Relative impact of insolation changes, fresh water fluxes and ice sheet on tropical climate seasonality and interannual variability

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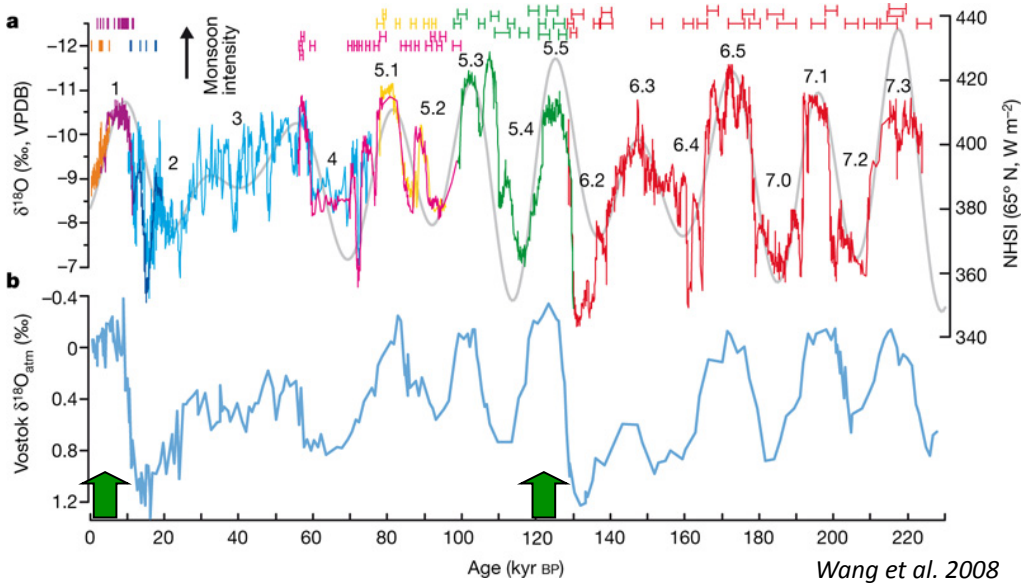
With thanks to lots of colleagues

Monsoon and ENSO in the past

Sanbao cave, China : monsoon record

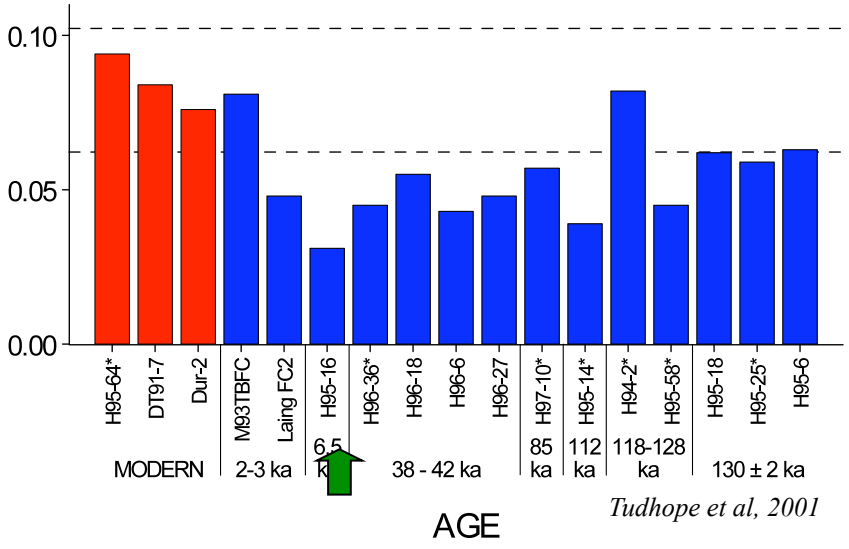


Wang et al. 2008

- Fluctuations at the orbital time scales:
  Eccentricity (100 kyrs) , obliquity (41 kyrs), precession (19 and 23 kyr)
- Lots of publications with model results
  (see Liu and Braconnot, in press for a review)
- Some rapid events are correlated with perturbations in the North Atlantic (not shown)

- Large variations in ENSO variability
- Model Evidences for a link with precession
  i.e Clement et al. (1999)
  + about 12 publications with model results

Coral records : ENSO



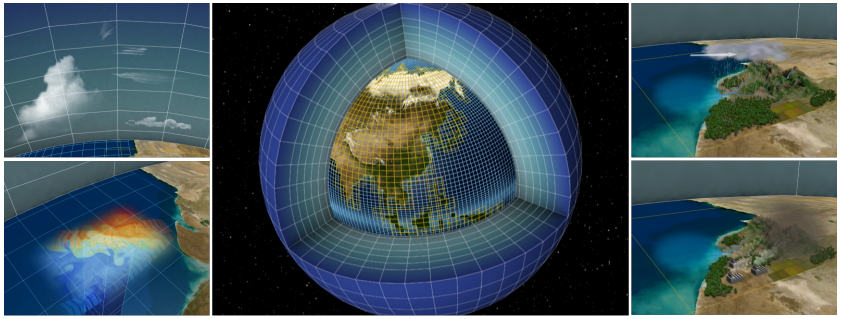
Tudhope et al, 2001

Periods considered in this talk

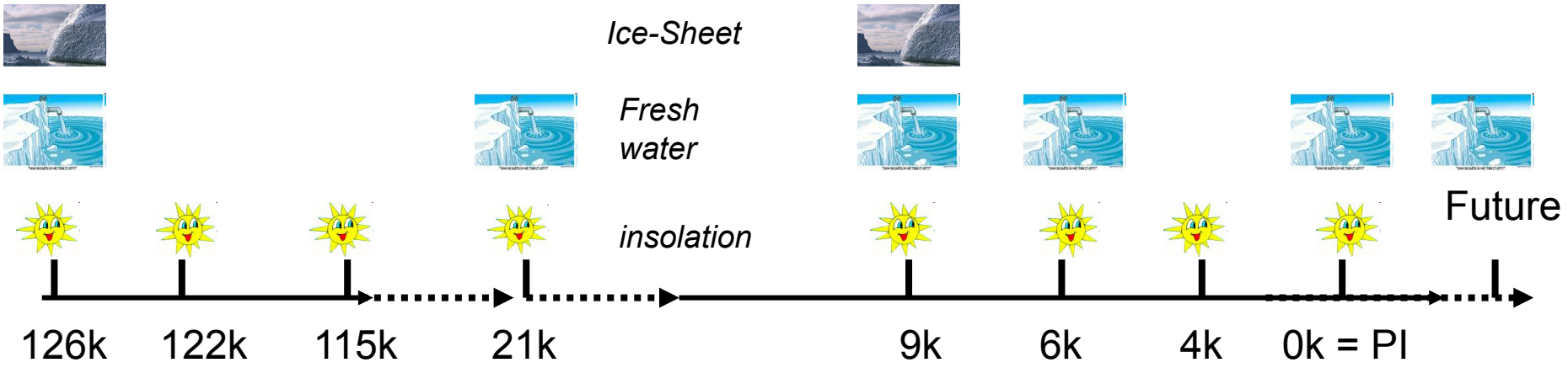
A suite of past climate simulations

➢ Paleoclimate Modeling Intercomparison Projet : multi model ensemble for the mid-Holocene (6k) and LGM (21k) climates (Braconnot et al. 2007)

➢IPSL-CM4 model (Marti et al., 2010)



➢Atmosphere (LMDZ)-ocean (NEMO)-sea-ice (LIM) et land surface (ORCHIDEE)
➢Coupling with biochemical cycles : NOT considered here



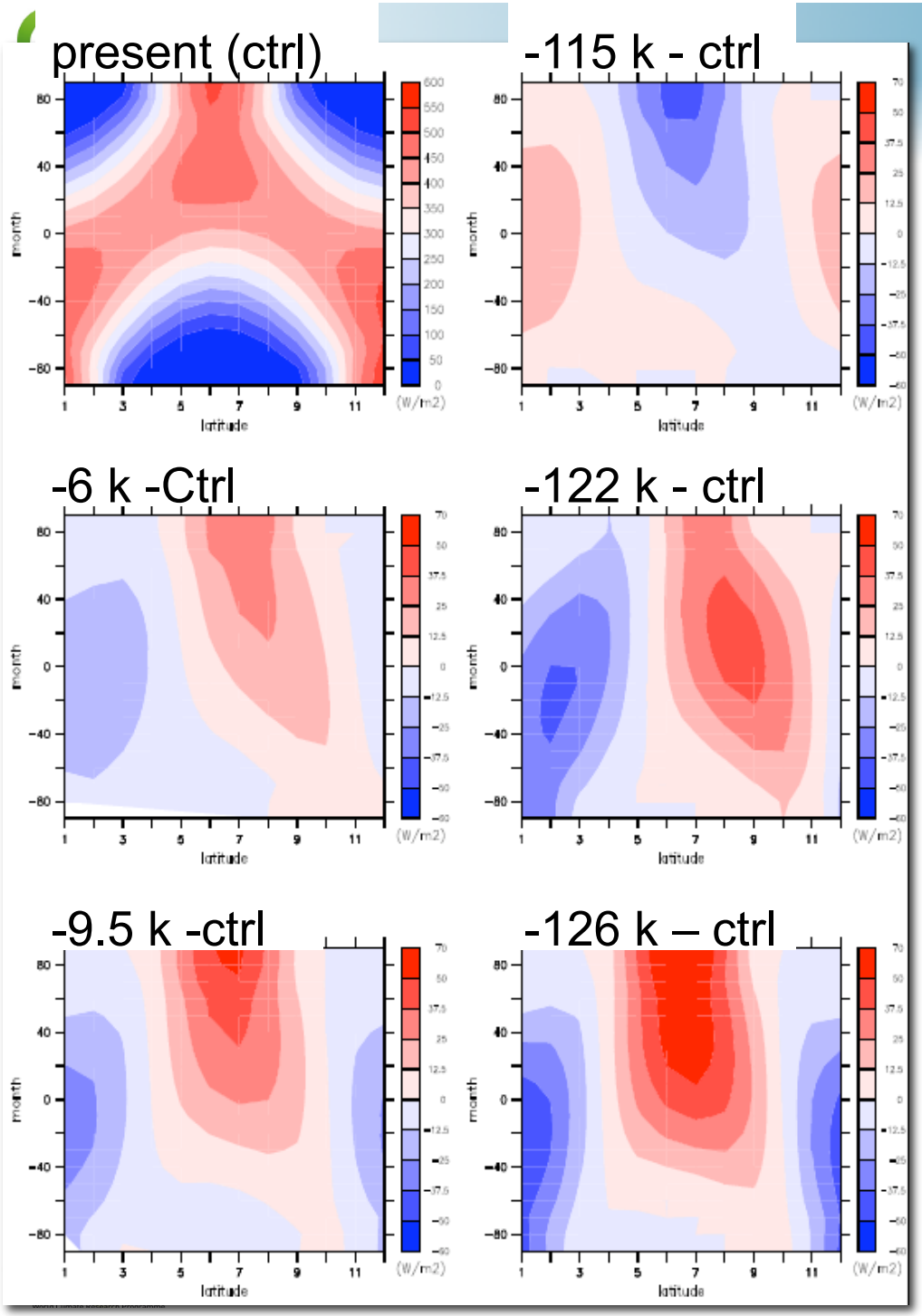
Simulations presented here 300 to 700 yr long,
mean seasonal cycle from last 200 to 400 years

Braconnot et al. 2008, Marzin and Braconnot, 2009, Kageyama et al. 2009, Swingedouw et al 2009; Braconnot et al. 2011

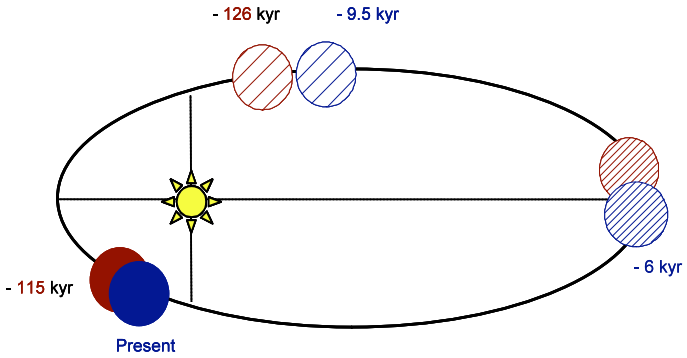
Response of monsoon and ENSO to changes in insolation

Paleoclimate Modelling PMIP3 Intercomparison Project

Insolation and seasonality



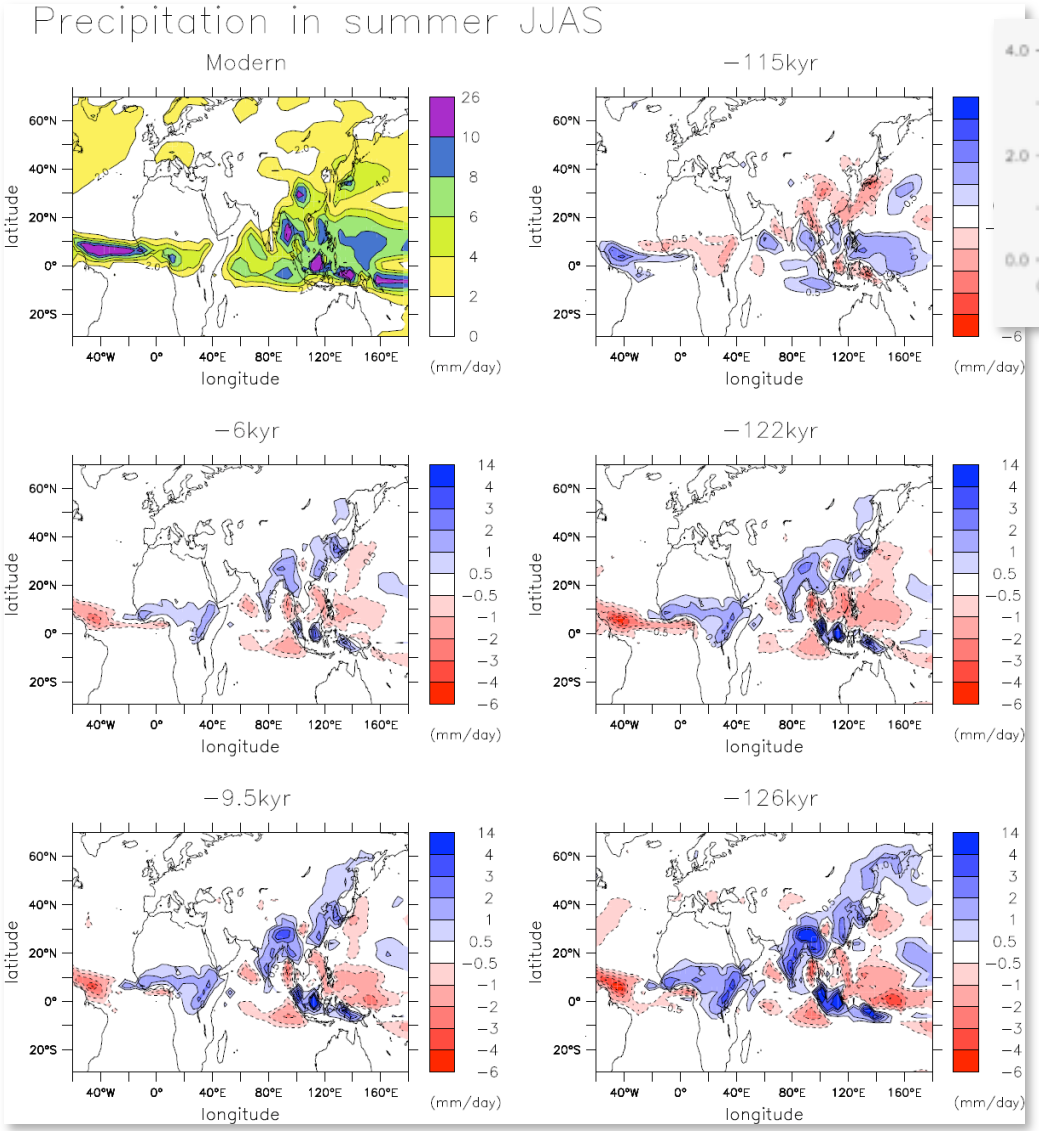
Insolation as a function of latitudes and months for different periods



Location of the Vernal equinox

- Precession analogy between the Eemian and the Holocene
- Differences in magnitude and timing

Changes in JJAS precipitation

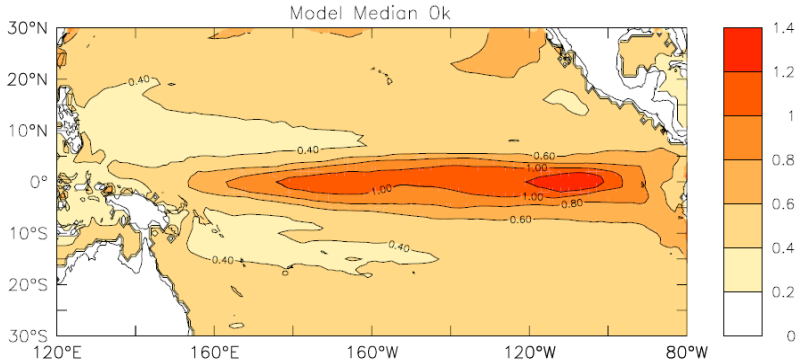


- Change in monsoon dominated by changes in water vapor advection
- Summer insolation shorter, but summer monsoon longer
- The relative response of the Indian and African monsoon is a function of precession (relationship between seasonal timing of insolation and monsoon development in each regions)

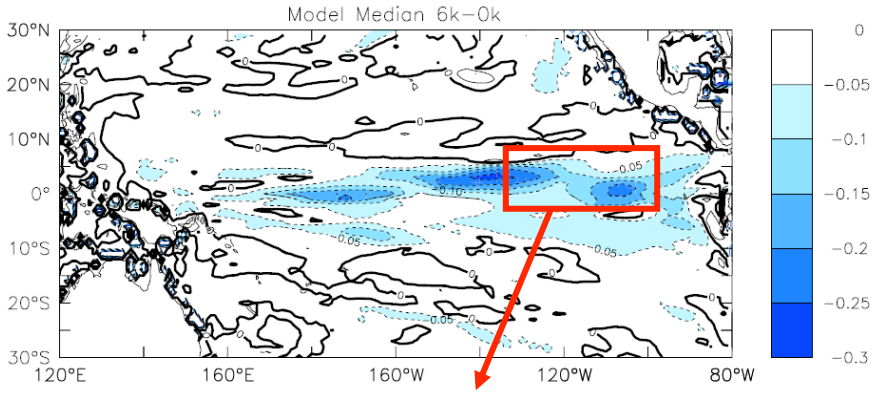
Marzin and Braconnot 2009, Braconnot et al. 2008

ENSO in PMIP mid-Holocene simulations

Interannual variability (model median)

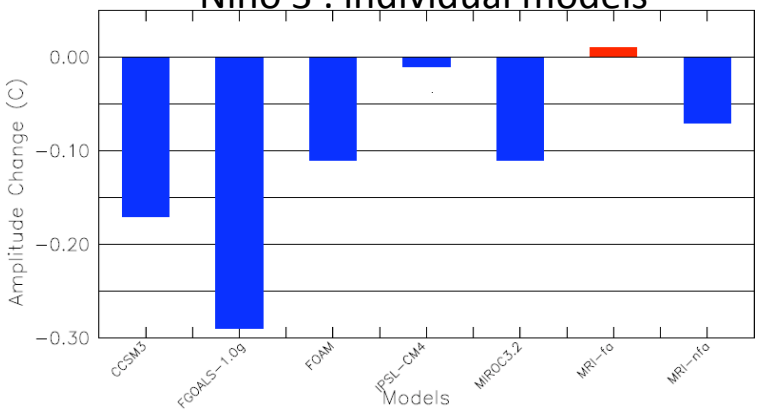


MH change in Interannual variability (model median)



- Almost all simulations show reduced ENSO
- Consistent with several records (corals, shells, giant bivalves…) , but smaller magnitude
- The changes in large scale dynamic (interhemispheric gradient, enhanced monsoon) have a strong constraint on the mean annual cycle

Niño 3 : individual models



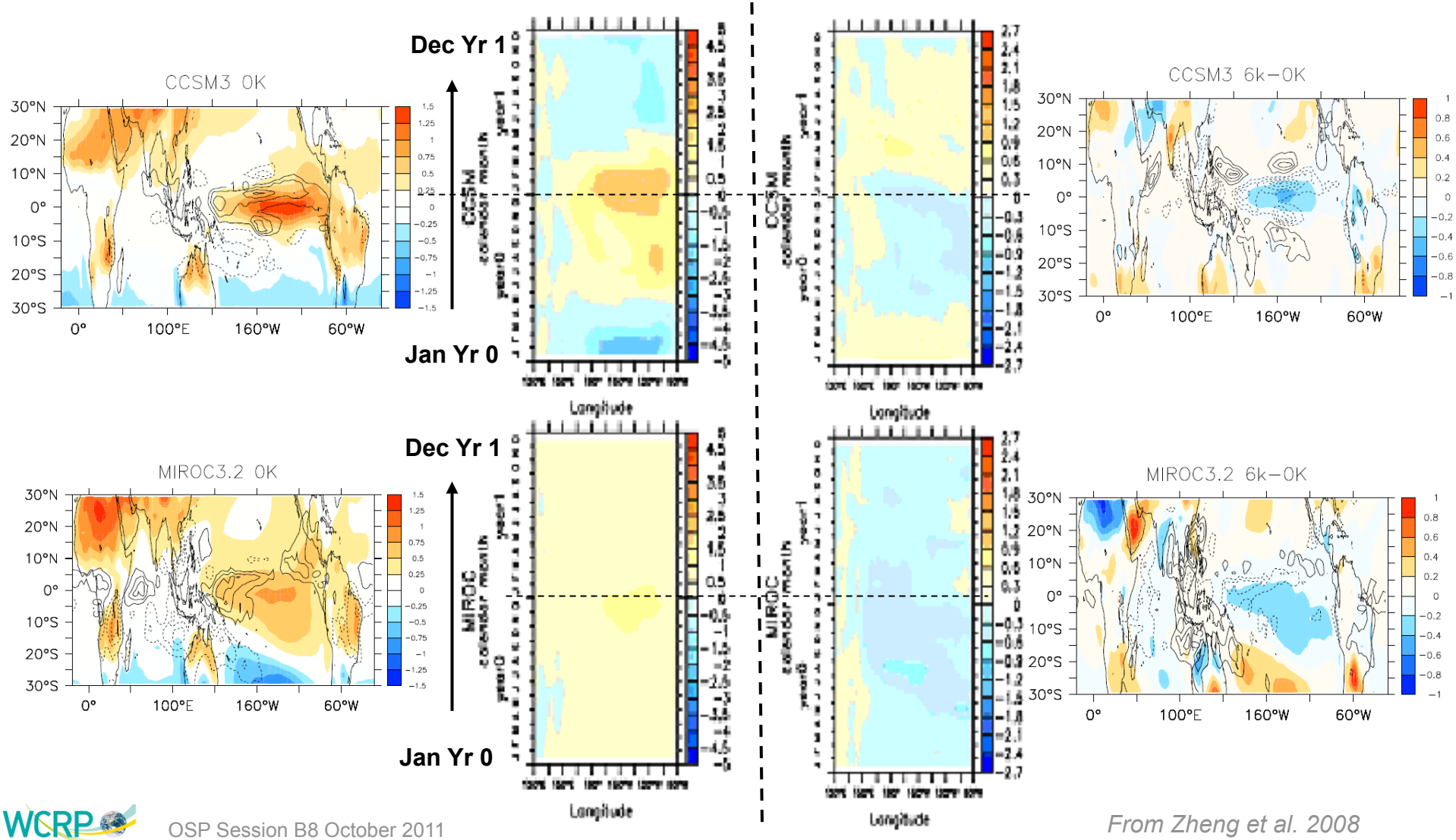
Zheng et al 2008

El-Niño composites for 2 models

SST : colour
Rain : isolines

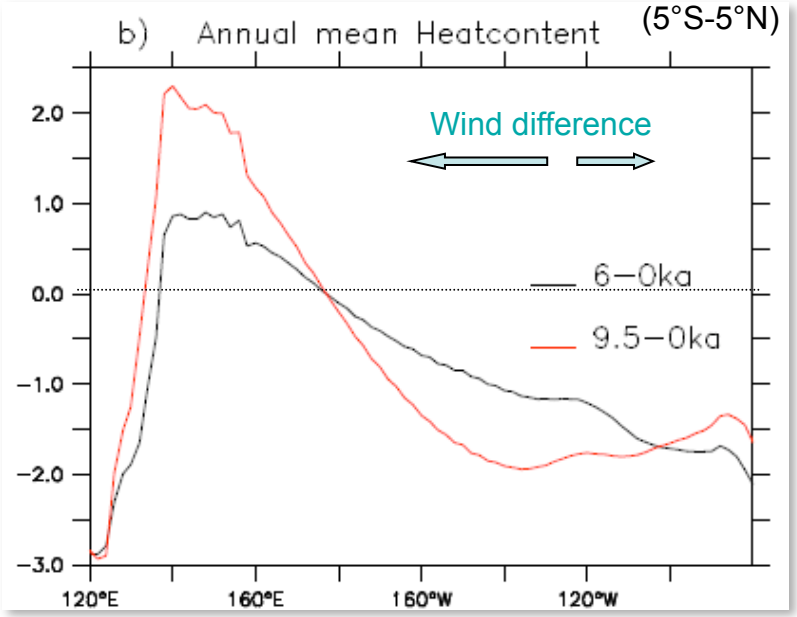
CTRL

6ka -CTRL

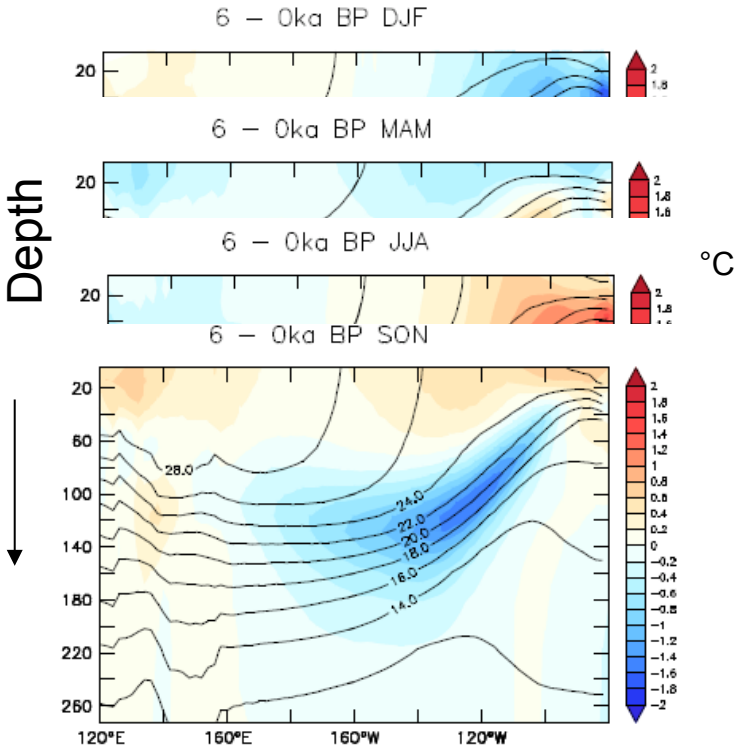


From Zheng et al. 2008

Relationship with changes in ocean mean state in the IPSL 6k simulation



5°S-5°N equatorial section : Pacific 6k-0k



➢ Annual mean :
Strengthening E/W wind and heat content gradient (no direct link SST/wind)

➢In Autumn (SON) :
Upwelling (thermocline) + warmer surface water in the east counteract downwelling El-Niño anomaly
El-Nino development is damped

Luan et al. In prep

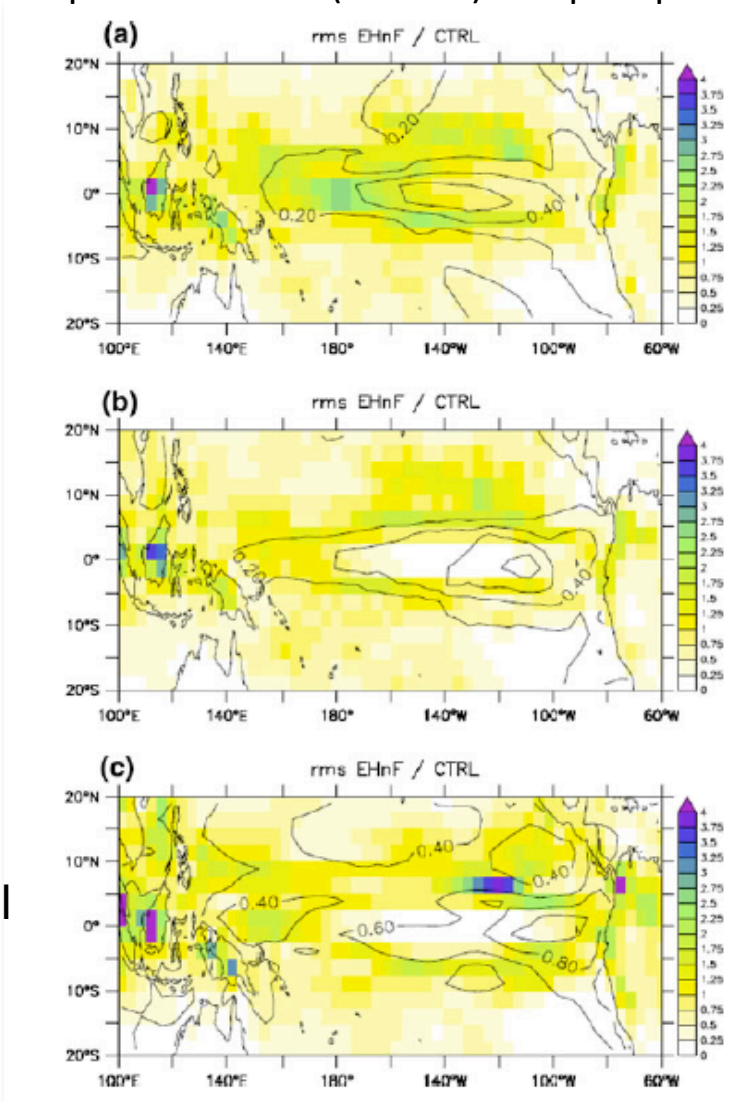
Relative impact of insolation on SST considering seasonality, El Niño or La Niña events

July yr0 to July yr 1 rms different between 9.5k and 0k composites for SST (isolines) and precipitation (colour)

Niño year

Niña year

Normal year



- Different patterns for El-Niño, La Niña and seasonality (normal)
- Changes in seasonality dominate the signal almost everywhere and are large in east Pacific
- Need to be accounted for in the interpretation of proxy records

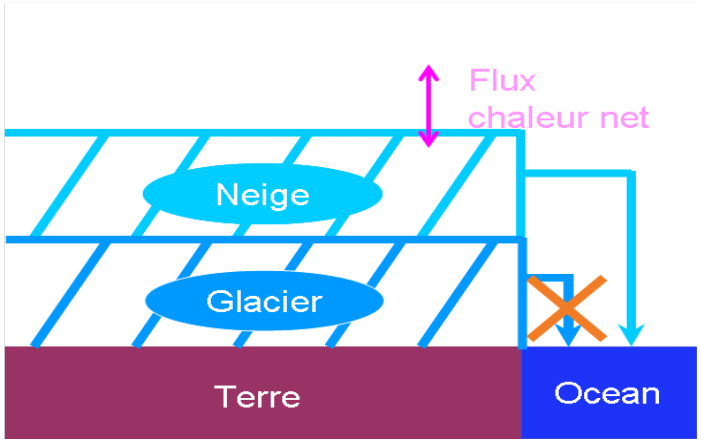
Braconnot et al., clim dyn, 2011

What is the role of the remnant ice sheet in the Early Holocene ?

What is the role of a fresh water flux induced by the ice-sheet melting during the Early Holocene ?

Sensitivity tests with the IPSL-CM4 model

Simulation	Total number of years	Climatology
9.5	600	250 to 350
9.5F	300	100 to 200
9.5IS	480	300 to 450



9.5F Interactive melting following Swingedouw et al 2006 for future climate

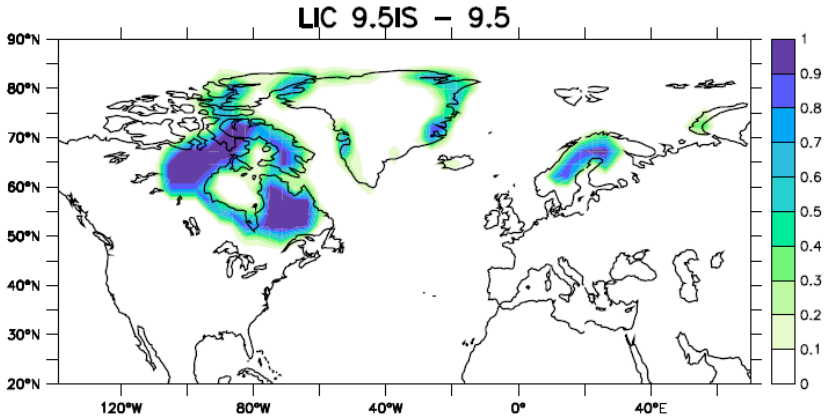


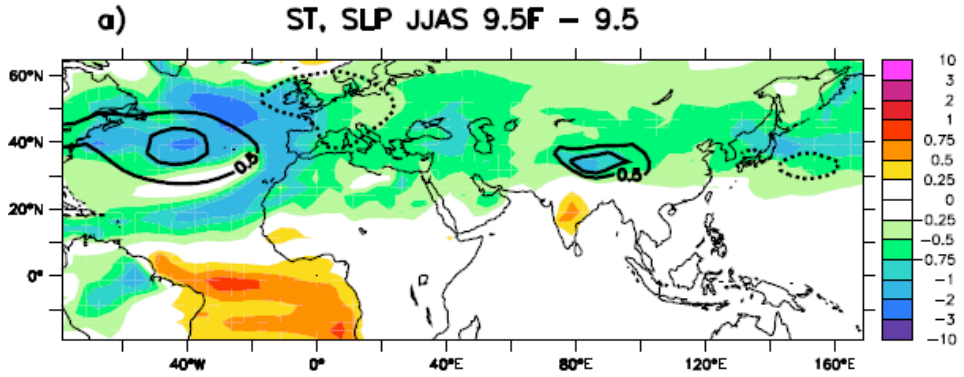
Fig. 1 Differences in land ice grid-point fraction between 9.5IS and 9.5

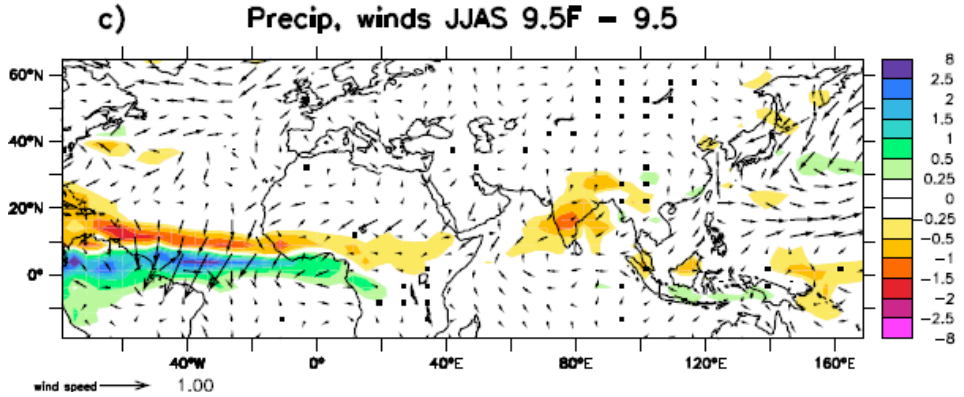
9.5IS : Peltier (2004) ice sheet reconstruction as boundary condition (no change in land/sea mask)

Marzin et al. Subm.

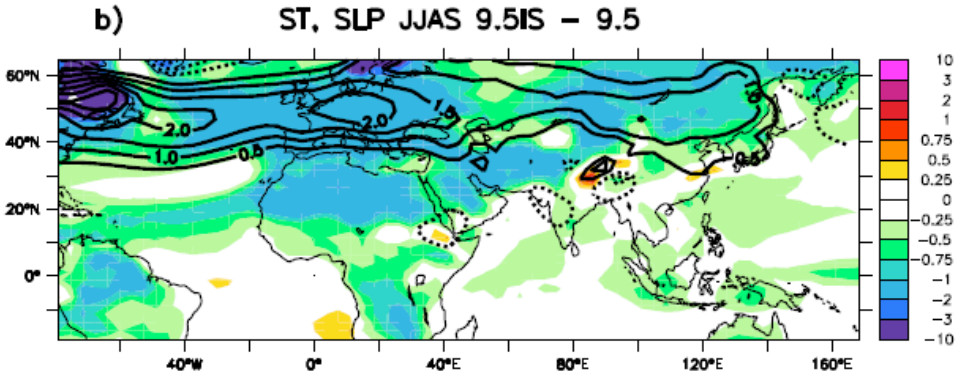
Impact on monsoon

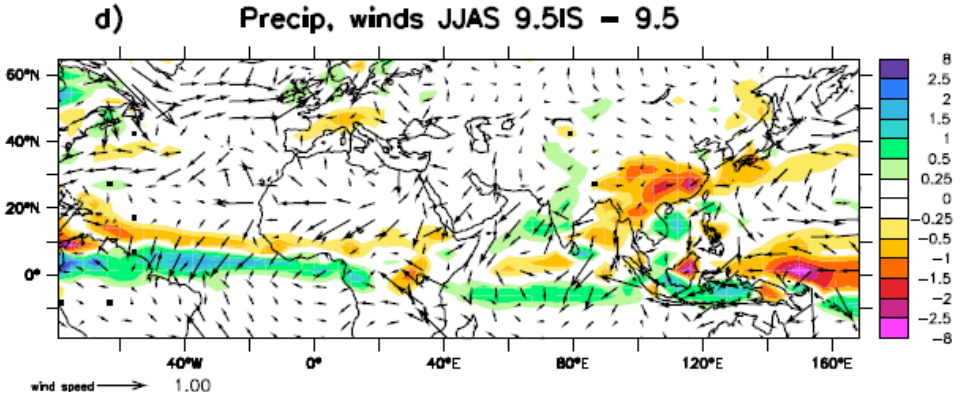
Fresh water flux





Ice sheet





Reduced ← Atlantic overturning → Little change

-0.22 PW at 30°N ← Ocean heat tranport →

Teleconnections throught the subtropical jets : important role of the SST pattern in the tropical Atlantic

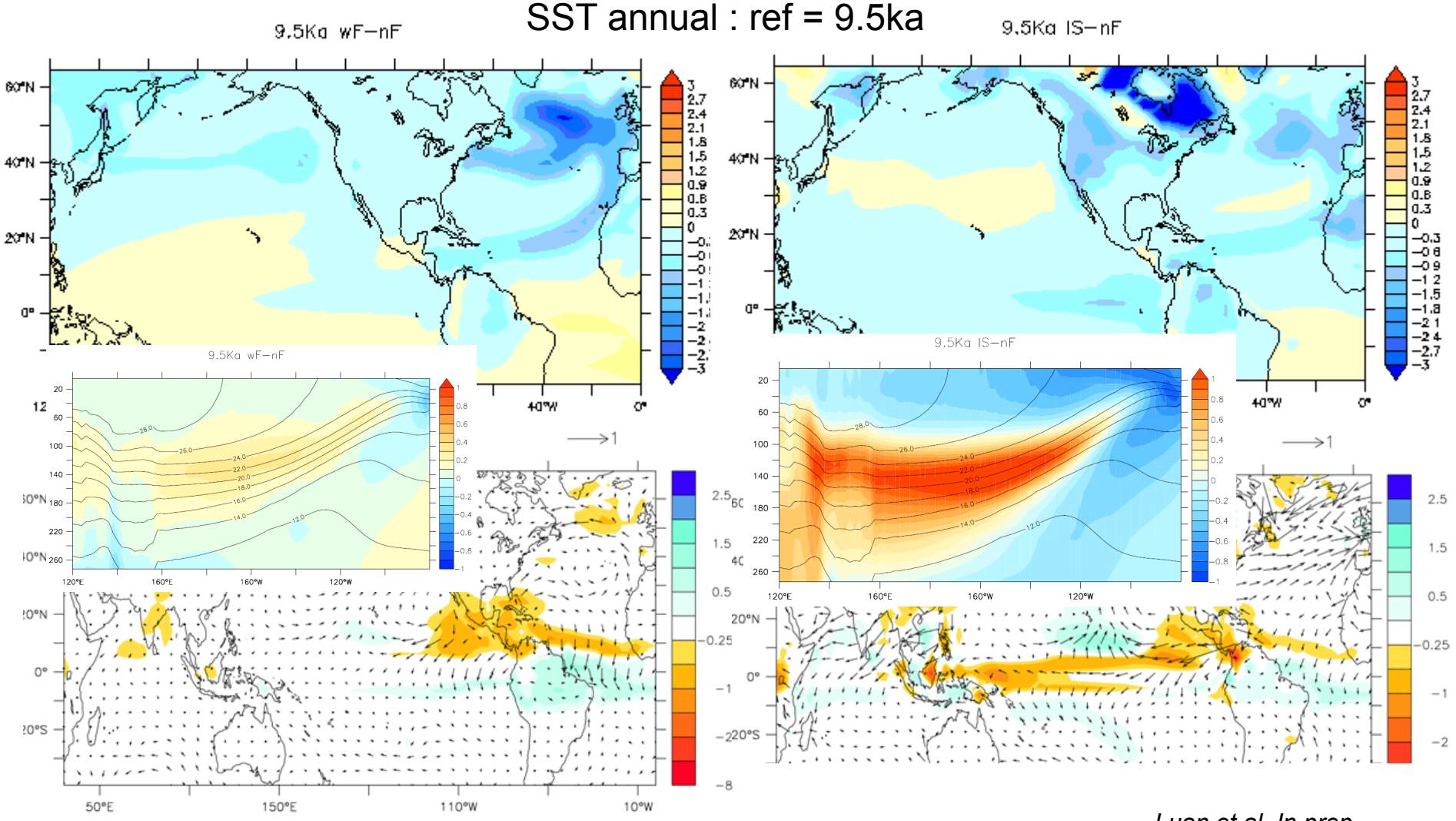
Marzin et al. Subm.

Annual mean changes in the Pacific

Fresh water

SST annual : ref = 9.5ka

Ice sheet

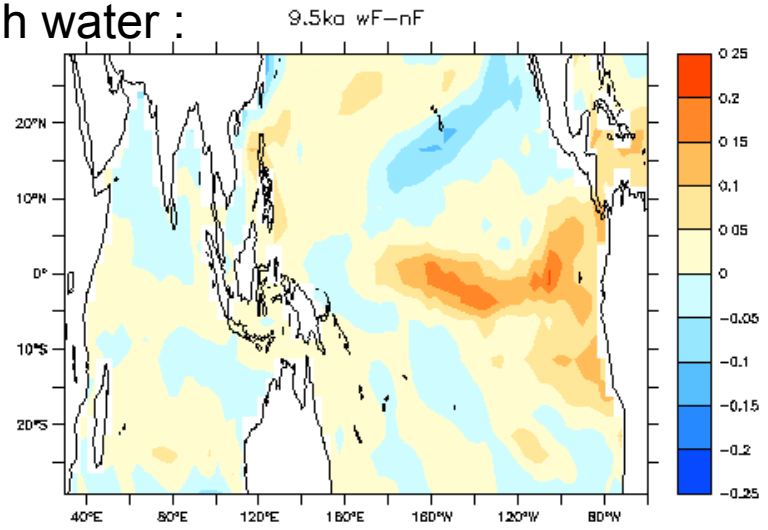


Luan et al. In prep

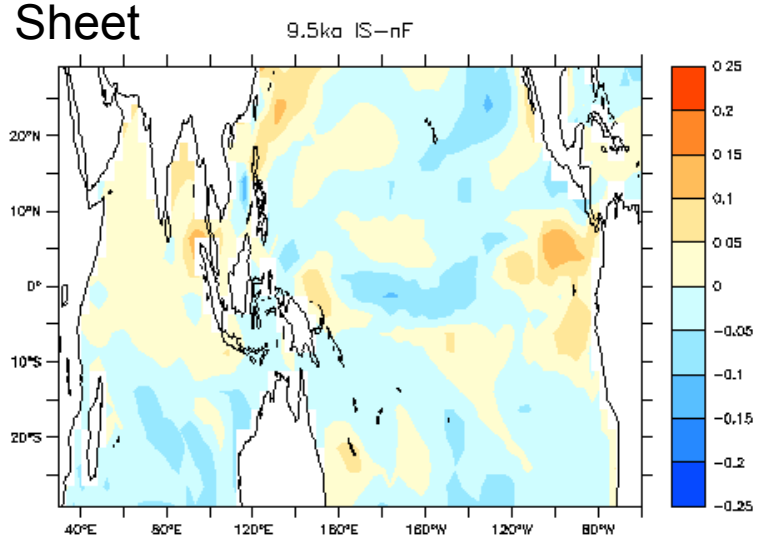
Link with interannual variability

SST : Change in interannual variance/ 9.5ka

Fresh water :



Ice Sheet



Mean state : E/W gradient across Pacific

Annual mean	SST	Heat content
9.5k	~2.9 °C	~ 45.8
9.5kwF	~2.9 °C	~ 45.6
9.5kIS	~3.2 °C	~ 50

- IS: strengthening of SST and heat content E/W gradient due changes in mean wind
- Both show increase downwelling in autumn / 9.5k with similar magnitude in the east
- Combination of changes in annual mean and seasonal variability explain similarities in the east and differences in the middle of the basin

months

Conclusion

- Results show that both the differences in the annual mean and in the phasing of the seasonal cycle with the development of the phenomenon under study need to be considered to understand monsoon or ENSO changes

- Increased NH seasonality amplifies African and Indian monsoons and reduces the magnitude of El-Niño events in the Holocene
- Fresh water flux partially counteract this effect
- The 9.5k ice sheet has similar impact than the fresh water flux on African monsoon and interannual variability in the east Pacific, but a more complex pattern over India and southeast Asia and further damp interannual variability in the middle of the basin.

- Need to be further tested and analyzed : the CMIP5 simulations offers an unique opportunity to compare in a coherent framework present past and future climates
- New data syntheses of high resolution data (coral, shells, tree rings…) are under development and will be used to evaluate model response