

Indian Ocean variability

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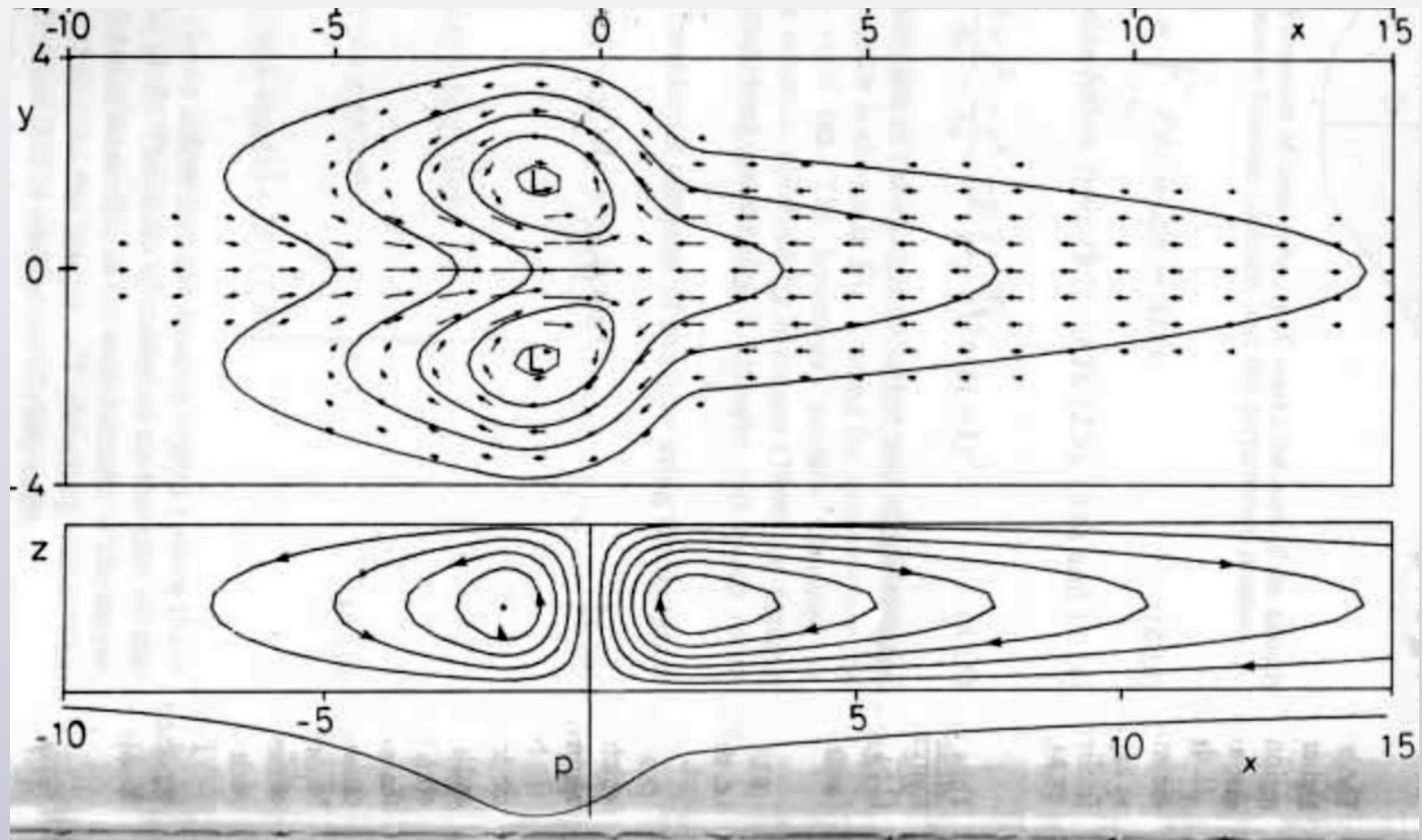
Pascal Terray, Pascale Delecluse,
Jean-Philippe Boulanger, Sébastien Masson,
Matthieu Lengaigne, Eric Guilyardi, Silvio Gualdi



Outline

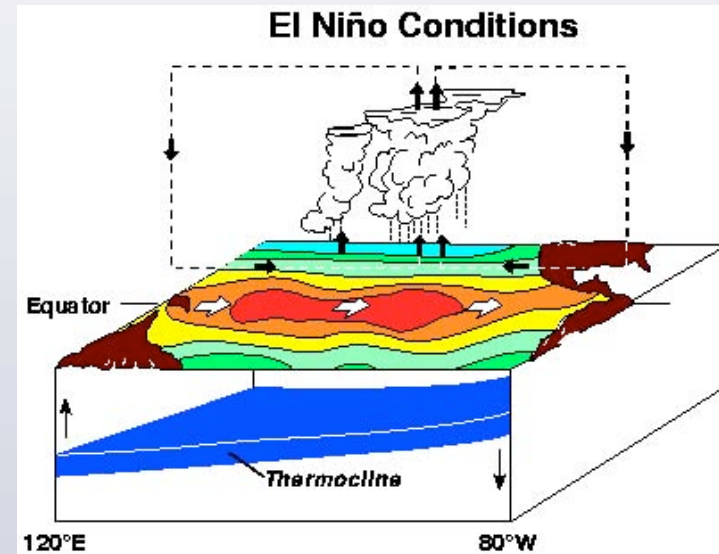
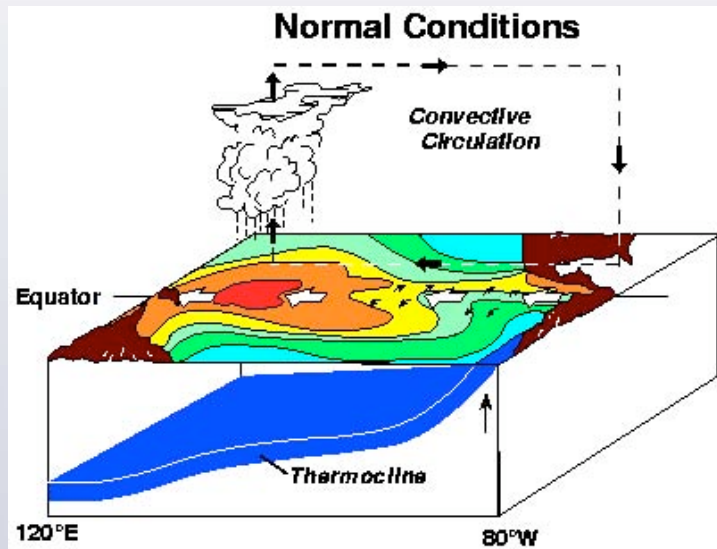
- Quick introduction to coupled feedbacks and the atmospheric response to heating
- What is the Indian Ocean dipole / zonal mode ?
- The IOD and ENSO
 - Experimental approach : removing ENSO from the coupled system
 - The intrinsic Indian Ocean variability
 - Triggers and the link to ENSO
- The dipole in the context of other Indo-Pacific modes of variability
- A complication: intraseasonal and interannual scale interactions

Matsuno - Gill atmospheric response to heating



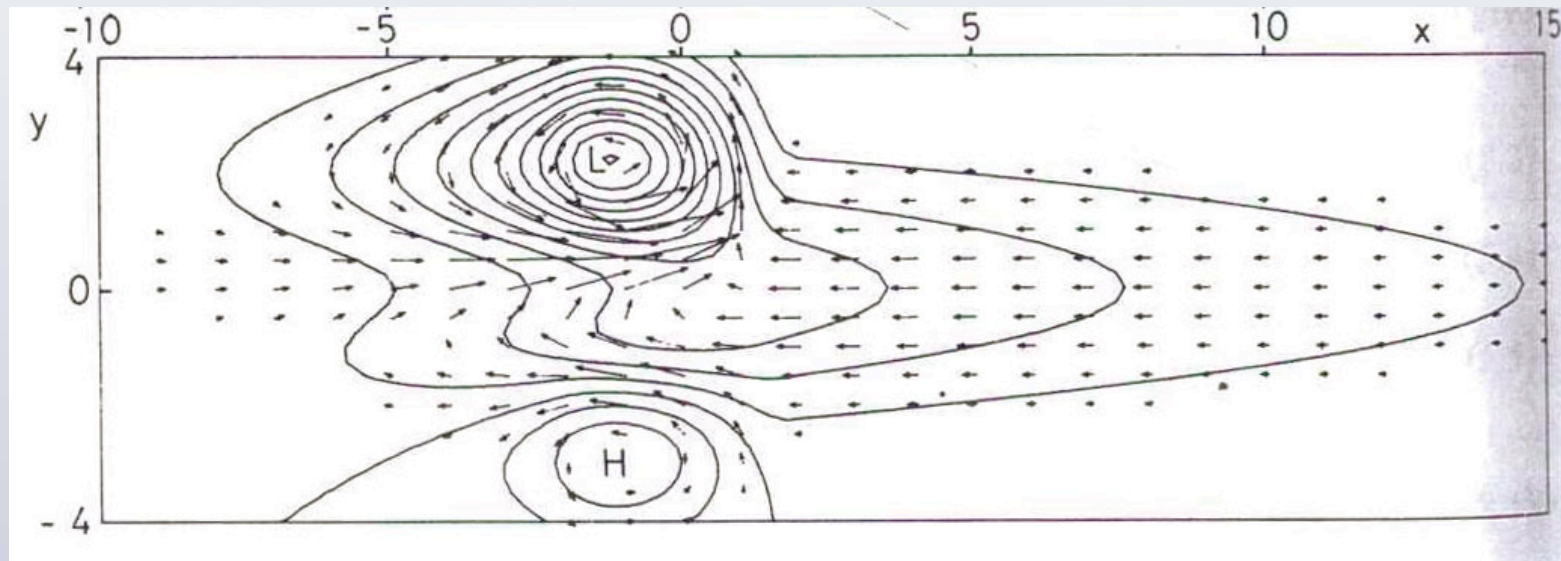
(Gill, 1980)

Positive feedbacks : wind-thermocline-SST



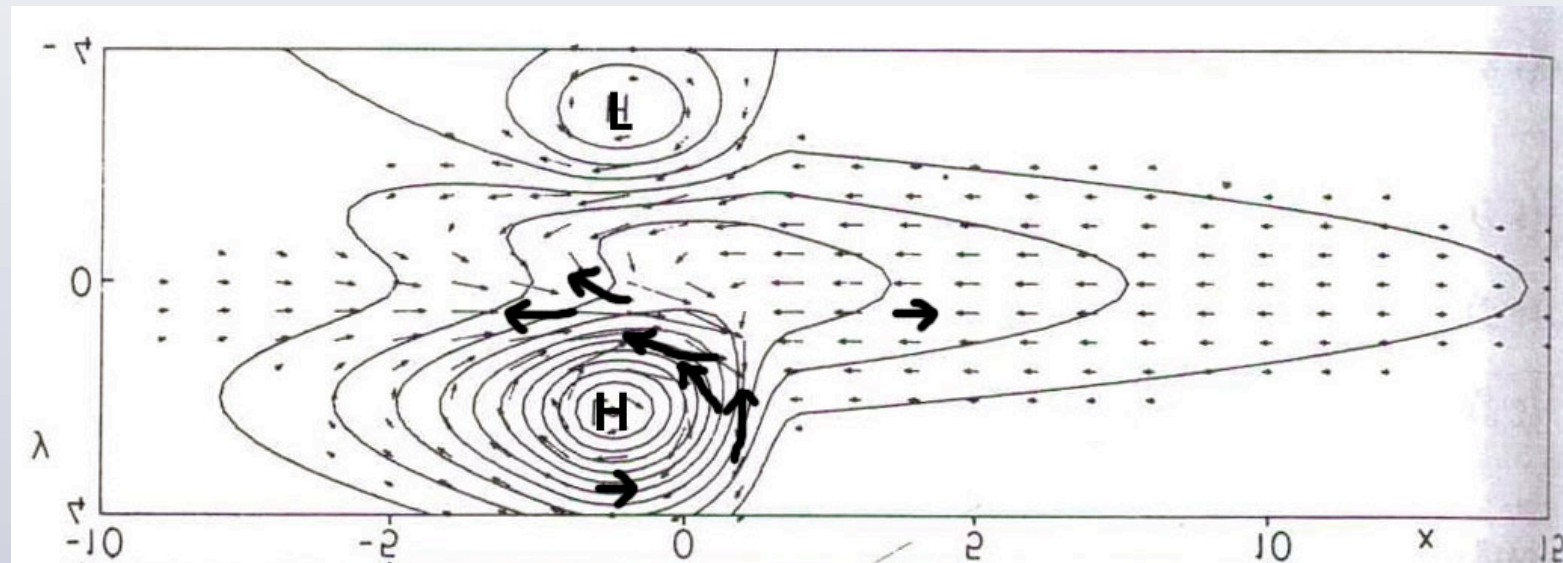
PMEL

off-equator heating

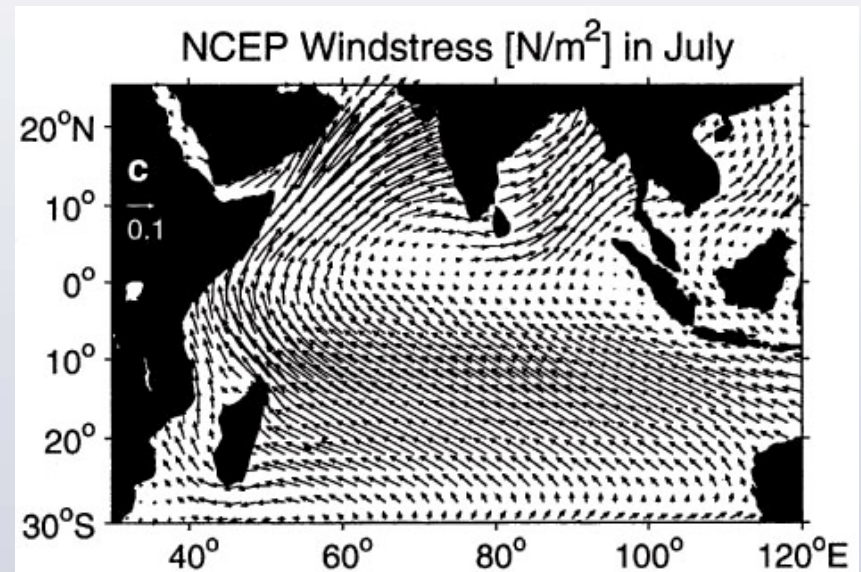
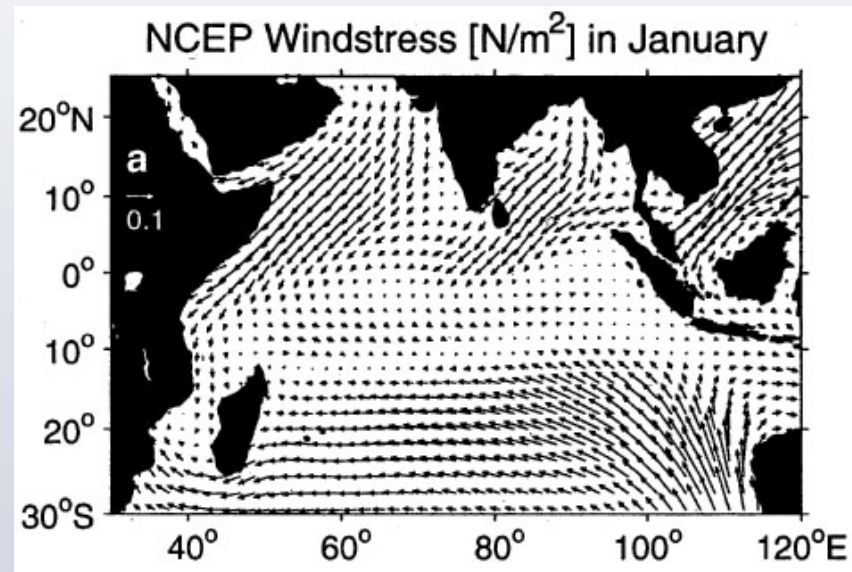


(Gill, 1980)

off-equator lack of heating (linear problem)

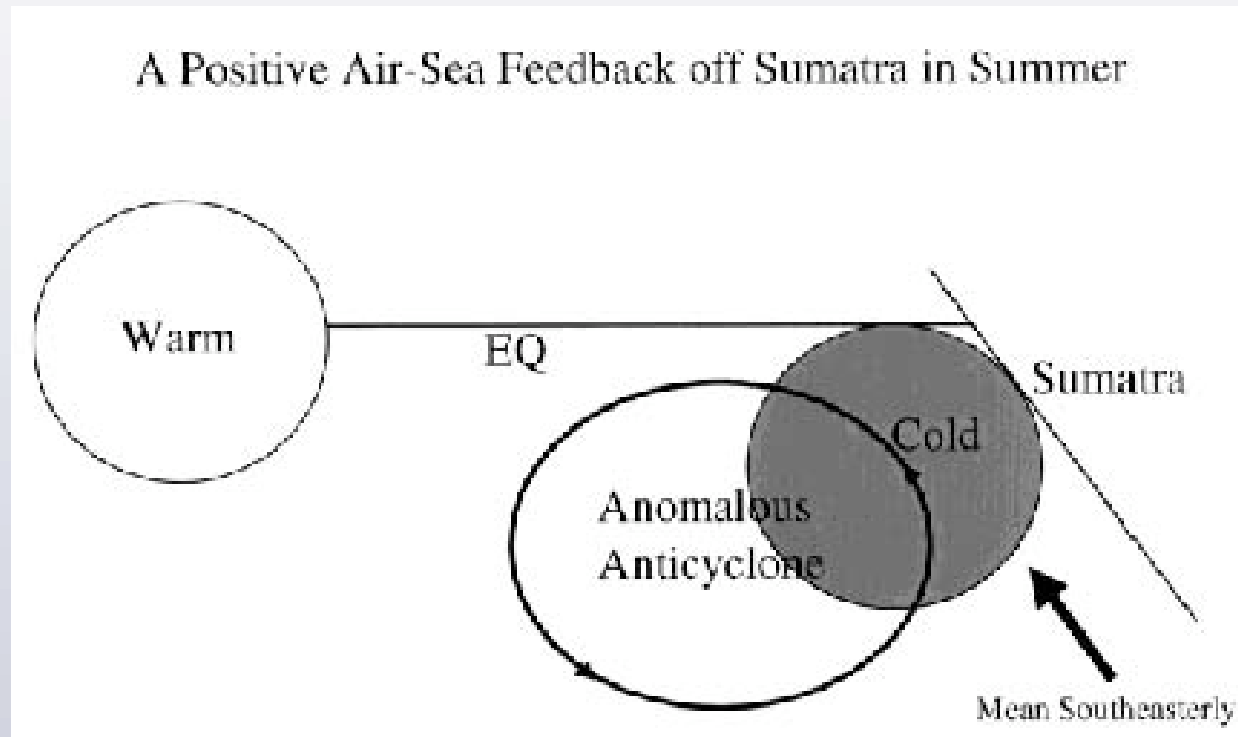


Indian Ocean monsoon cycle



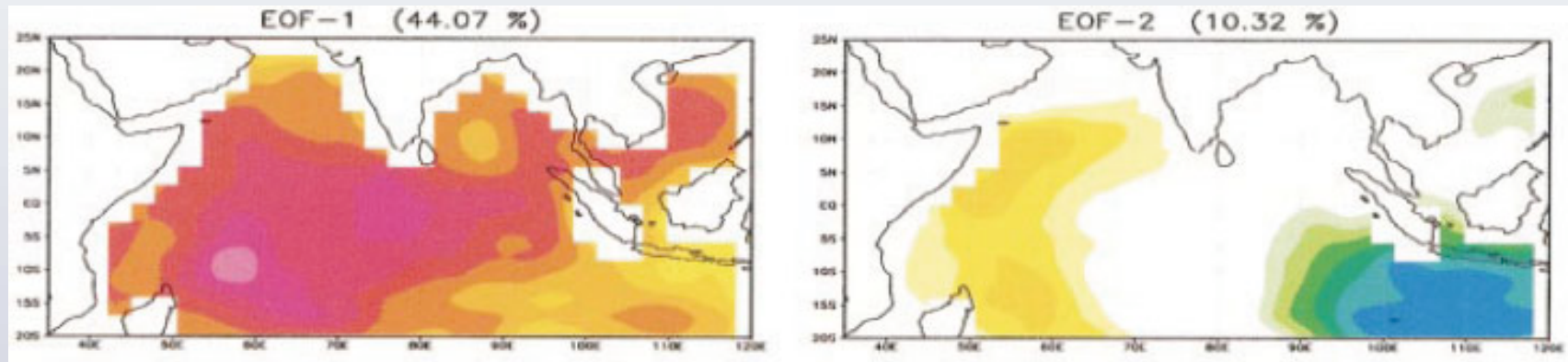
(Schott and McCreary, 2001)

Positive feedbacks : wind-evaporation-SST



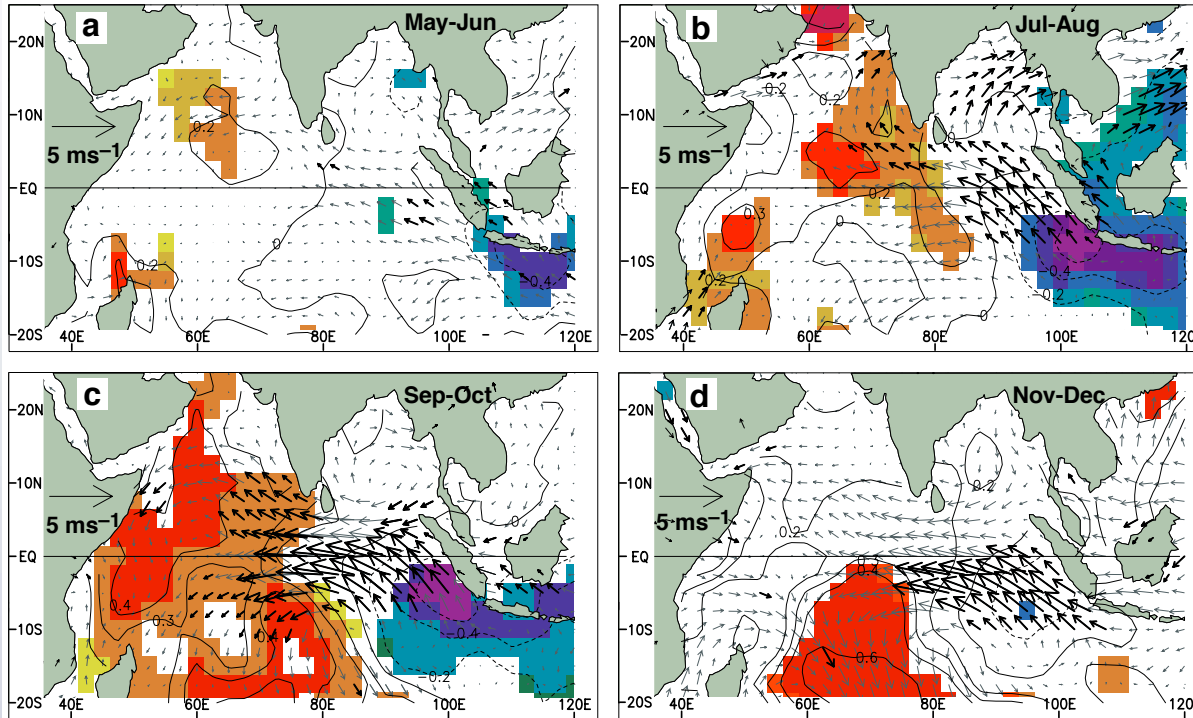
Li et al., 2003, in press

Indian Ocean variability: SST EOFs

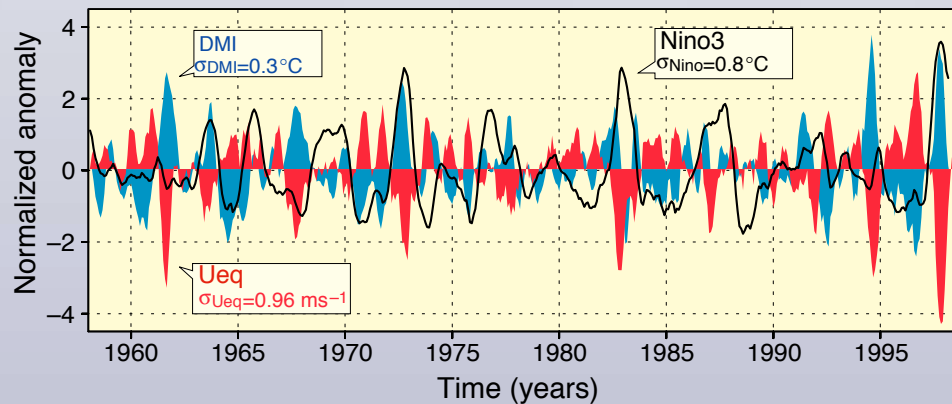


(Dommenges and Latif, 2001)

What is the 'dipole' ?

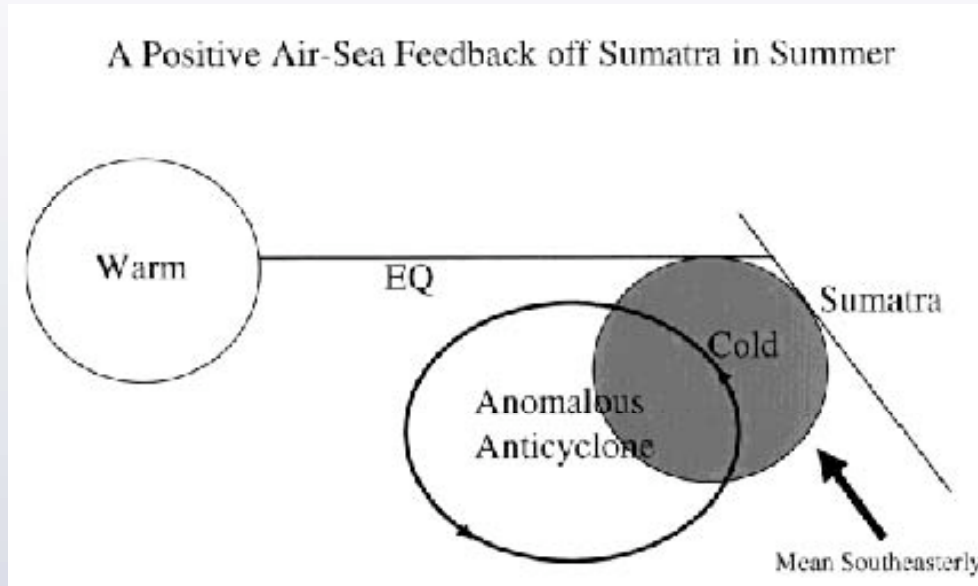


Saji et al., 1999



- **Impacts:** 1961 White Nile flood, 1997 outbreak of Rift Valley Fever (Kenya), drought (Indonesia)

What is the 'dipole' ?



Matsuno-Gill
atmospheric
response to
lack of heating

Li et al., 2003, in press

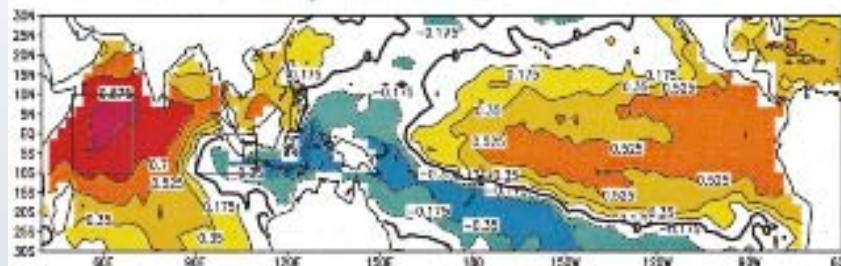
- Wind-thermocline-SST (Bjerknes, positive)
- Wind-evaporation-SST (seasonally positive)
- Cloud-radiation-SST (negative)
- Monsoon-ocean interactions

Is the dipole a dipole ?

Boreal fall season (SON):

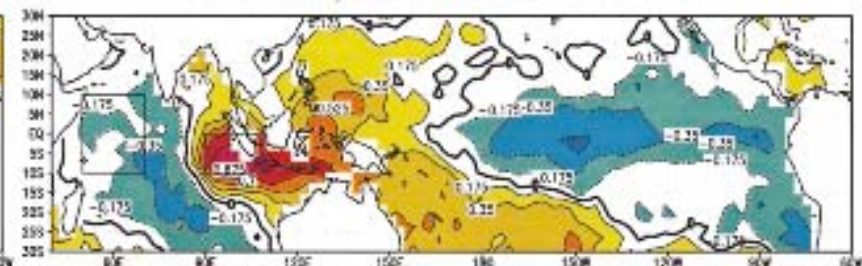
a)

Observations, correlation with western box



b)

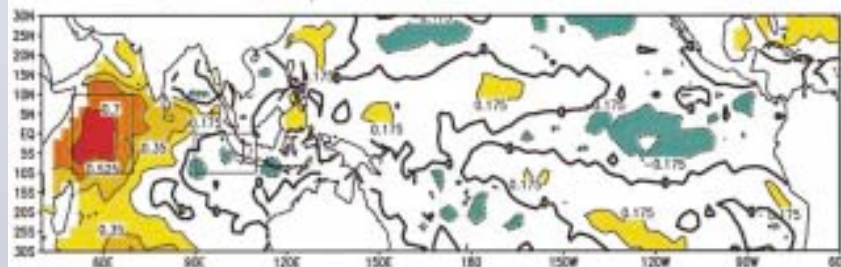
Observations, correlation with eastern box



ENSO signal removed / boreal fall season (SON):

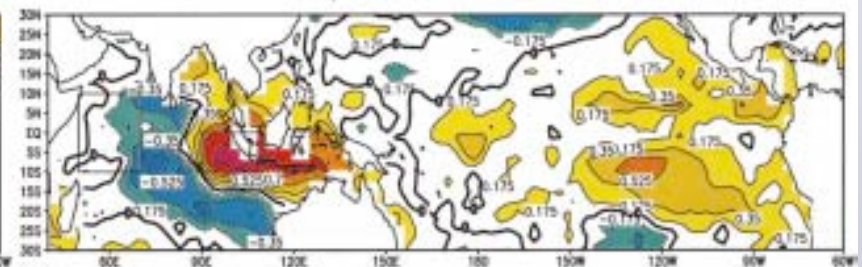
a)

Observations, correlation with western box



b)

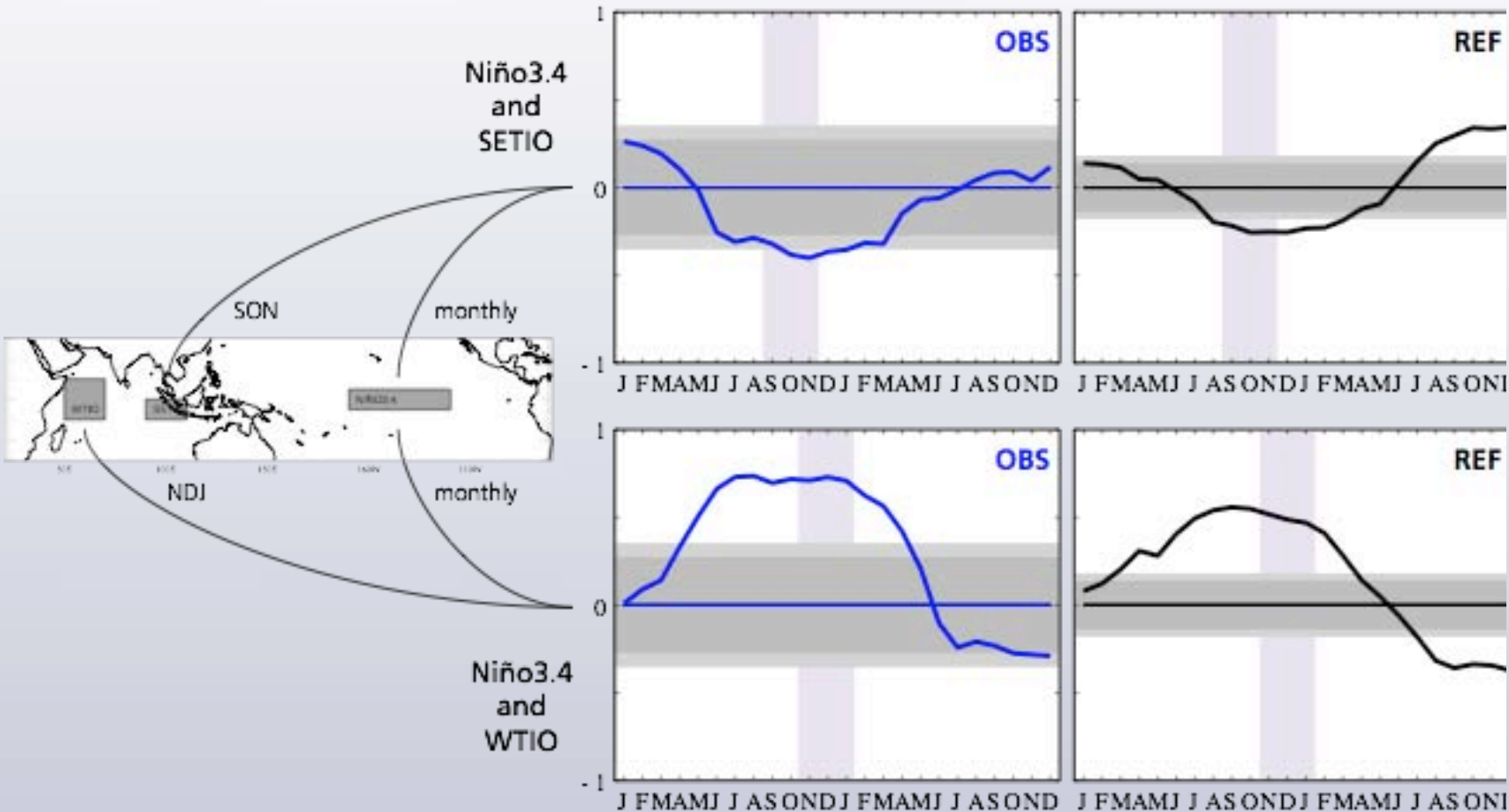
Observations, correlation with eastern box



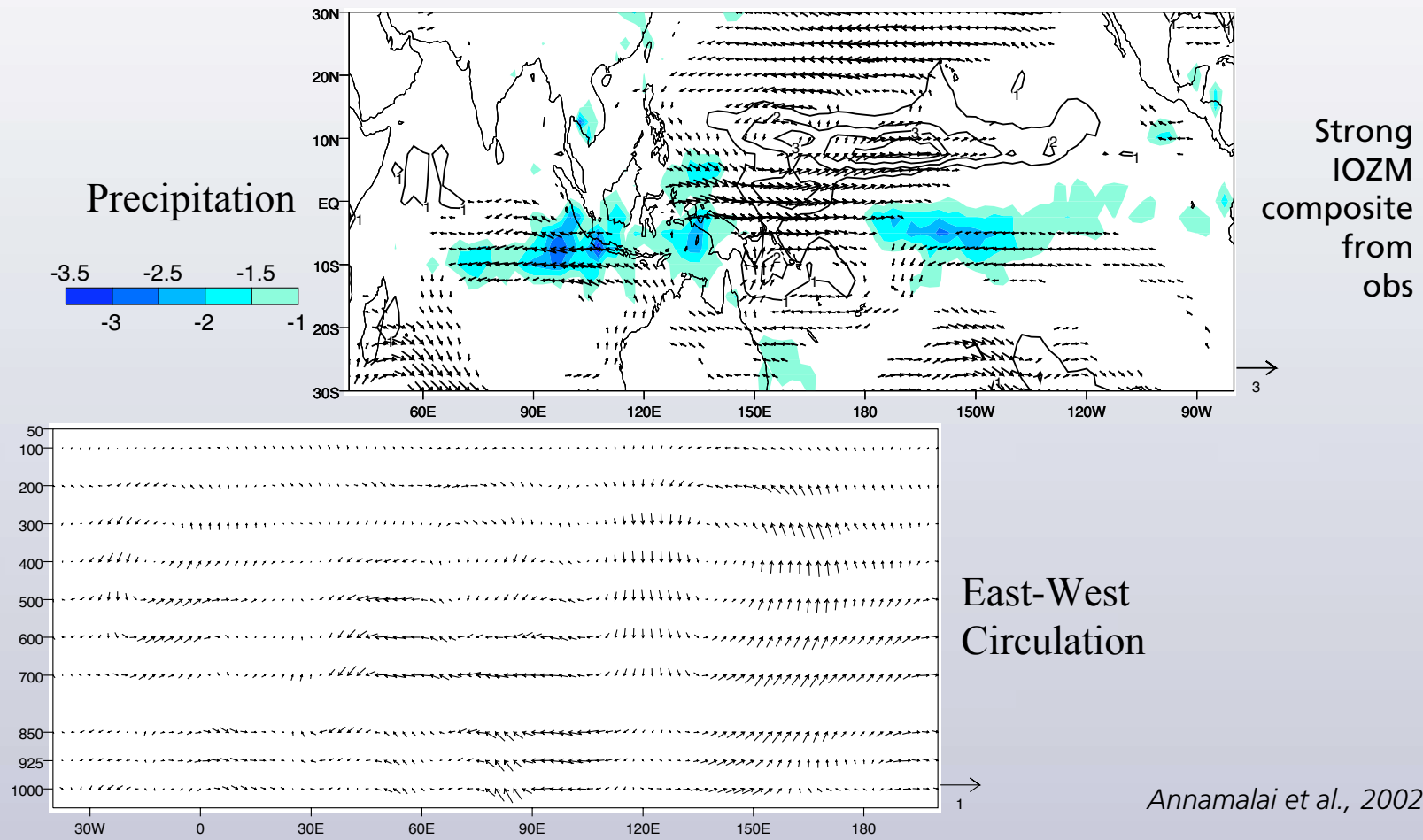
The link between the IOD and ENSO

- The link between Indian Ocean 'dipole' or 'zonal mode' variability (IOD) and ENSO is under debate
 - Indian Ocean **independent** (Saji *et al.*, 1999; Webster *et al.*, 1999; Yamagata *et al.*, 2002)
 - Indian Ocean **forced by ENSO** (Chambers *et al.*, 1999; Yu and Rienecker, 2000; Baquero-Bernal *et al.*, 2002; Gualdi *et al.*, 2003)
 - Indian Ocean **damped mode** linked to ENSO (Murtugudde *et al.*, 2000; Annamalai *et al.*, 2002; Li *et al.*, 2003)

Links between Indian and Pacific Oceans

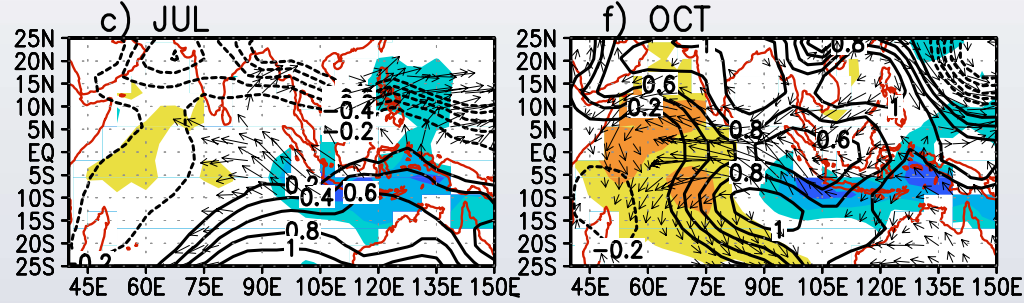


How might they be linked ?

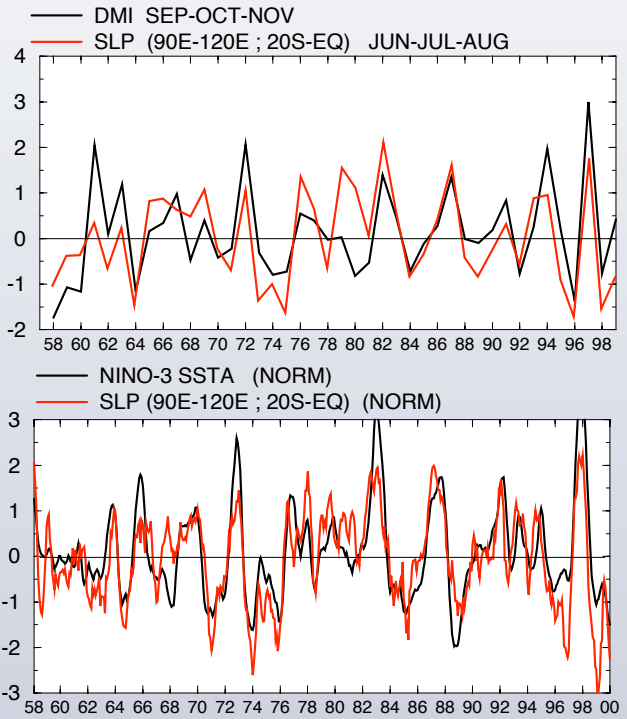
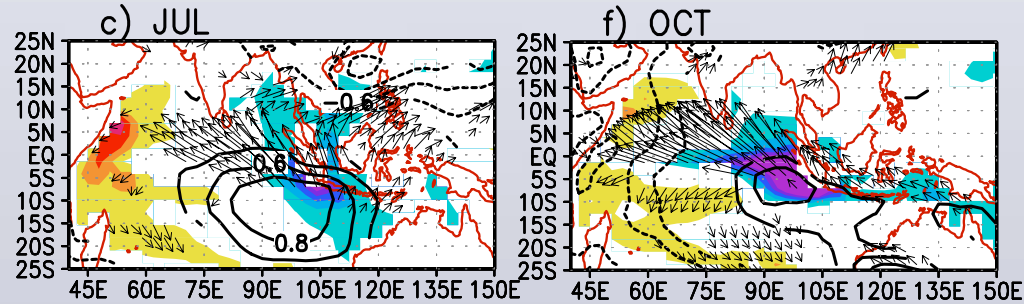


How might they be linked ?

Observations



SINTEX model



Gualdi et al., 2003

Essential questions

- What is the intrinsic variability of the coupled Indian Ocean and atmosphere ?
- What is the link to the Pacific ?
- **Approach** : twin experiment with a coupled model
 - free reference simulation
 - ENSO-supressed simulation

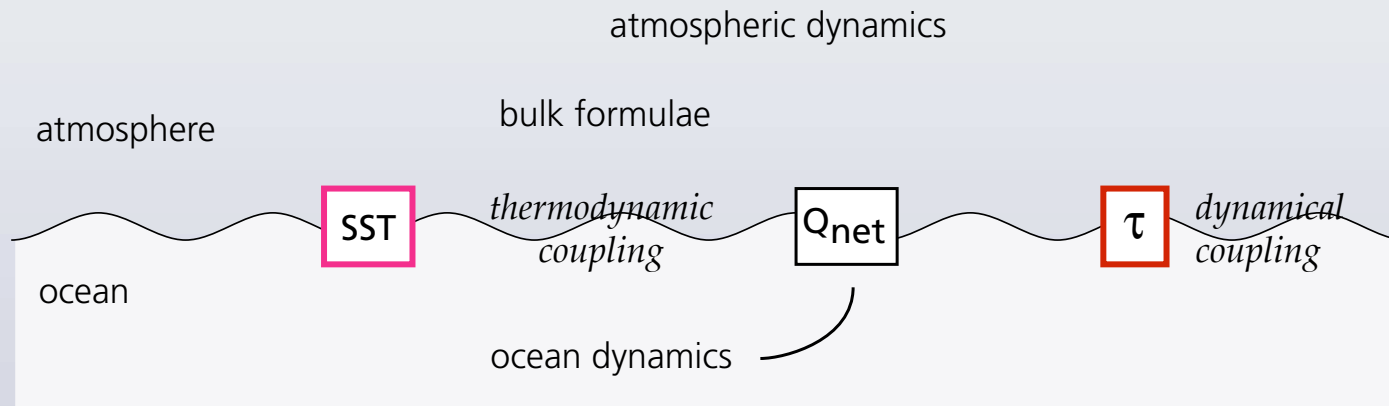
Coupled model

- SINTEX
- OPA Ocean ORCA2 global config (LODYC)
 - $2^\circ \times 1.5^\circ$, 0.5° near equator
 - 31 levels, 10 m near surface
- ECHAM4 Atmosphere (MPI Hamburg)
 - T30 ($\sim 3.75^\circ$)
 - 19 vertical layers
- Reference simulations
 - Guilyardi *et al.* (2003a and b) : 200-year simulation, focus on ENSO
 - Gualdi *et al.* (2003a and b) : role of resolution, Indian Ocean dynamics

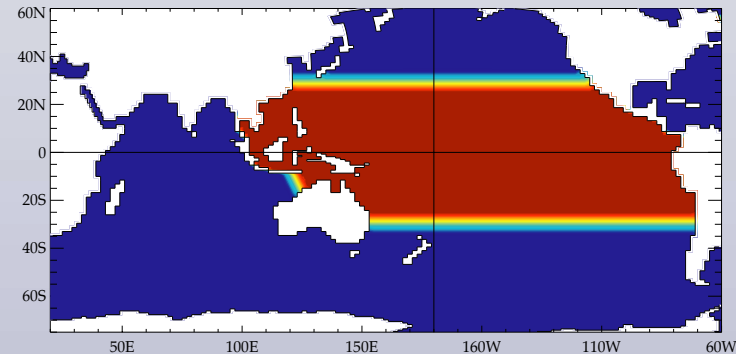


Supressing ENSO

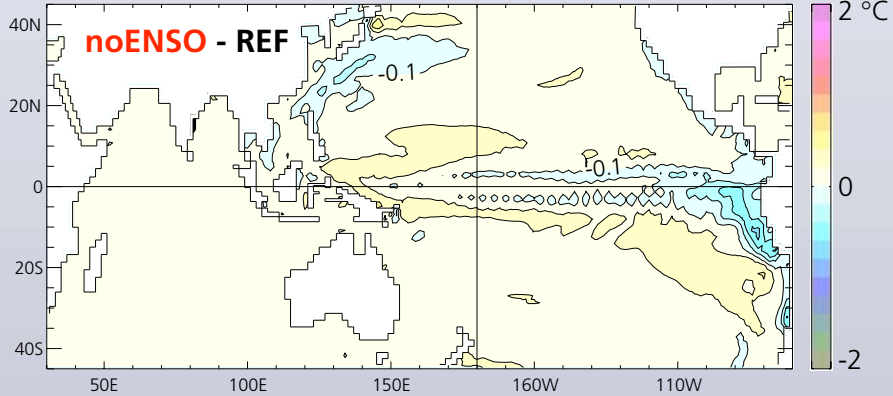
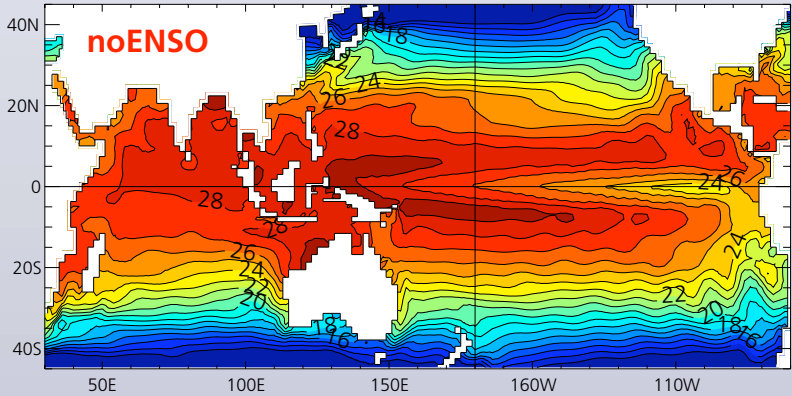
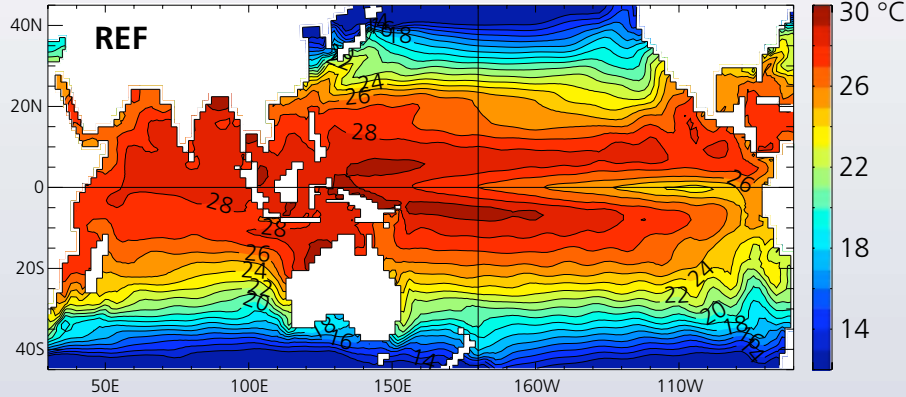
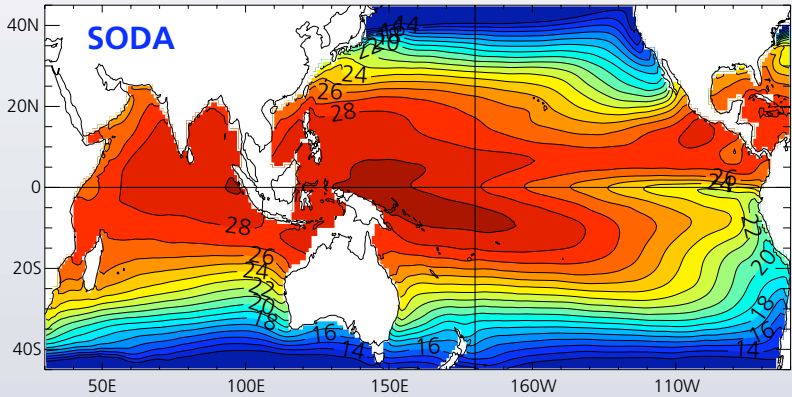
- Constrain tropical Pacific
- At which point in the coupling ?



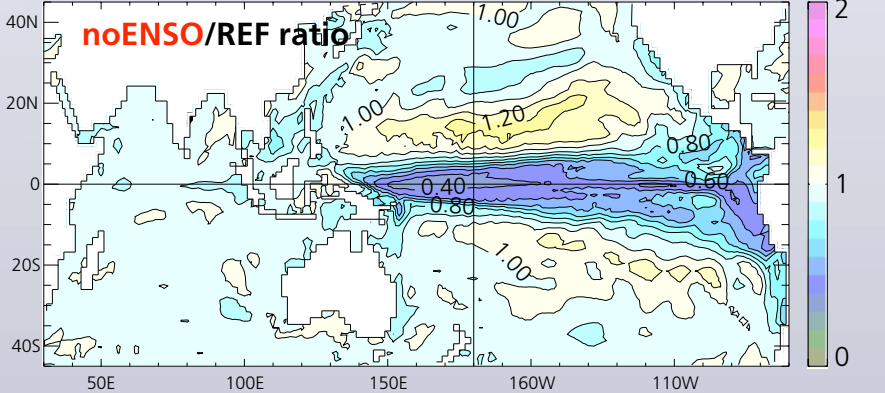
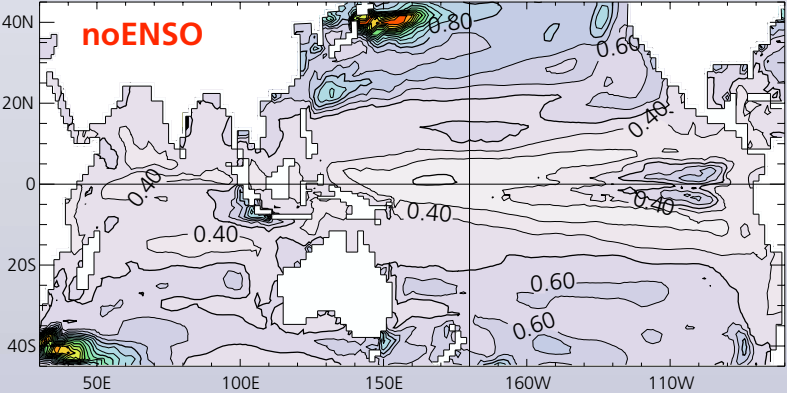
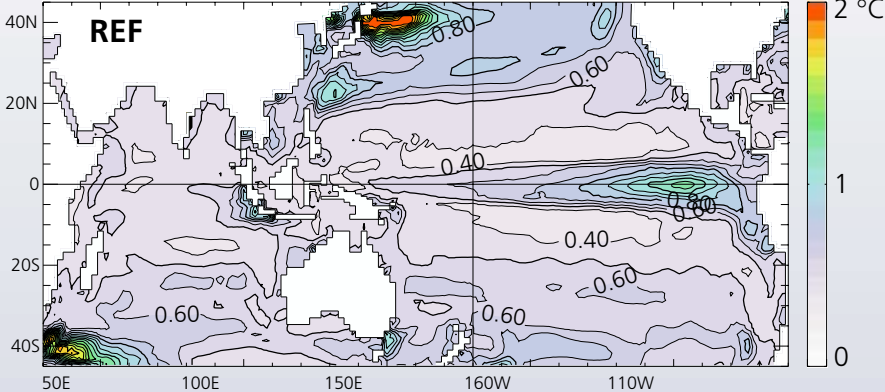
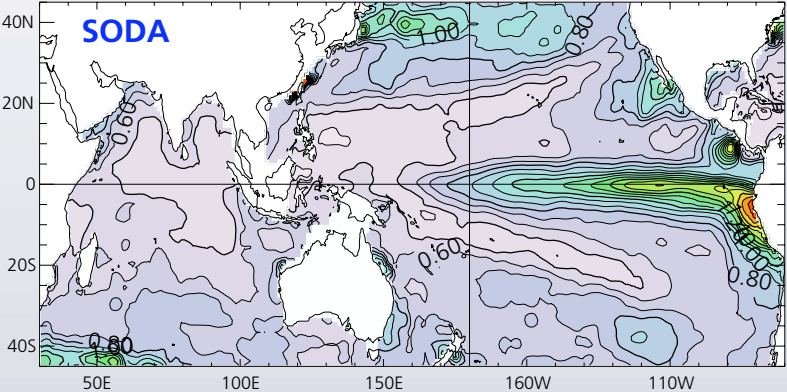
experiment	REF	CTAU	CSST
constraint	—	wind τ	SST
run years	200	200	100



Effect of the constraint : mean SST

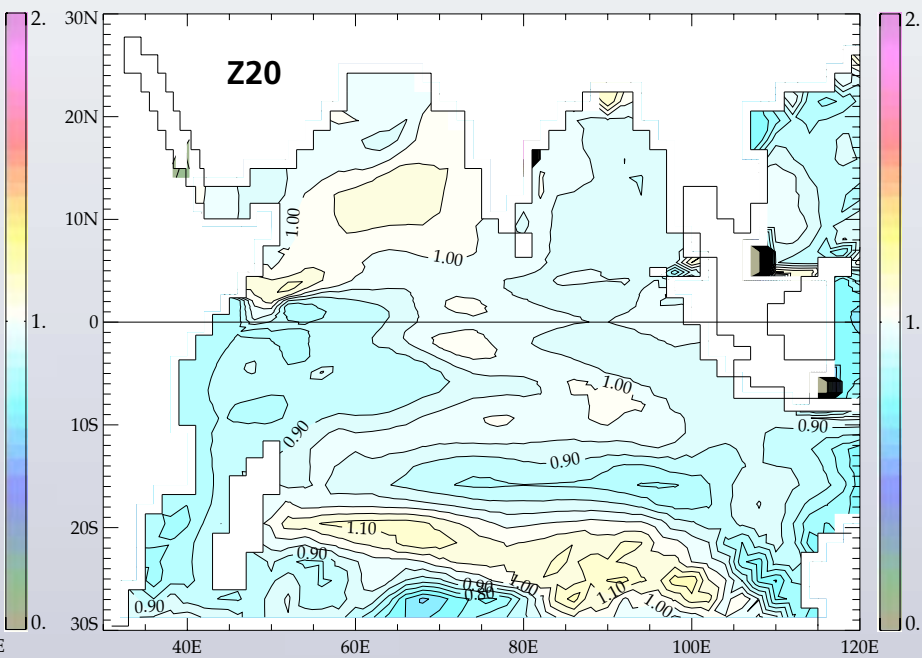
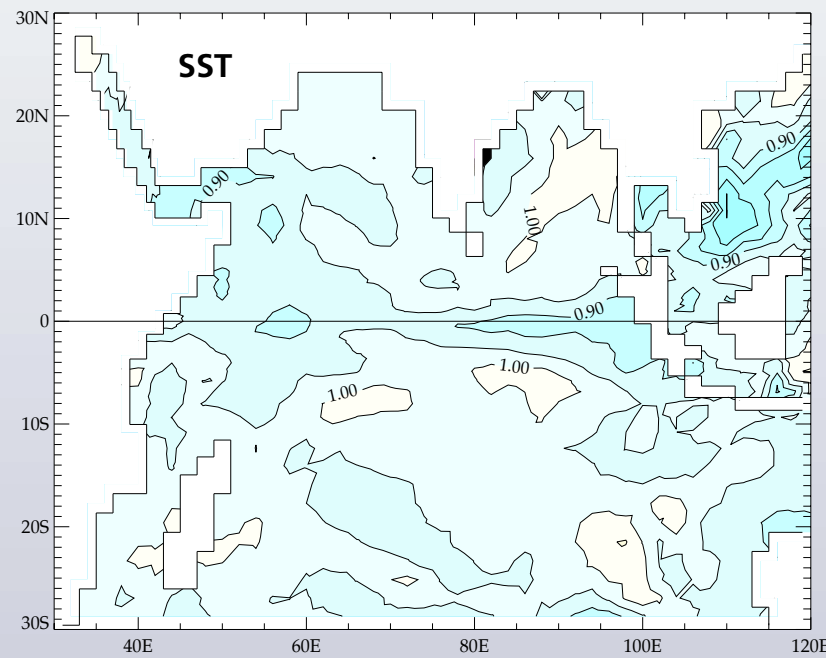


Effect of the constraint : SST variability

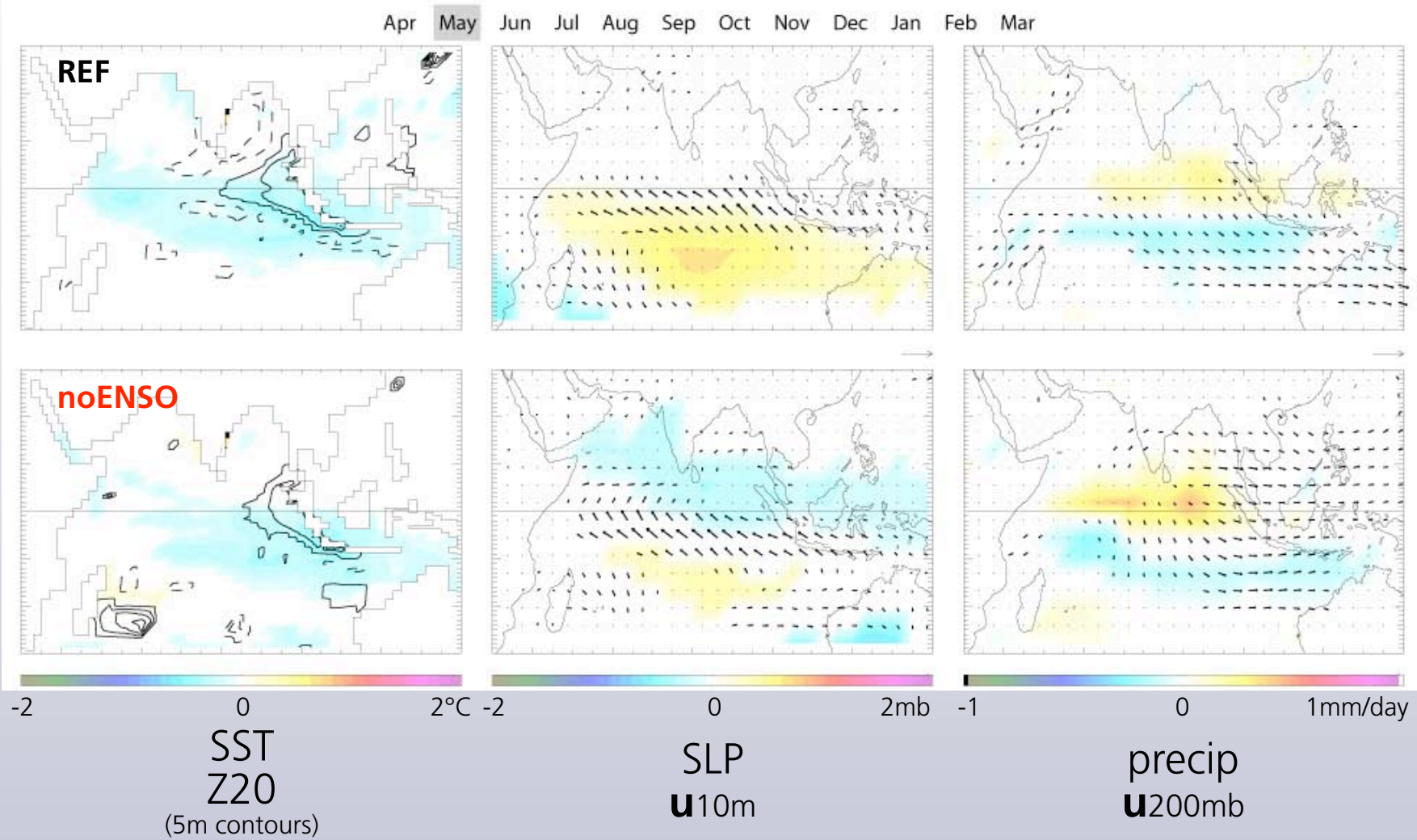


Remaining Indian Ocean Variability

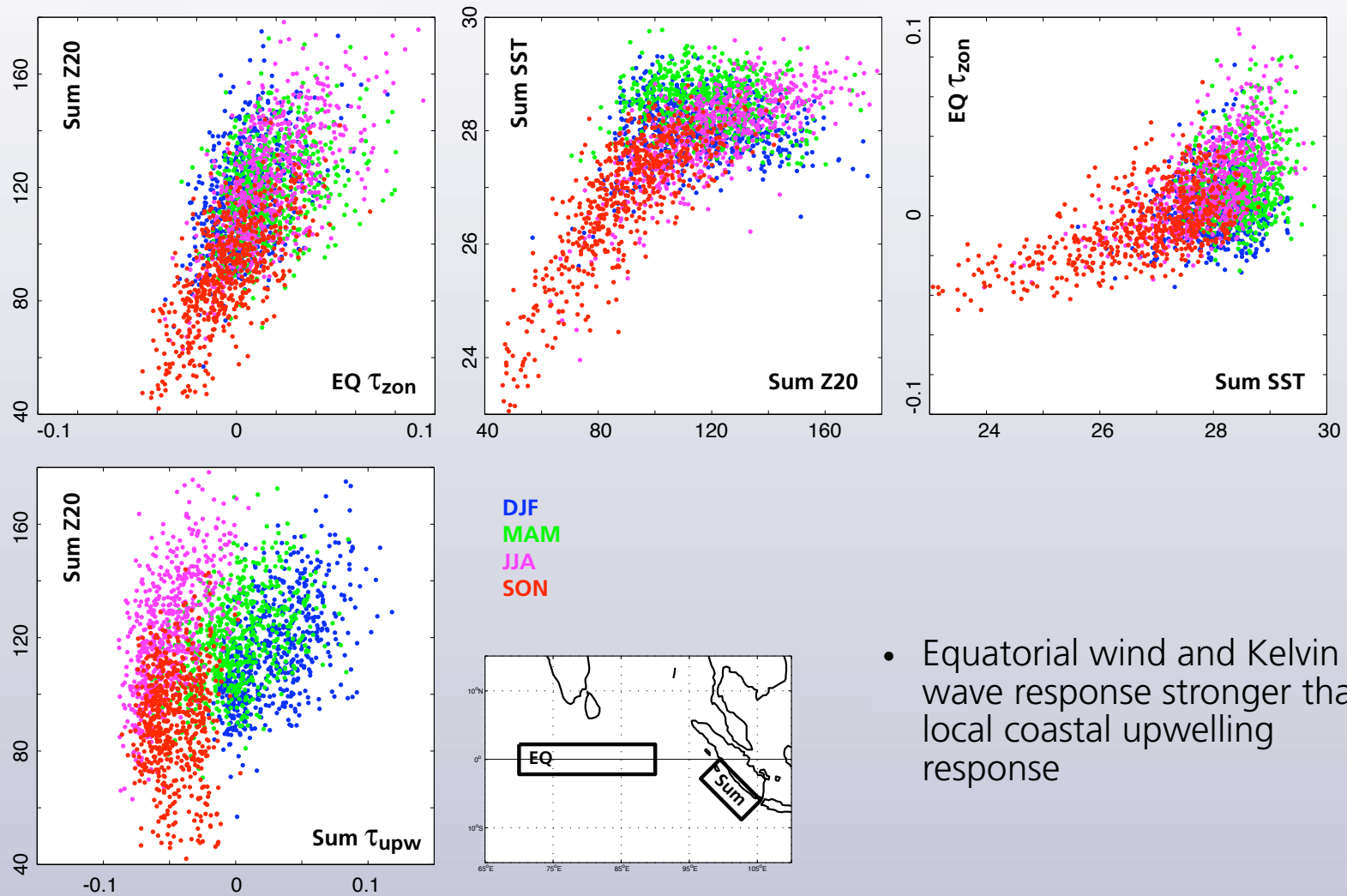
CTAU / REF std ratio



Composite IOD : REF and noENSO

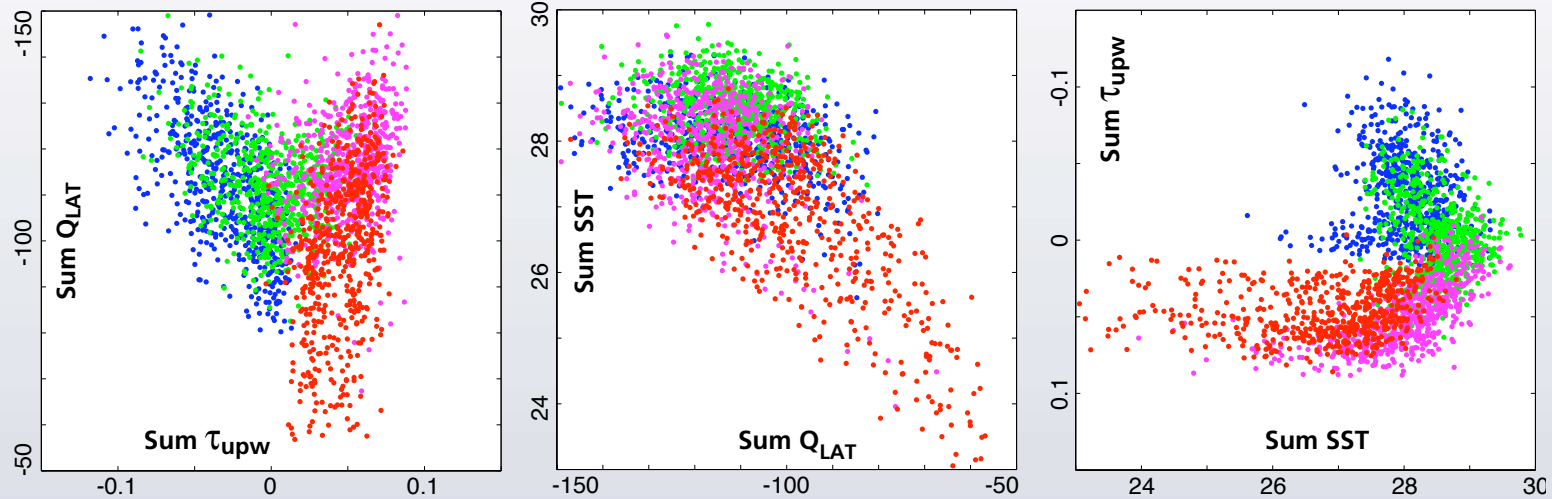


Feedbacks : wind-thermocline-SST (Bjerknes)

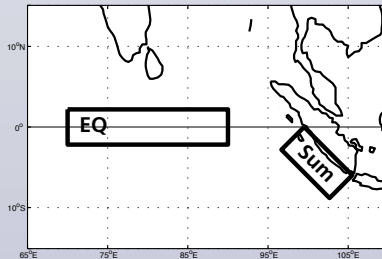


- Equatorial wind and Kelvin wave response stronger than local coastal upwelling response

Feedbacks : wind-evaporation-SST



DJF
MAM
JJA
SON

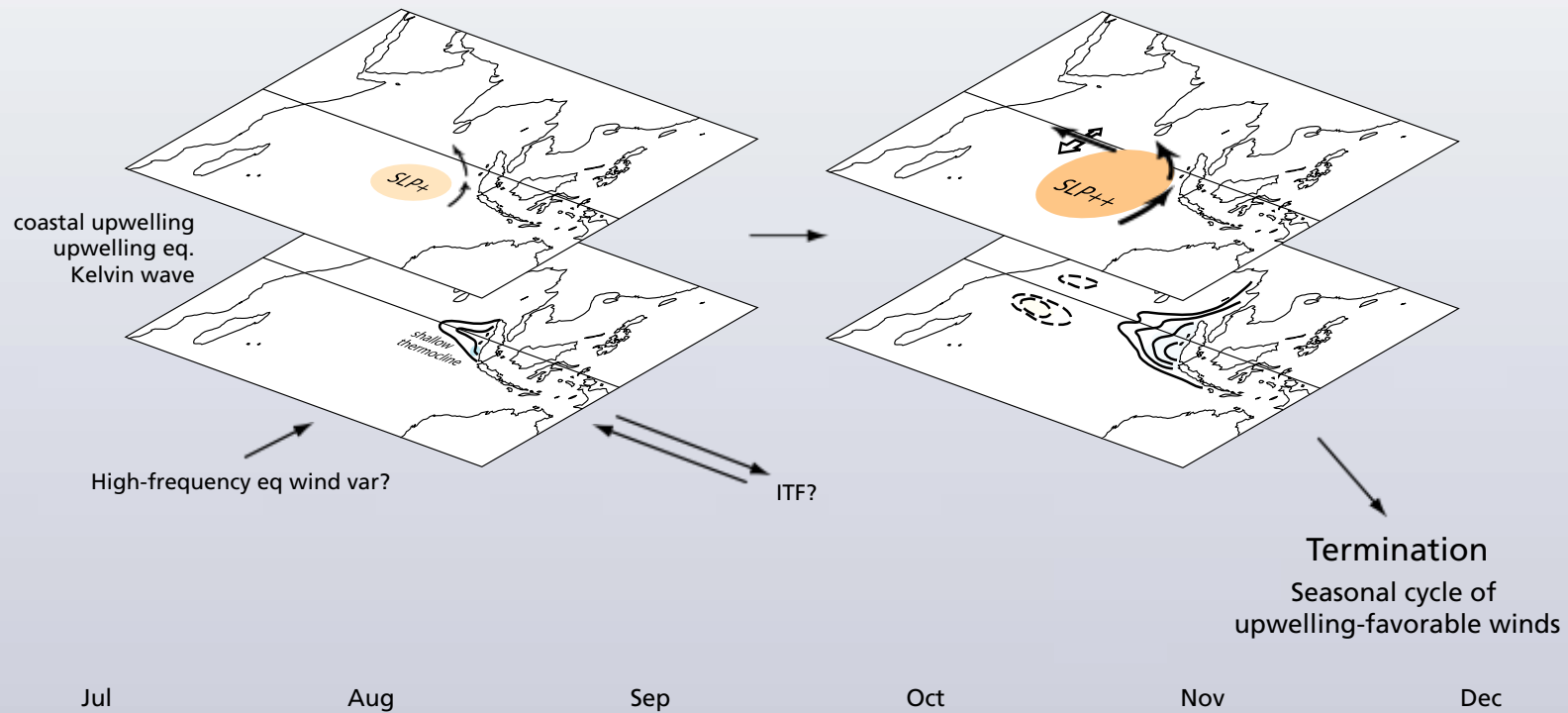


- Latent heat flux is limited by reduced saturation specific humidity over cold water → negative relationship
- Not a positive feedback in this model

Schematic evolution

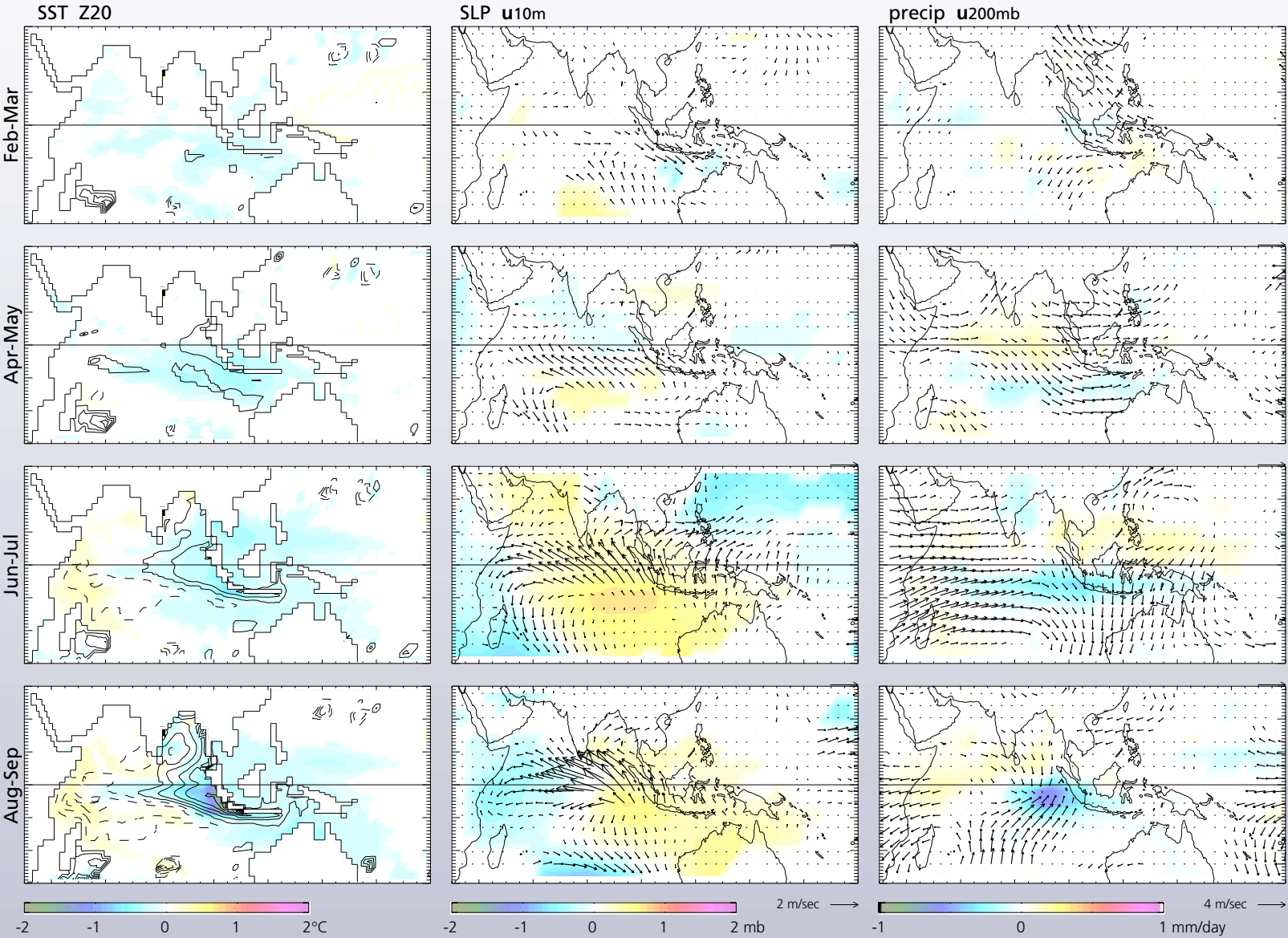
Early evolution

Coupled amplification



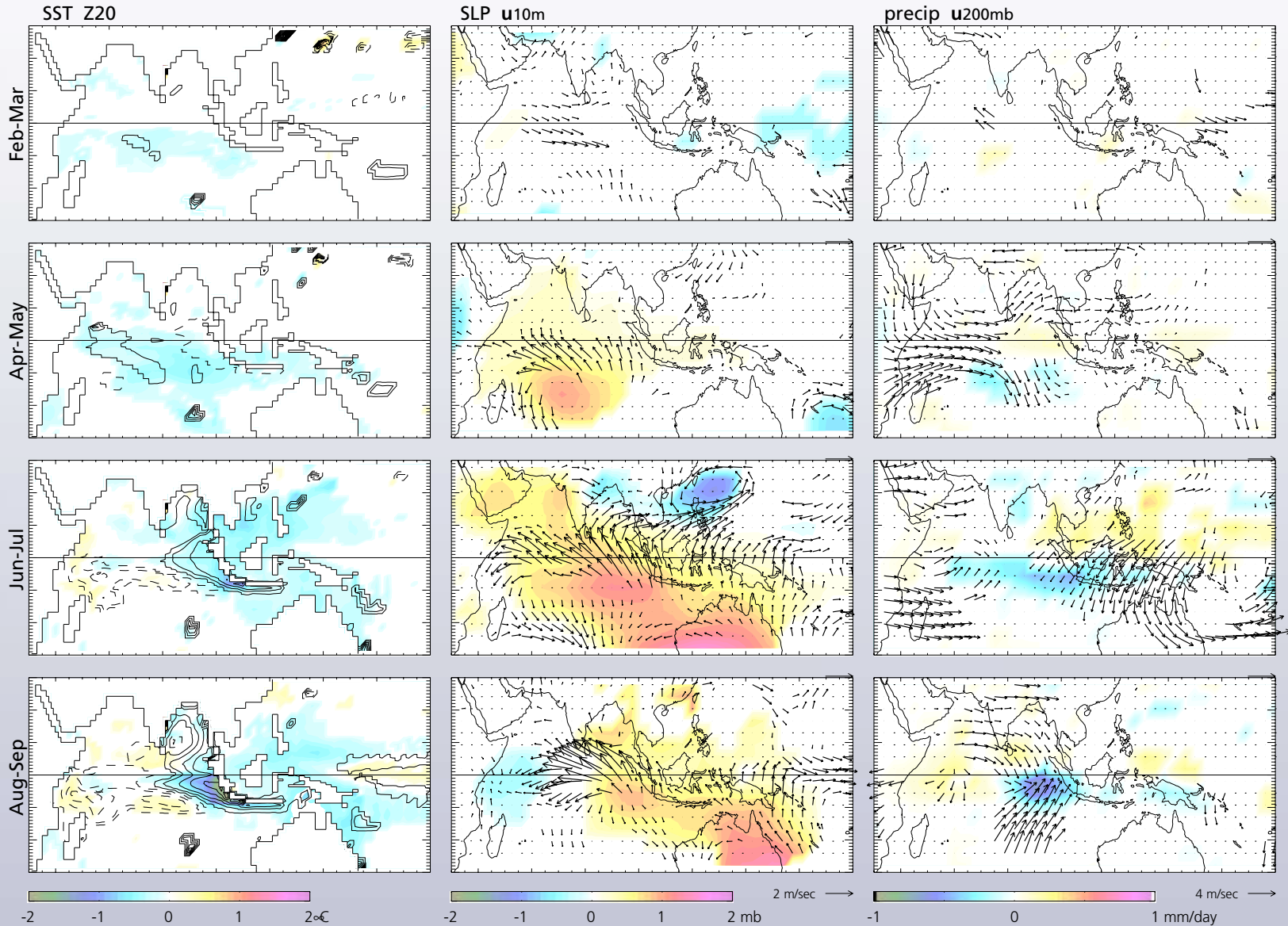
Composite IOD : noENSO

IOD: 29/200 yrs



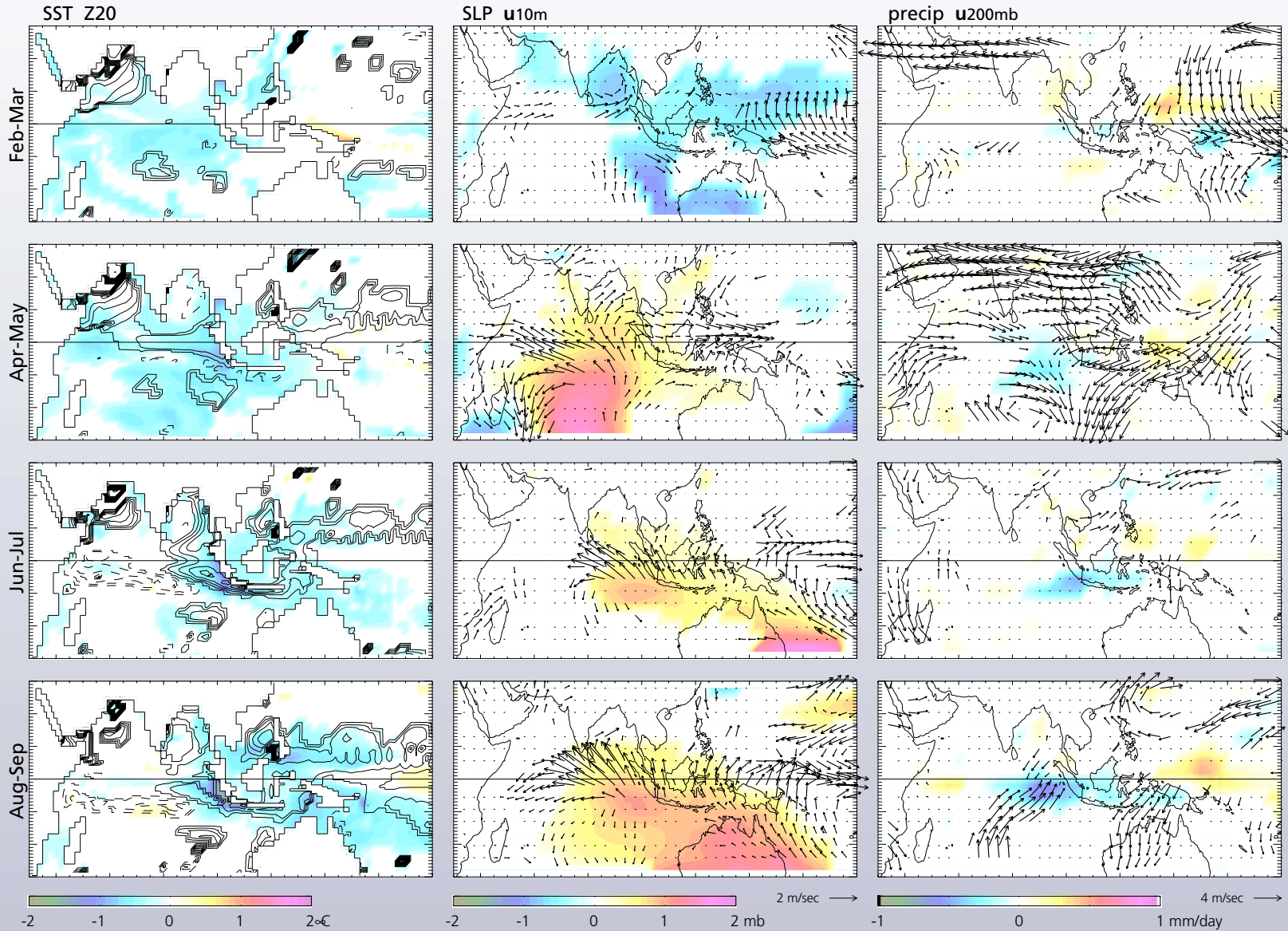
Composite IOD : REF with MCprecip

IOD+Had: 12/200 yrs
IOD: 37/200 yrs



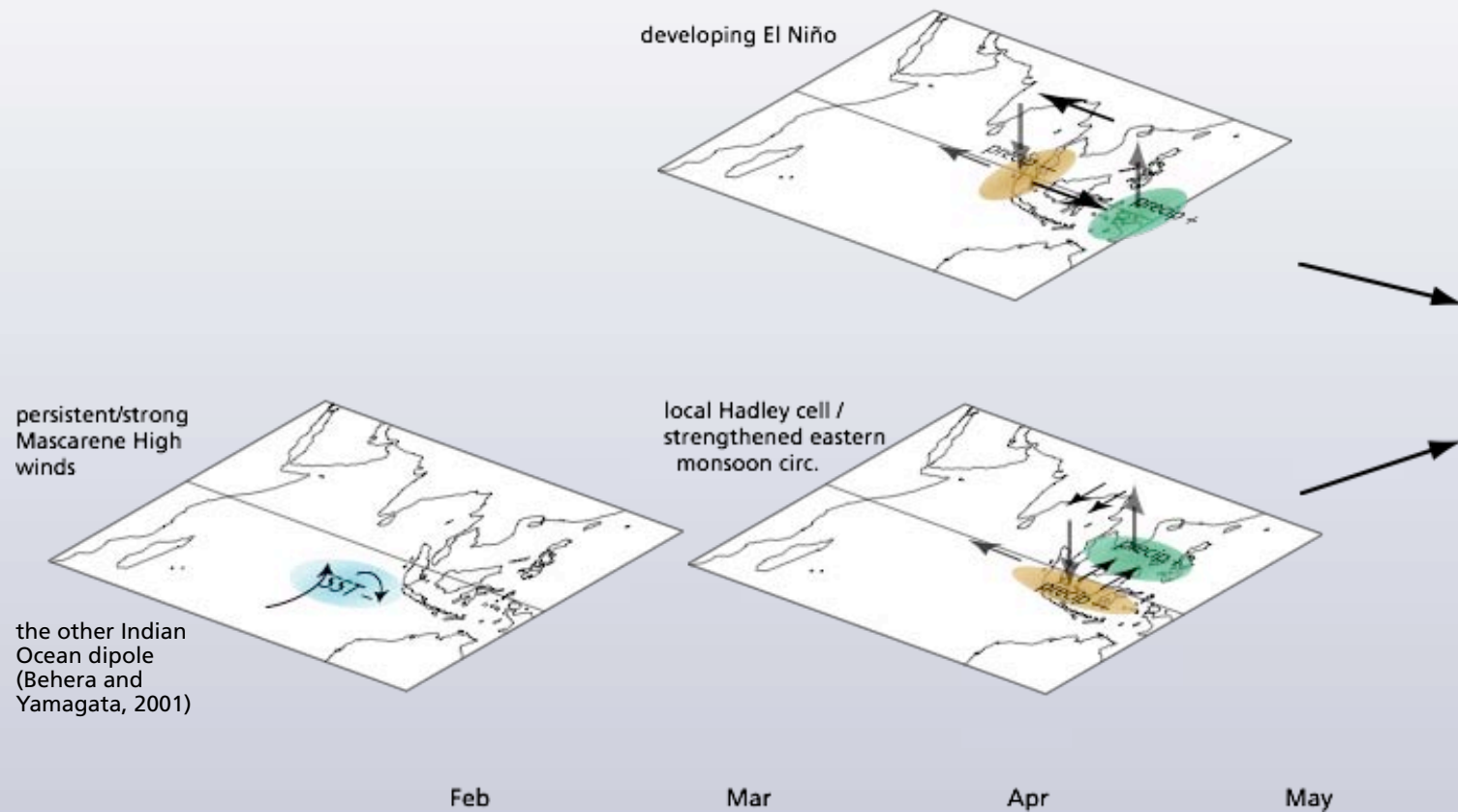
Composite IOD : REF with El Niño

IOD+Niño: 7/200 yrs
IOD: 37/200 yrs



Schematic evolution (early)

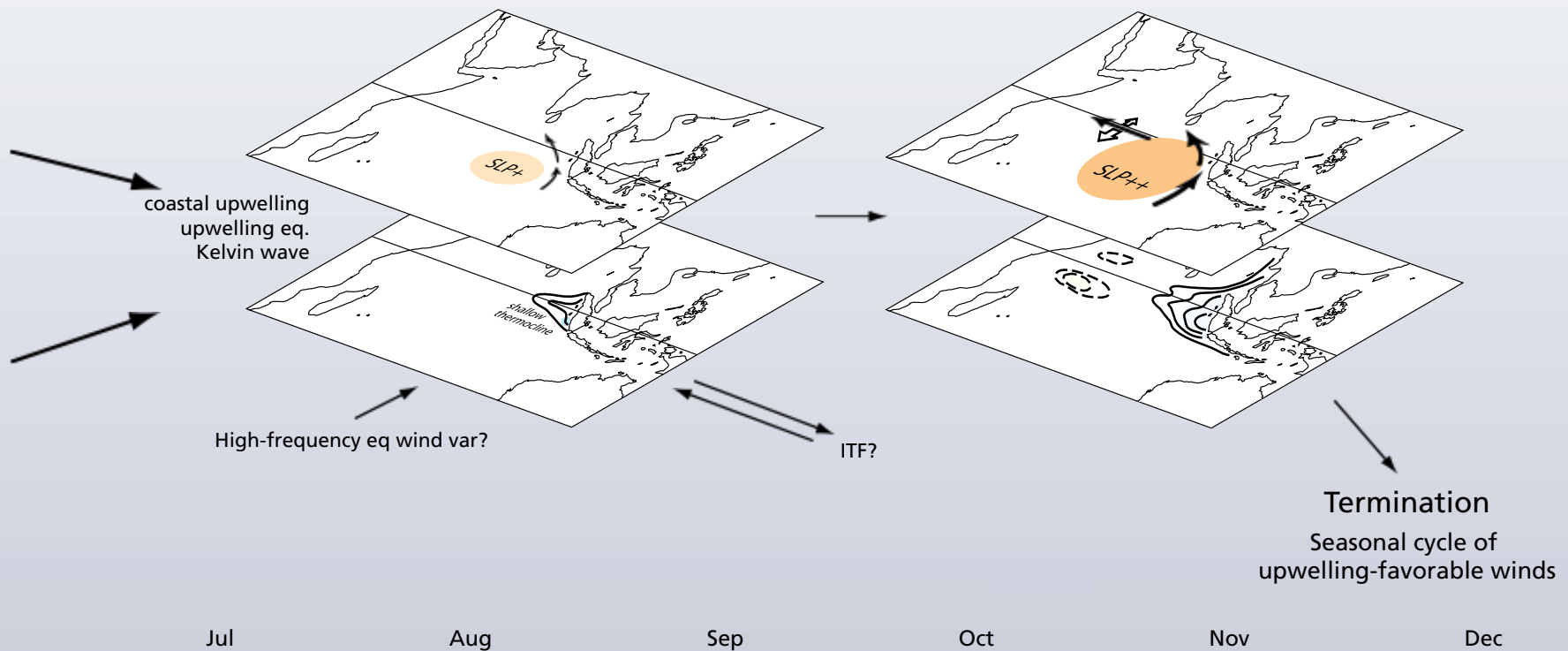
Trigger / Precursors



Schematic evolution (late)

Early evolution

Coupled amplification



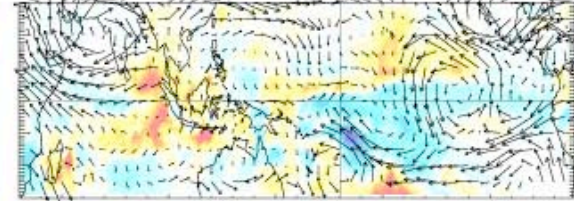
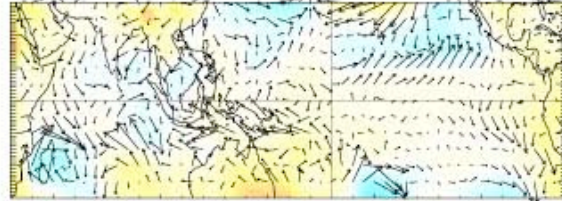
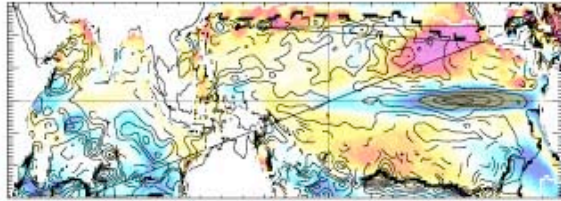
1994 IOD evolution

SODA SST / Z20

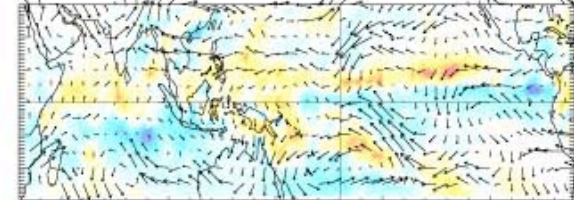
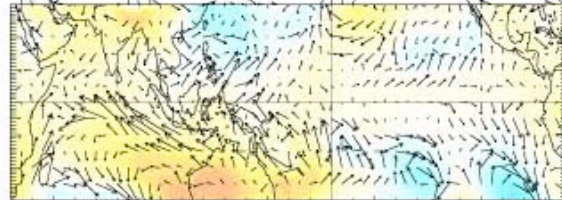
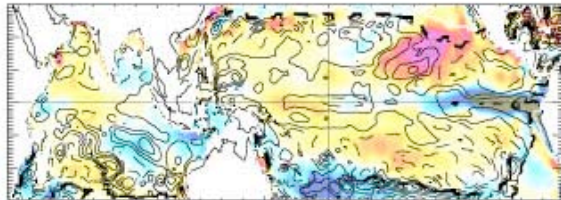
NCEP SLP / u_{10m}

CPC Precip / NCEP u_{200mb}

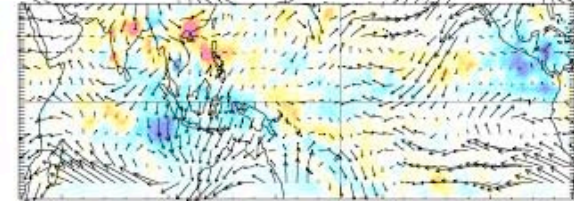
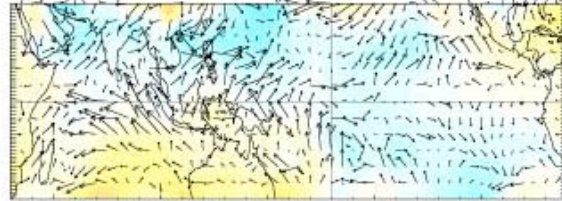
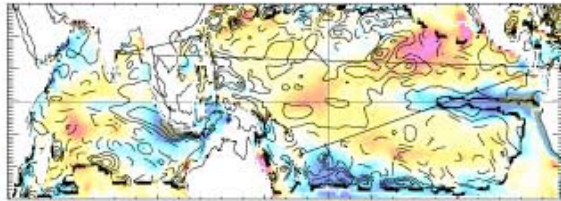
Feb-Mar



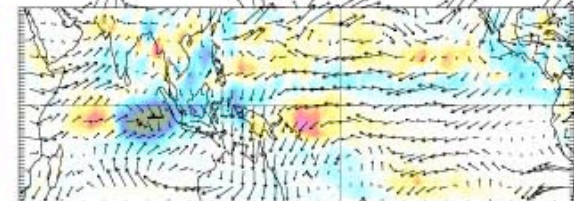
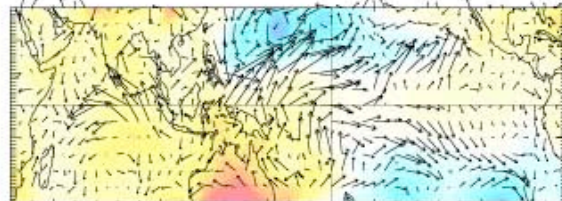
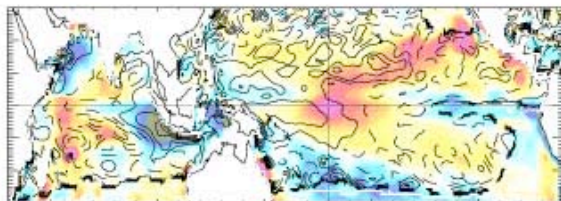
Apr-May



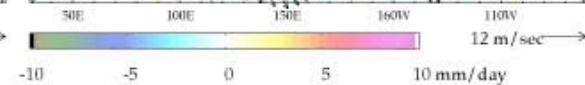
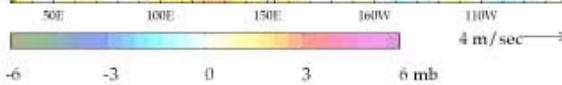
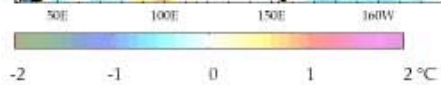
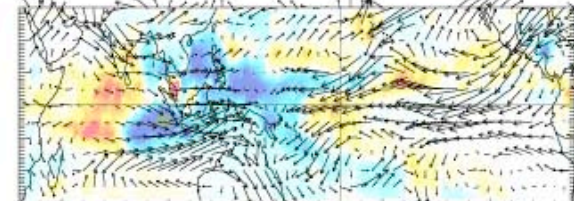
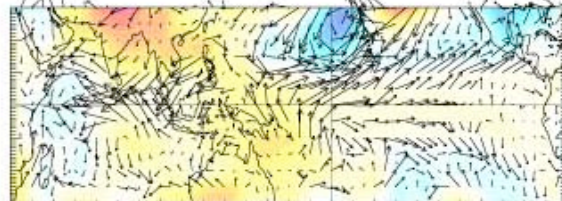
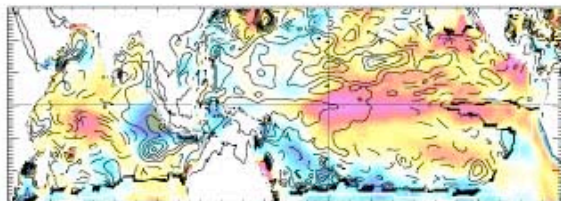
Jun-Jul



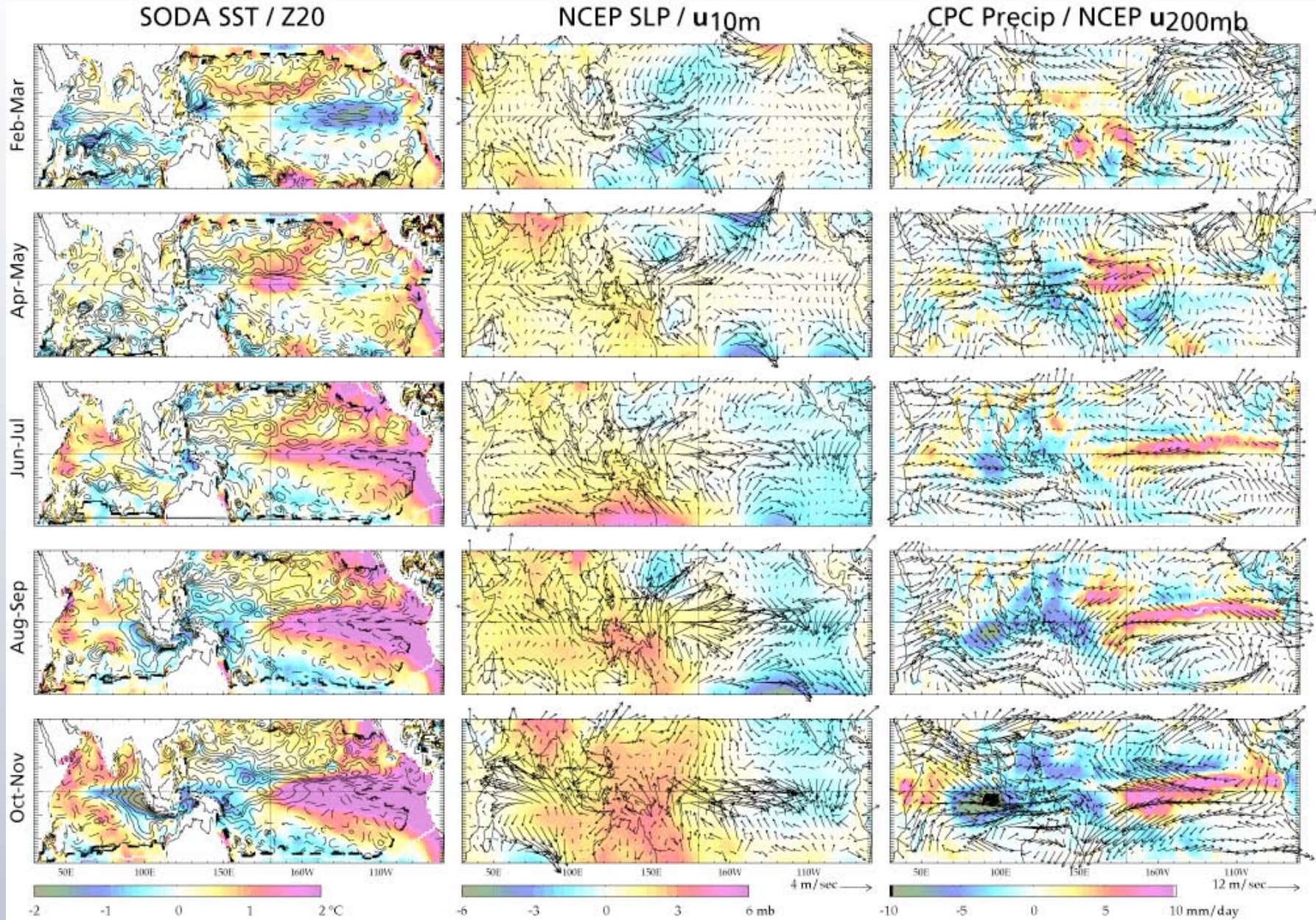
Aug-Sep



Oct-Nov



1997 IOD evolution



Summary

- The wind constraint acts as an effective damper of ENSO in the coupled model
- Without ENSO, the amplitude of variability in the tropical Indian Ocean is only slightly reduced
- The IOD evolution is similar with and without ENSO
 - thermocline-SST-wind feedback (Bjerknes)
- IOD is triggered by a shift in the center of convection
 - Hadley, meridional shift
 - Walker, zonal shift : avenue for phase locking with ENSO

Next time

- The full Monsoon - Indian Ocean - Pacific Ocean system
- Intraseasonal oscillations and the IOD