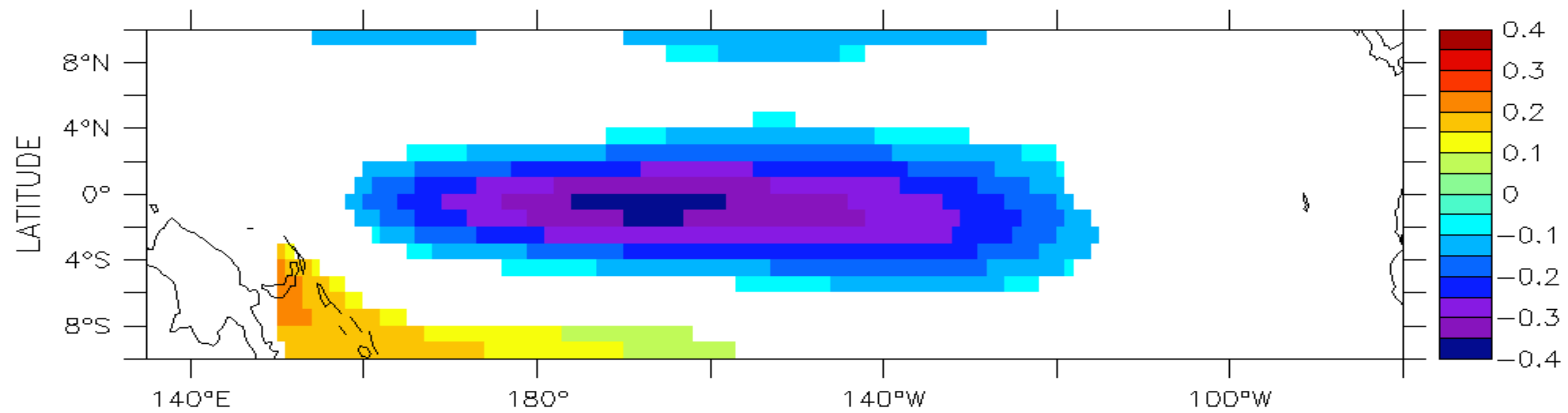
SST response along the equator

IOD collapses

IOD appears



SST response in Feb-March



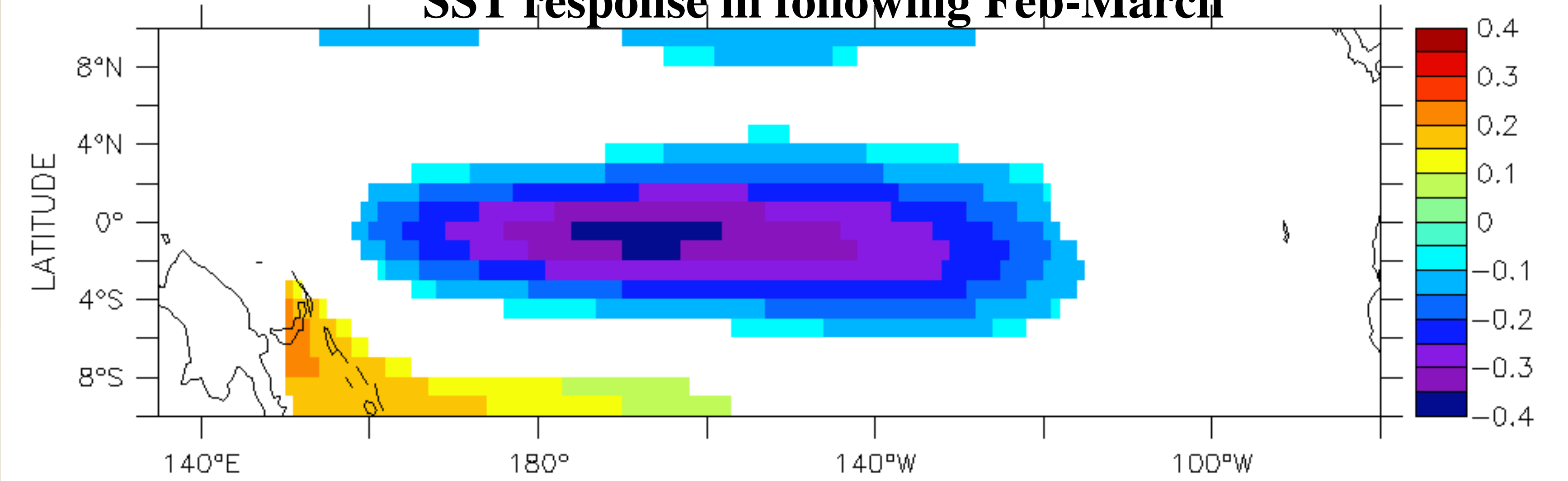
=> IOD significantly affects central Pacific SST in spring (SST' already of 0.4°C in this uncoupled setup), mostly through zonal advection of SST, i.e. displacement of the warmpool eastern edge

Atmospheric and oceanic response to IOD forcing

Main message:

Physically, the equatorial Pacific responds to windstress temporal variations.
Shallow water model of the Pacific forced by the AGCM experiments
=> IOD has its strongest influence on central Pacific SST in following spring.

SST response in following Feb-March

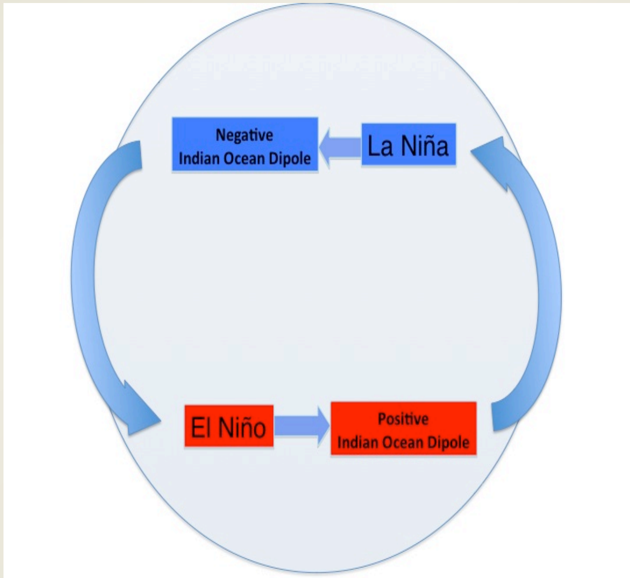


zonal advection of SST, i.e. displacement of the eastern edge of the warmpool

In the real world with the ocean-atmosphere coupling, this would trigger the Bjerkness feedback, if WWV preconditionning is favourable

Some issues

1) Are the IOD and WWV influences on following El Niño/La Niña robust before the 1980s, and are they stable interdecadally?

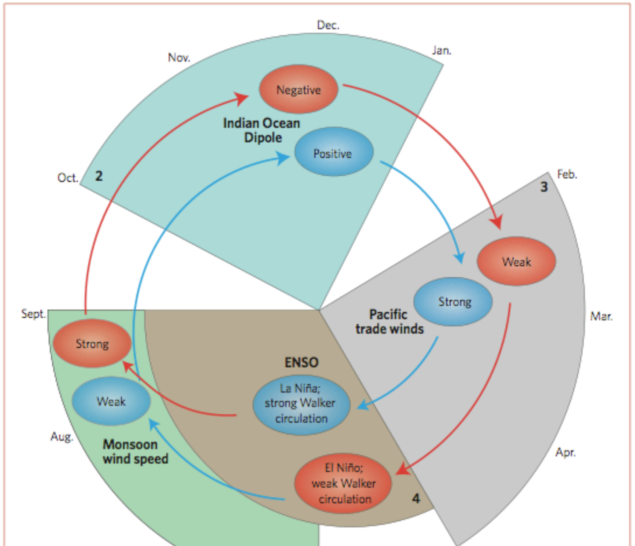


2) IOD-ENSO interactions and biennality?

Is Asian monsoon an active participant in it?

(Webster and Hoyos 2010)

3) Which types of ENSO are the IOD and WWV predictors of? Can we use IOD and WWV to improve one year-lead climate predictability globally, thanks to El Niño global teleconnections?



Webster and Hoyos 2010

News&Views, Nature Geoscience

Outline

- 1) Introduction: IOD influence on following El Niño - mechanisms and issues
- 2) Construction of historical indices for IOD and WWV from the 1870s
- 3) Robustness and interdecadal stability of IOD and WWV influences on following El Niño

Outline

- 1) Introduction: IOD influence on following El Niño - mechanisms and issues

- 2) Construction of historical indices for IOD and WWV from the 1870s:

ENSO: reconstructed indices Niño3.4 (and ESOI) of Bunge and Clarke [2009]
=> reliable

IOD: too many SST gaps to use the DMI
=> improvement through spatial regression: IOD_{hist} based on HadiSST (idem with HadSST2 and ERSSTv3b)
=> reliable

WWV: unsufficient historical subsurface obs. => need of a proxy

A Warm Water Volume (WWV) proxy based on windstress temporal integral

Main starting idea:

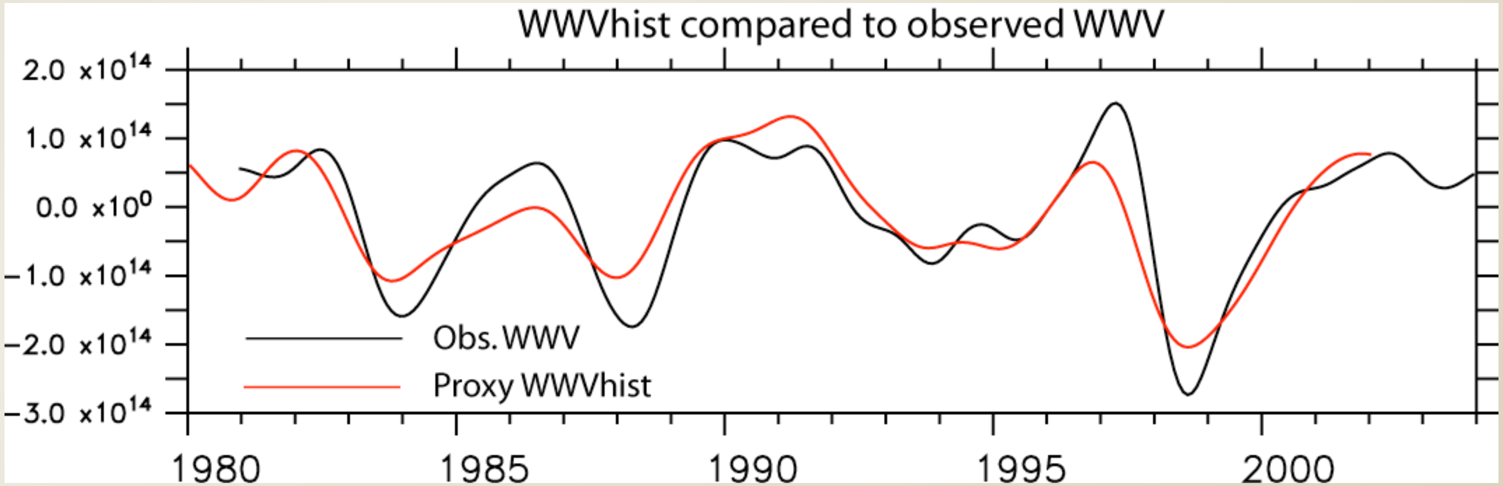
WWV interannual variations forced by equatorial zonal windstress (τ_x) :

$$dWWV/dt = -rWWV - \alpha\tau_x \ \sim= \ - \alpha\tau_x$$ [Jin (1997a,b), Burgers et al. (2005)]

=> WWV estimated as the temporal integral of τ_x

⇒ Construction of a WWV_{hist} historical proxy using windstress from 20th Century atmospheric reanalysis (1871-2008)

⇒ Good comparison with modern observations (correl. 0.87):



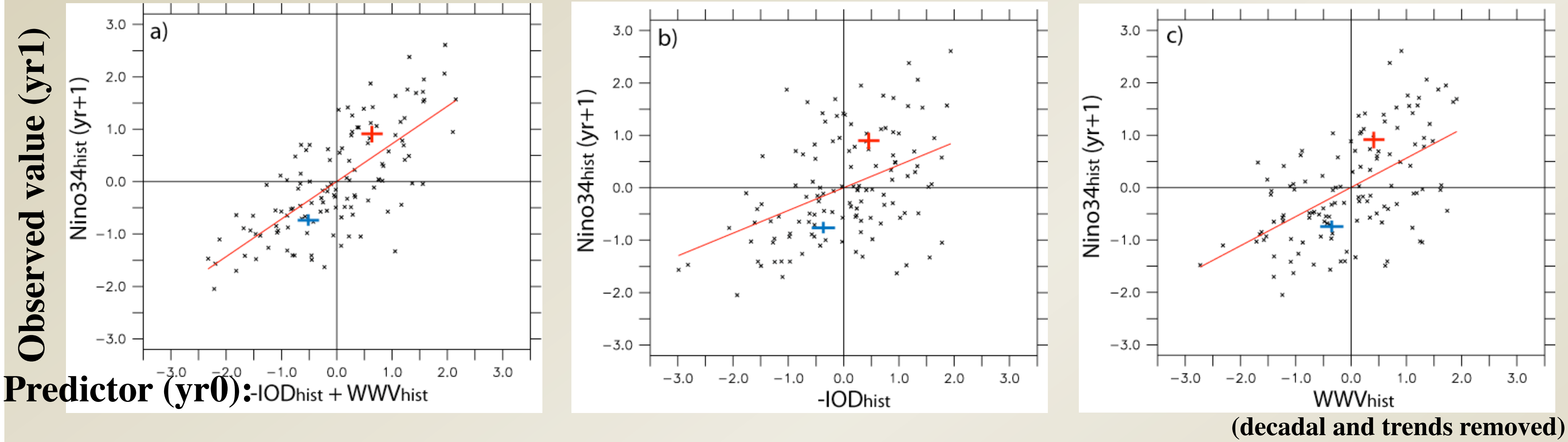
Outline

- 1) Introduction: IOD influence on following El Niño - mechanisms and issues

- 2) Construction of historical indices for IOD and WWV from the 1870s

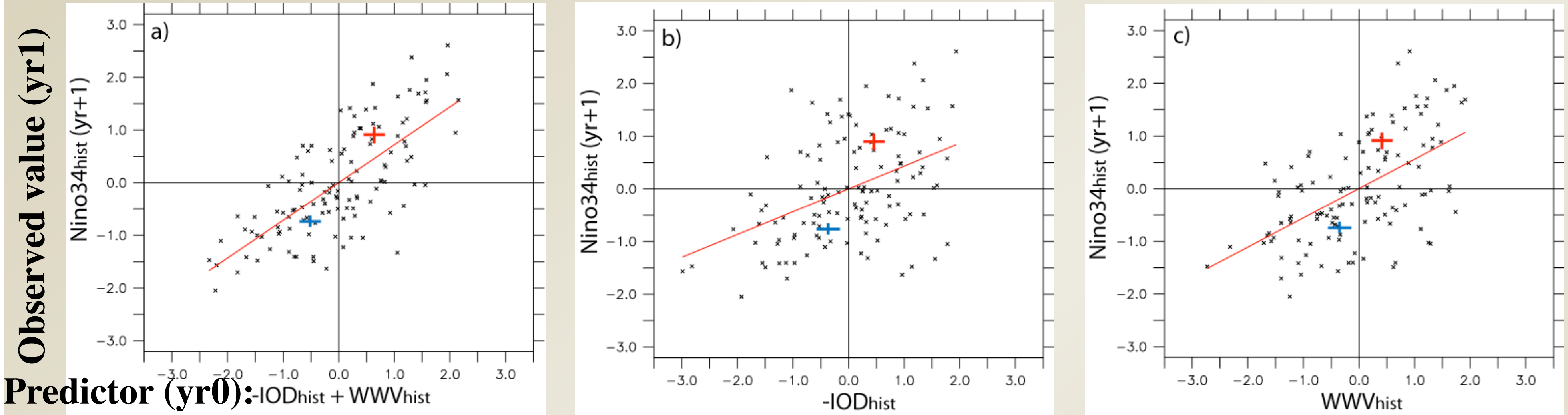
- 3) Robustness and interdecadal stability of IOD and WWV influences on following El Niño

Robustness of IOD and WWV influences on following year's El Niño during the 1870s-2000s period



=> good symmetric skill of –IOD+WWV to hindcast El Niño/La Niña events one year in advance

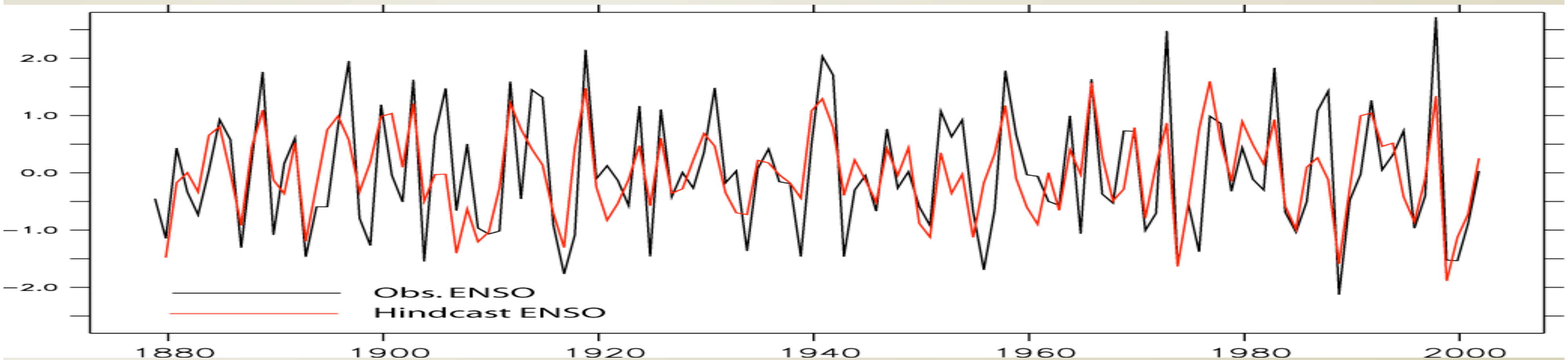
Robustness of IOD and WWV influences on following year's El Niño during the 1870s-2000s period



(decadal and trends removed)

=> good symmetric skill of –IOD+WWV to hindcast El Niño/La Niña events one year in advance

Observed Niño3.4$_{hist}$ (NDJ) and its hindcast using –IOD$_{hist}$ + WWV proxy with a ~1 year lead

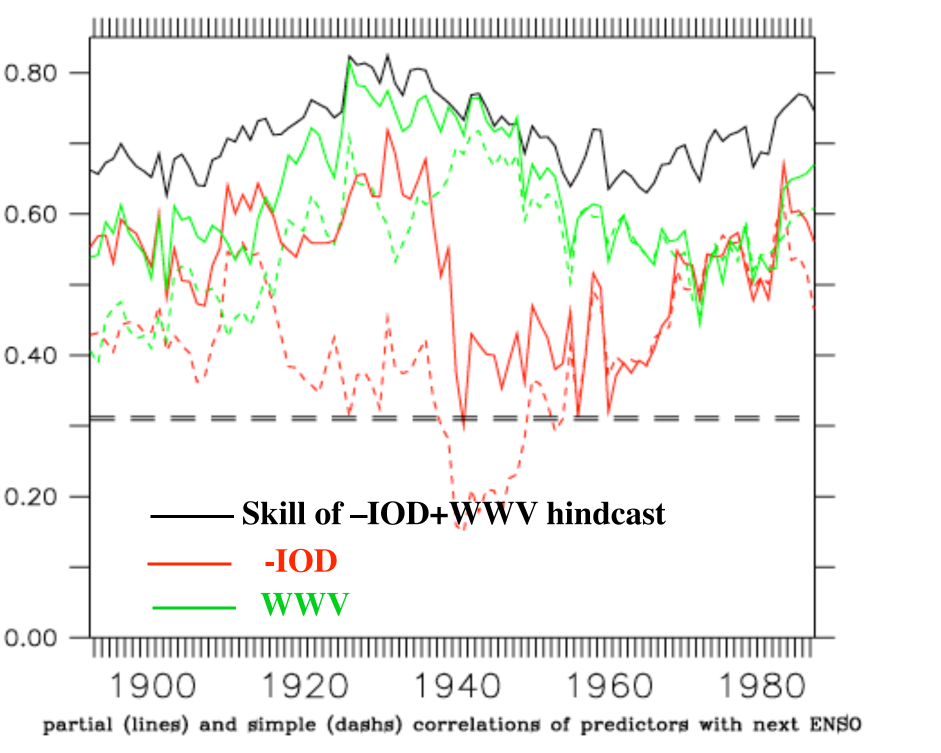


Correlation skill: 0.72

Interdecadal variations of IOD and WWV influences on ENSO?

One-year lead correlations with ENSO, in a 30 years sliding window

Historical observations



⇒ **Significant partial correlations of IOD and WWV with following year's ENSO**

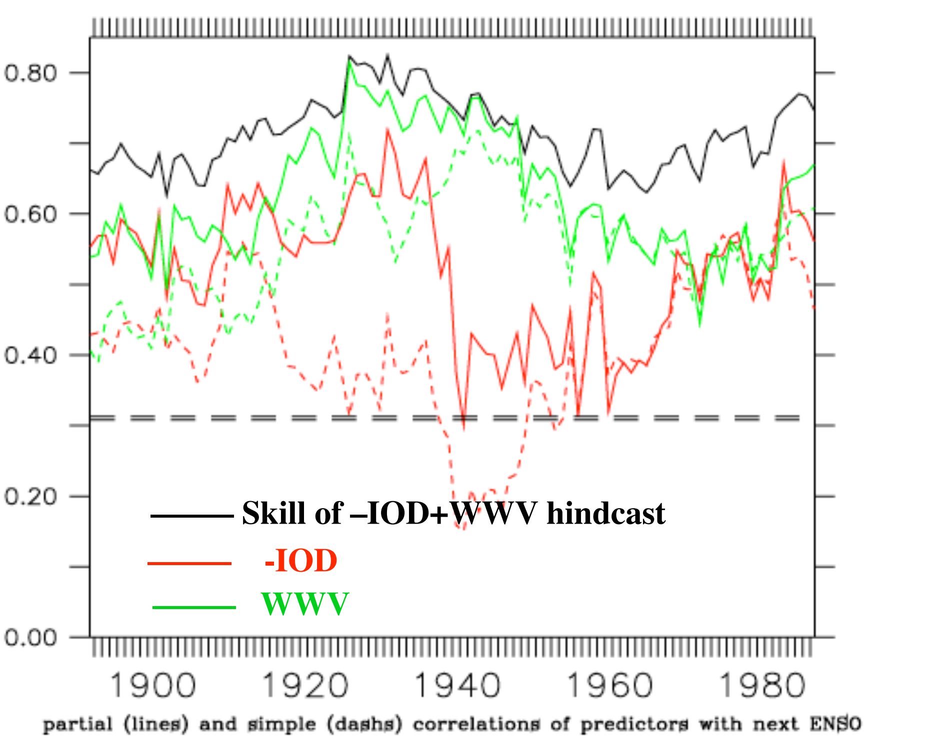
⇒Good and stable skill of –IOD+WWV hindcast regression

(with some interdecadal variations in the relative contributions of IOD and WWV)

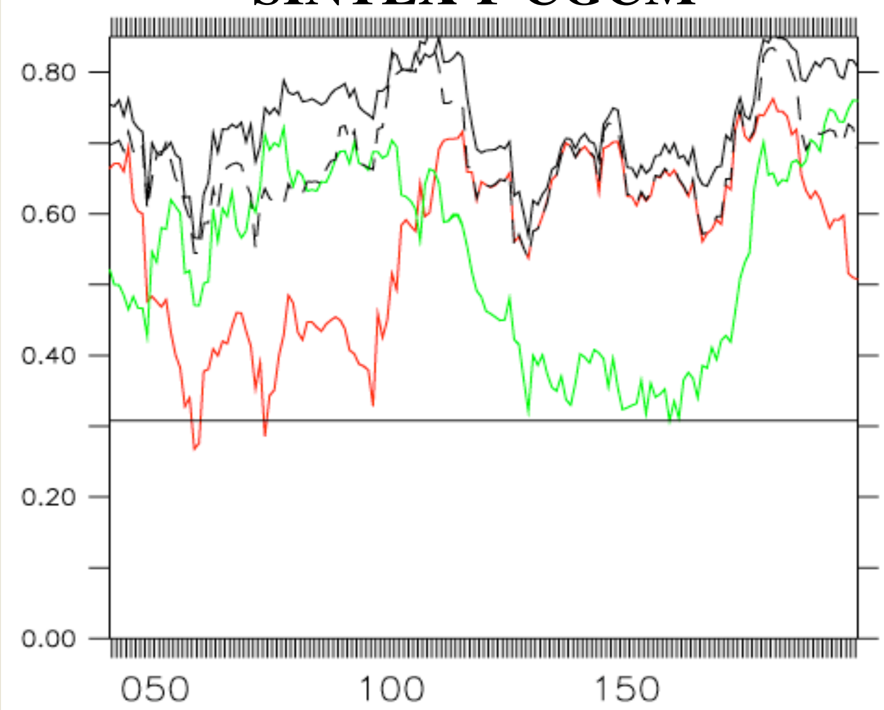
Interdecadal variations of IOD and WWV influences on ENSO?

One-year lead correlations with ENSO, in a 30 years sliding window

Historical observations



SINTEX-F CGCM



continuous line when using the **WWV$_{proxy}$**
dashed line when using the **exact WWV**

⇒ Significant partial correlations of IOD and WWV with following year's ENSO

=> Robustness in the CGCM also
=> Validation of the WWV$_{proxy}$ method)

⇒Good and stable skill of –IOD+WWV hindcast regression
(with some interdecadal variations in the relative contributions of IOD and WWV)

Testing other suggested predictors of following year's ENSO

Multiple regression for hindcasting next ENSO (NDJ0) using IOD_{hist}, WWV_{hist} and a 3rd predictor shown below:	Regression coefficient for 3rd predictor	Regression coefficient for IOD (SON-1)	Regression coefficient for WWV (SON-1)	Skill of multiple regression
Indian Ocean basin-wide warming/cooling (IOBW in JFM 0)	-0.09±0.15	**-0.34±0.15**	**0.58±0.10**	**0.72**
ENSO (NDJ-1)	0.11±0.15	**-0.49±0.15**	**0.55±0.11**	**0.72**
Indian summer monsoon (All Indian Rainfall in JJAS-1)	0.02±0.11	**-0.40±0.11**	**0.57±0.10**	**0.72**

=> IOD influence: not a statistical artefact of the "biennial nature of El Niño"

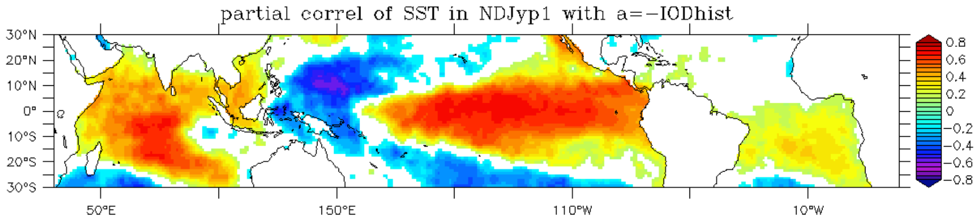
⇒Indian summer monsoon: not a precursor of following year's El Niño => probably not an active participant in IOD-ENSO interactions and biennality

Different contributions of IOD and WWV to the low and high-frequency parts of ENSO

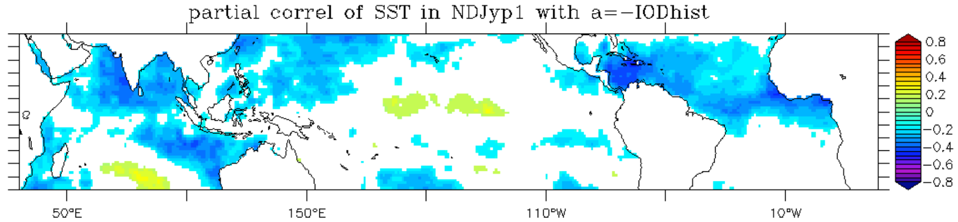
Partial correlation of SST in winter with previous year's –IOD or WWV, for:

« high-freq » HF band (2-3 years) — « low-freq. » LF band (3-7 years)

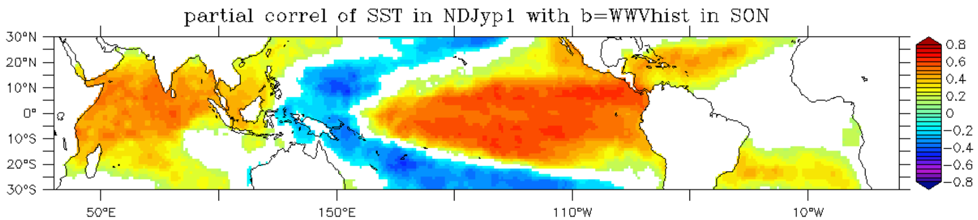
-IOD (HF band)



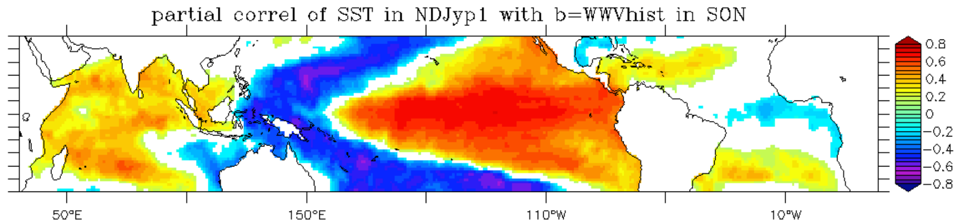
-IOD (LF band)



WWV (HF band)

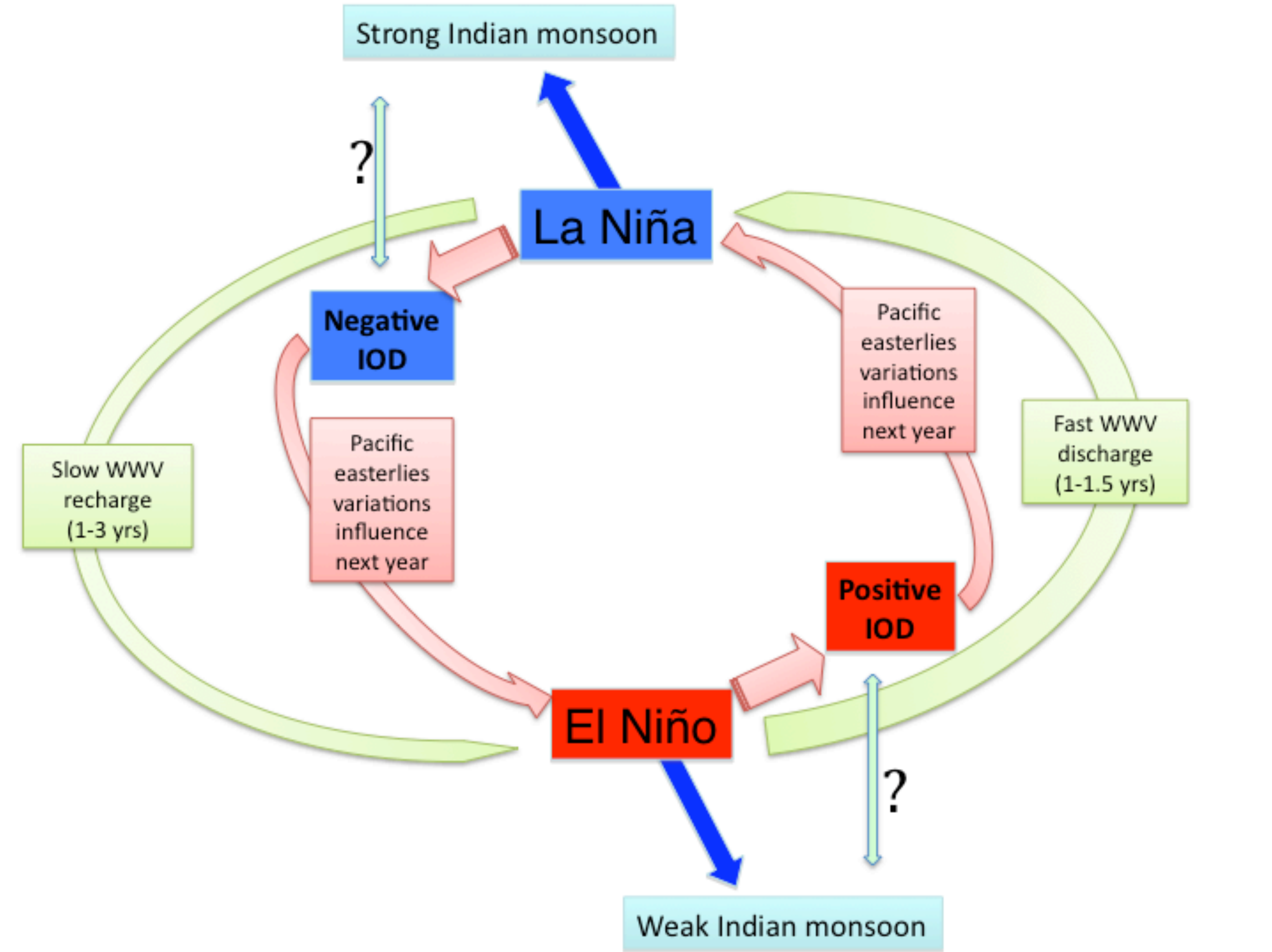


WWV (LF band)



=> IOD brings predictability for the HF band of ENSO (i.e. for year to year transitions, « biennality »), while WWV brings also predictability for the LF part of ENSO (> 3 yrs).

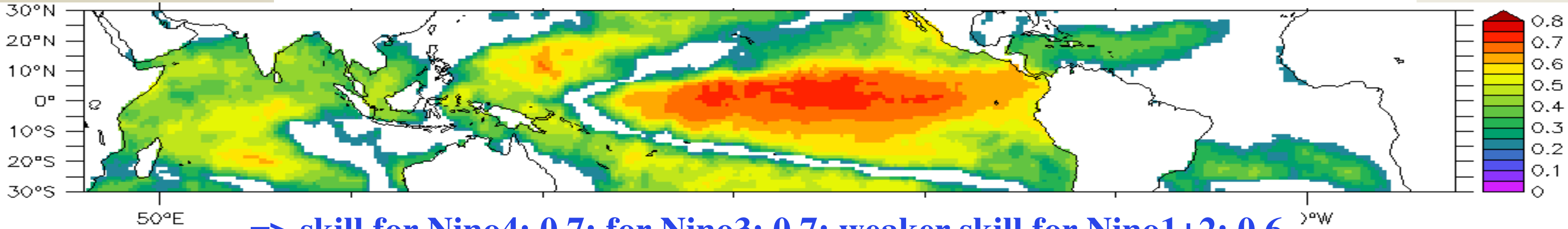
IOD-ENSO-WWV interactions: schematic



IOD-ENSO interactions could be crucial to the tropospheric tropical biennial tendency (TBO; Meehl et al. 2003, Kug et al. 2006) and interfere with the slower Pacific WWV recharge

Which types of ENSO do IOD and WWV favour?

Skill of –IOD+WWV regression to hindcast following year's winter SST



=> skill for Nino4: 0.7; for Nino3: 0.7; weaker skill for Nino1+2: 0.6

Hindcast scores for various indices and ENSO types, using	Partial correl. of IOD_{reg} (without WWV)	Partial correl. of WWV (without IOD)	Correl. skill of IOD+WWV hindcast model
DNino3.4	-0.55	0.64	0.72
-D_ESOI	-0.53	0.62	0.69
Nino_c (central Pac.)	-0.49	0.61	0.68
Nino_e (extreme east)	-0.19	0.41	0.43
EMI (Modoki)	-0.41	0.44	0.55

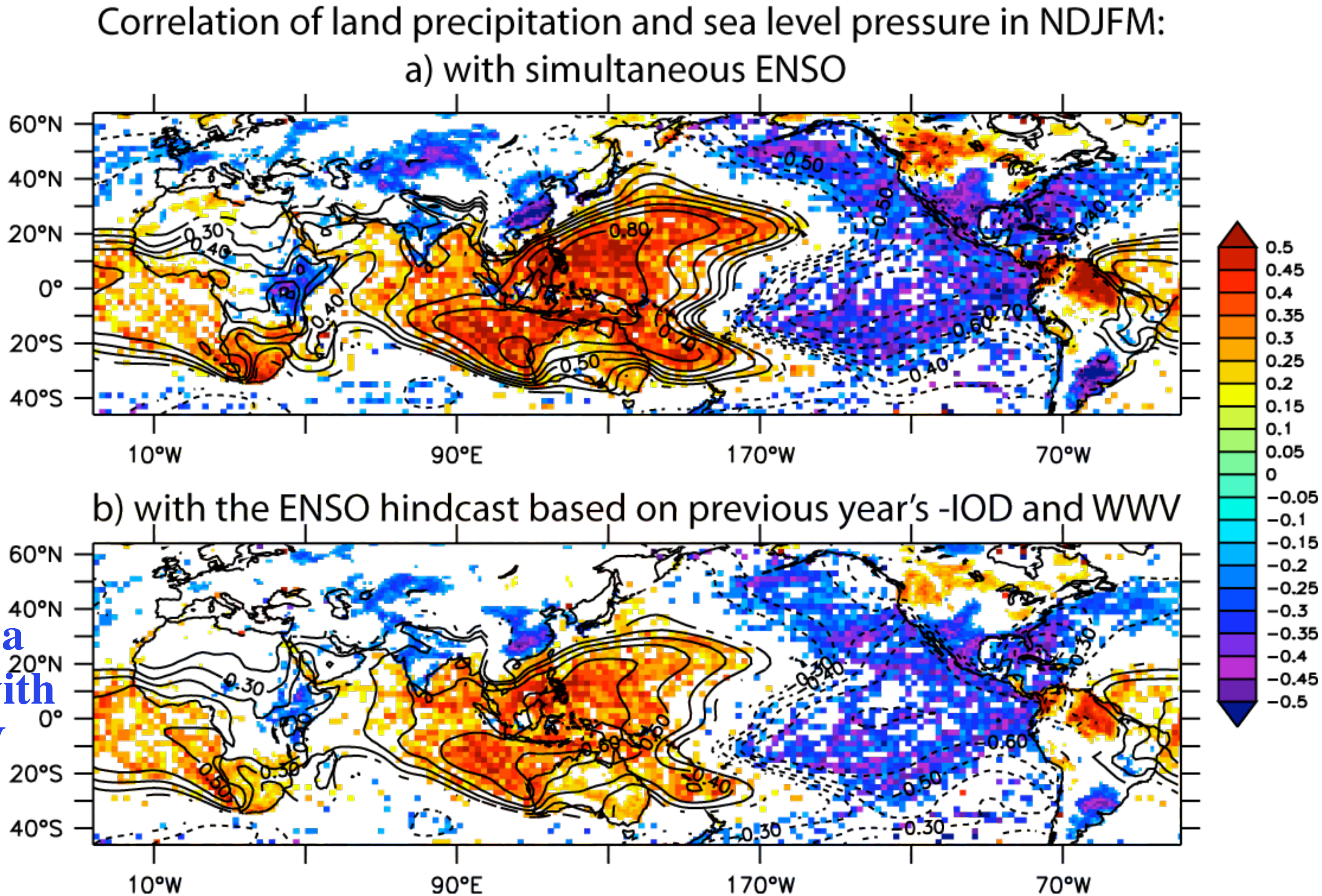
⇒skill of–IOD+WWV maximal for central-east Pacific SST, and thus for typical ENSO events. Skill significant for all ENSO indices, but weaker for Nino_e index (« extreme east » character of El Nino, as defined by Takahashi et al. 2011), whose skill mostly comes from WWV.

⇒ IOD influences mostly one dimension of the Pacific PC1/PC2 space, the Nino_c one.

Potential predictability brought by –IOD and WWV predictors for historical precipitation (GPCC, 1901-2008, color on land) and SLP (ICOADS, color on sea; 20CR, black contours)

ENSO global teleconnections

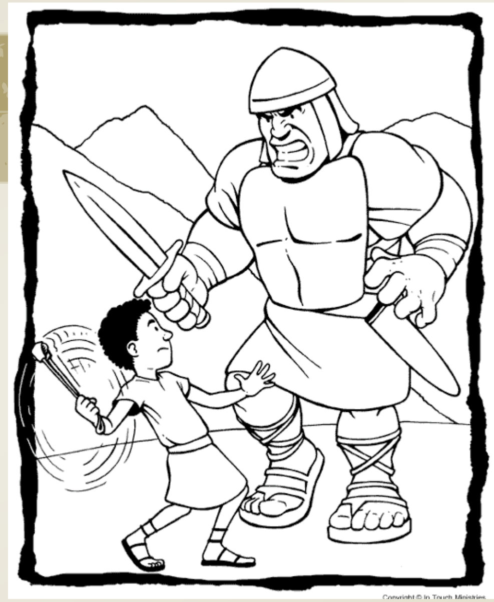
Hindcast with a one-year lead with –IOD+WWV



=> Significant hindcast with a one-year lead of rainfall and SLP global patterns, thanks to ENSO teleconnections (e.g. skill of 0.46 for central-northwest America

1.5 year lead, for SST or 20CR precipitation over 1872–2008. As examples, the correlation skill to hindcast following year's precip-

Conclusions



❖Mechanism: the IOD can influence ENSO triggering, mainly through zonal advection and central Pacific SST'.

❖Construction of reliable historical indices IOD$_{hist}$ and WWV$_{hist}$ (available online) => useful for historical studies.

❖Robustness of IOD (~40%) and WWV (~60%) influences on next year's El Niño/La Niña throughout the 1870s-2000s period => interdecadally stable skill

❖IOD and ENSO interactions => biennial tendency (passive Indian monsoon?)
+ slow WWV recharge-discharge cycle
=> the Indo-Pacific "ocean": "one" ocean-atmosphere system for ENSO?

❖IOD mostly predictor of ENSO transitions for classical moderate ENSO with classical teleconnections, the Nino_c dimension of the Pacific PC1/PC2 space.
WWW also a predictor for the Nino_e one, at least in observations.

Perspectives

Still many questions to answer, and half of the ENSO variance unexplained…:

- Influences of IO and WWV on ENSO types, HF/LF parts…
- bienniality/TBO: needs further obs./GCM studies
- Interdecadal variations: stochastic and physical parts?
- Interactions with the Atlantic (e.g. Rodriguez-Fonseca et al. 2009, Ding et al. 2012, Ham et al. 2013)? secondary complementary role, as suggested by M. Watanabe (2008a,b)?

=> a need to better understand and *quantify* the Indian Ocean - Pacific –Atlantic interactions, through both models and a sustained observational network for the tropical coupled ocean-atmosphere system (e.g. TAO/TRITON array…).

Related manuscripts: Izumo et al. 2010, *Nat. Geosci.;* Izumo et al. 2013, *Clim. Dyn.;* Dayan et al., to be submitted.