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**UNIVERSITÄT  
BERN**

**OESCHGER CENTRE**  
CLIMATE CHANGE RESEARCH

# El Niño-Southern Oscillation and the ocean carbon cycle in CESM1: impact of the climatological mean state

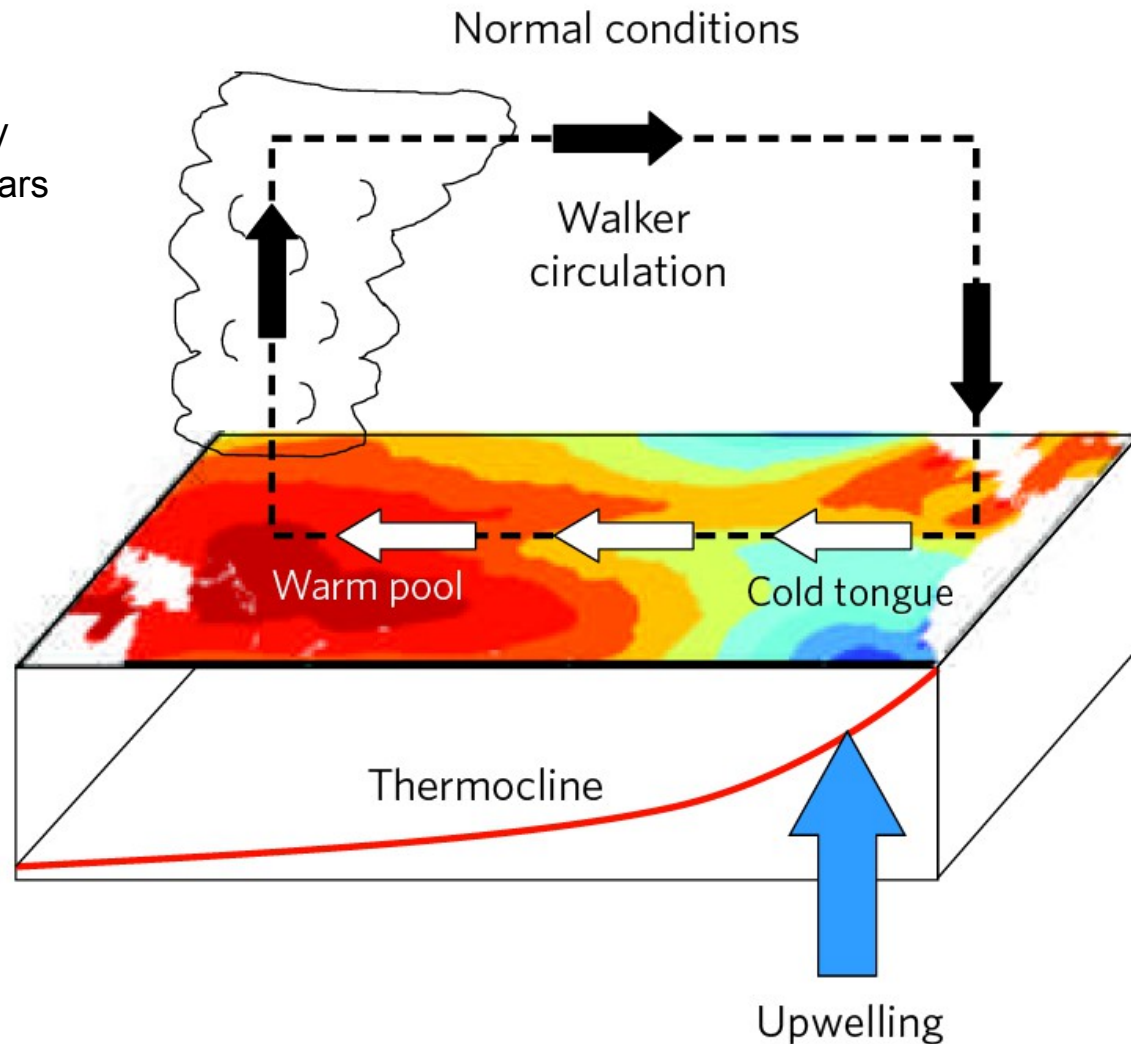
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Climate and Environmental Physics &  
Oeschger Centre for Climate Change Research, University of Bern

# INTRO

## - El Niño-Southern Oscillation (ENSO)

- important source of natural variability
- occurring at periodicities of 2 to 7 years
- **Southern Oscillation:**  
seesaw in atmospheric pressure
- Cold phase: **La Niña**  
strong trade winds  
→ shallow thermocline, cool SSTs
- Warm phase: **El Niño**  
weak trade winds  
→ deep thermocline, warm SSTs

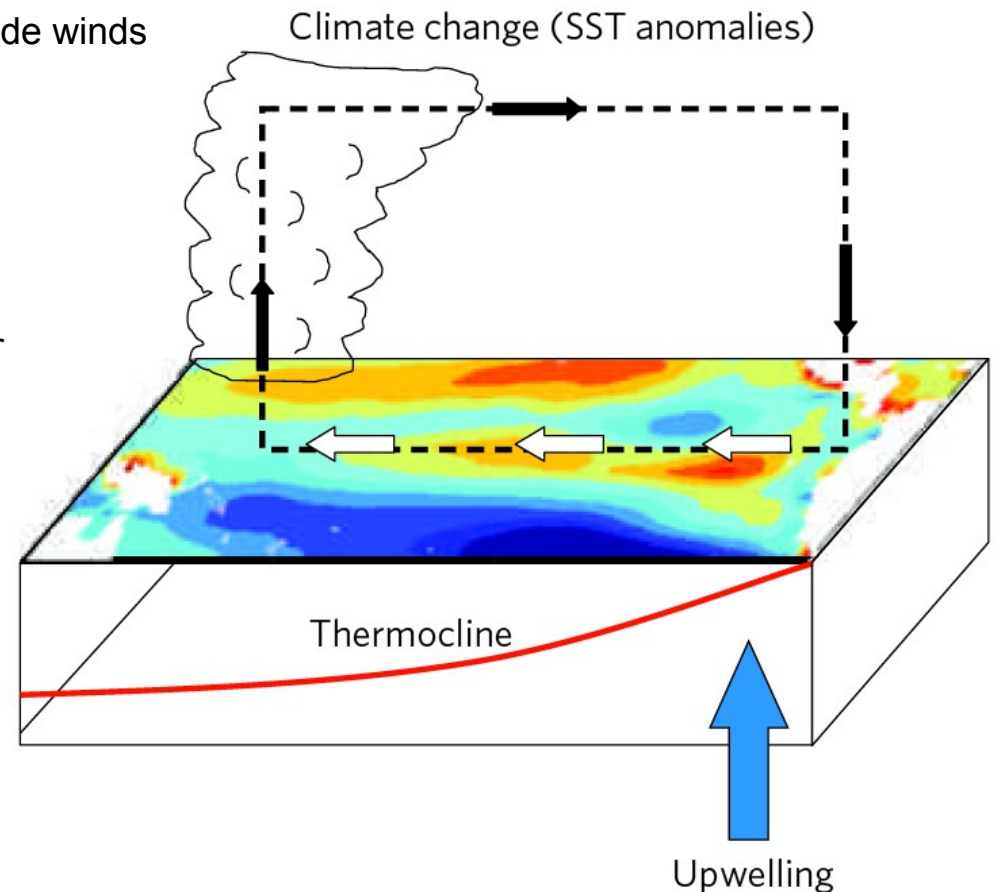


# INTRO

## - changing mean state

Likely changes of the mean climate in the Pacific region include..

- weakening of the Walker circulation/trade winds
  - reduced upwelling
  - shoaling of thermocline
- increase in thermal stratification
- SSTs increase fastest near the equator

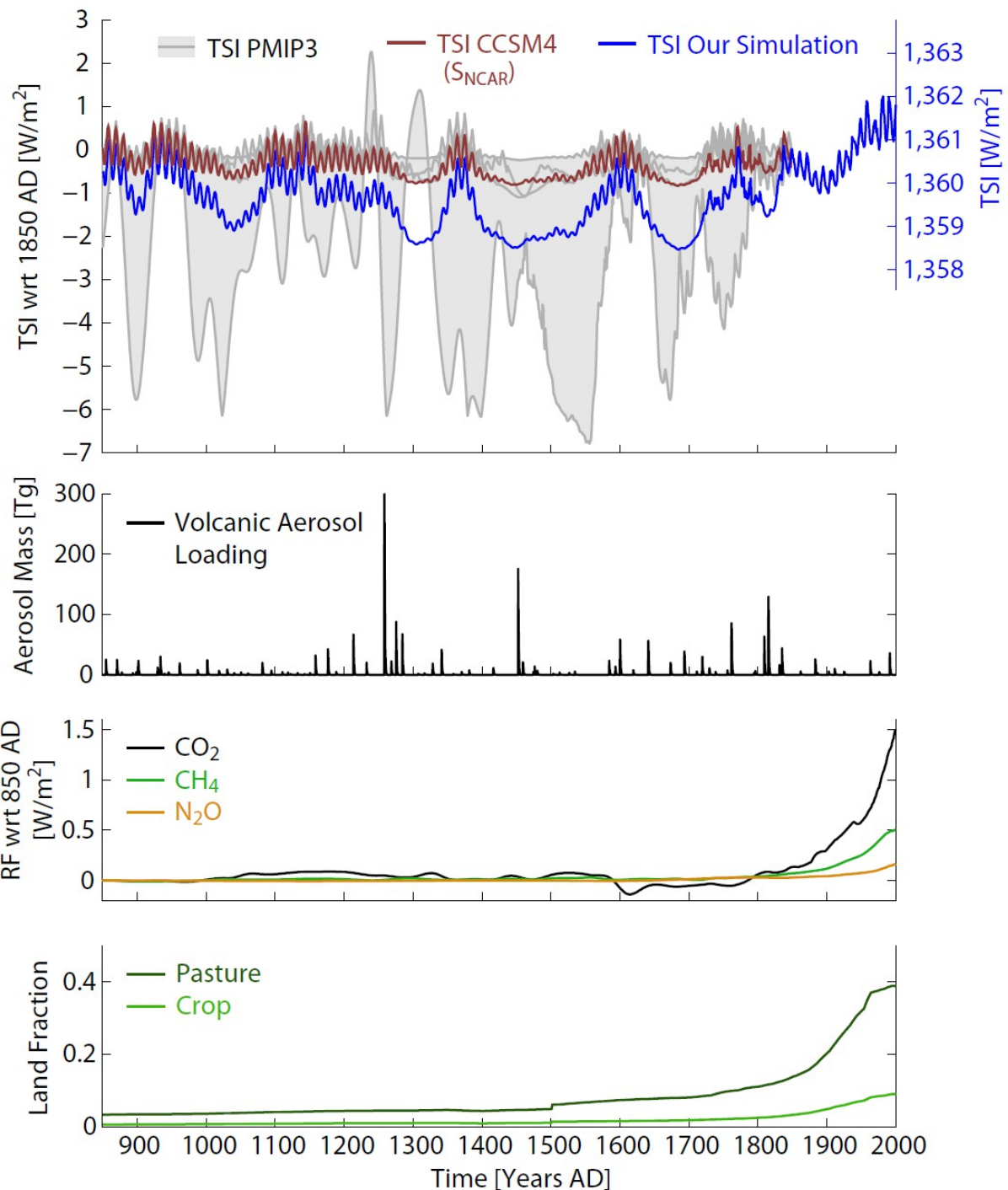


# METHODS

## - NCAR CESM1

- LM simulation, 850-2100
- fully coupled, incl. interactive ocean carbon cycle
- resolution POP/BEC:
  - horizontal:  $1^\circ$
  - vertical: 60 levels

- used for analysis:
  - 1030-1129 (“control”)
  - 1645-1715 (maunder)
  - 1850-2005 (historical)
  - 2005-2100 (rcp8.5)

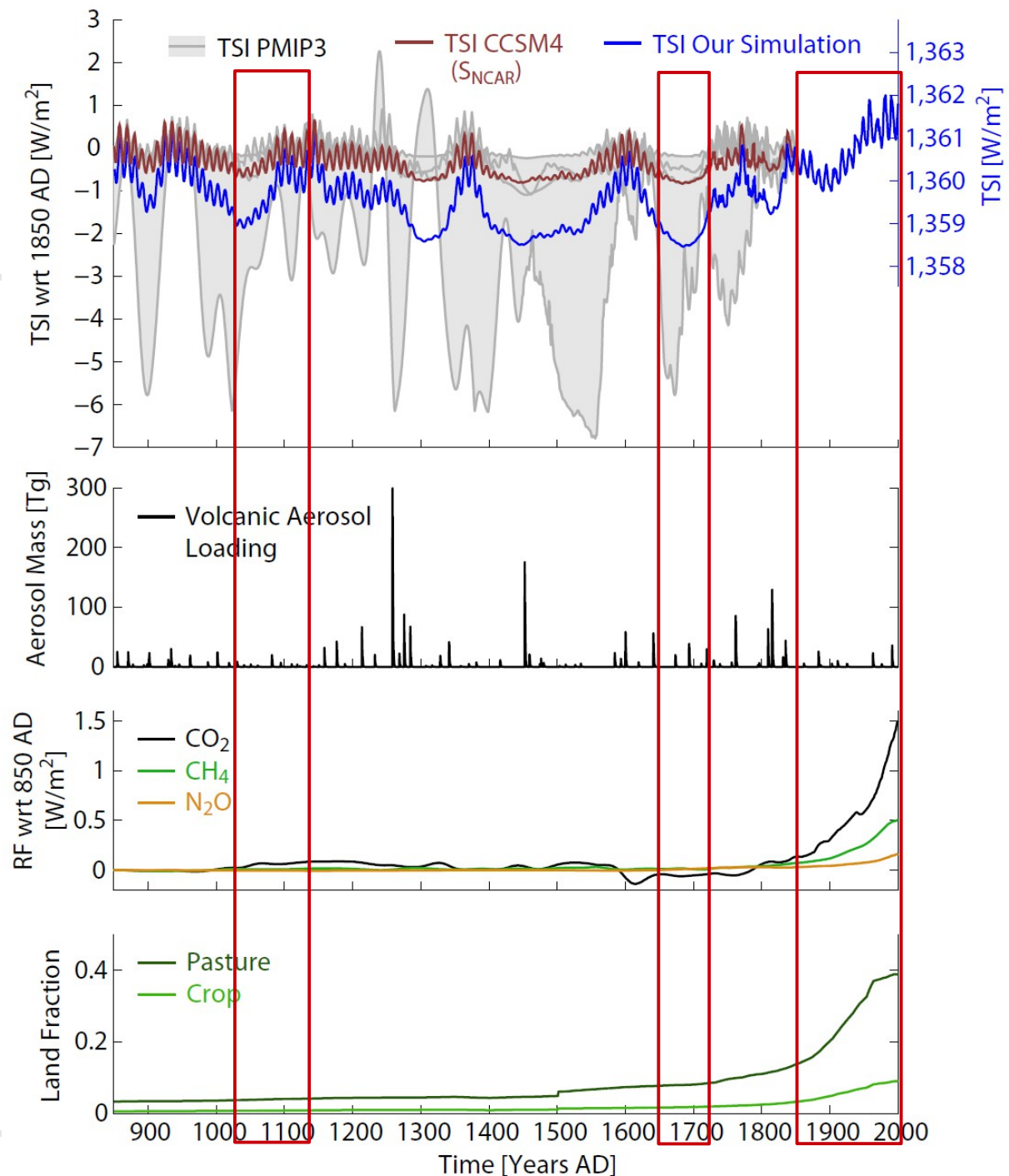


# METHODS

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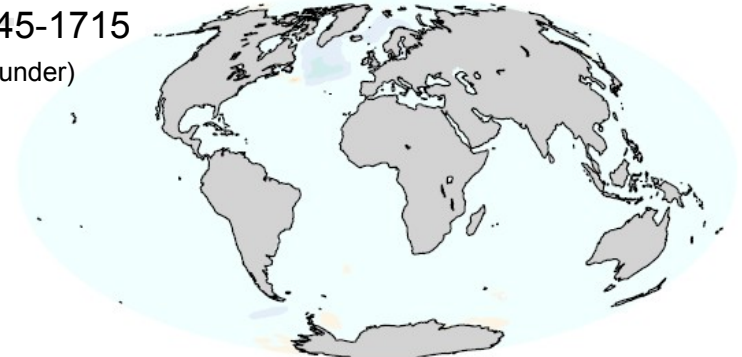
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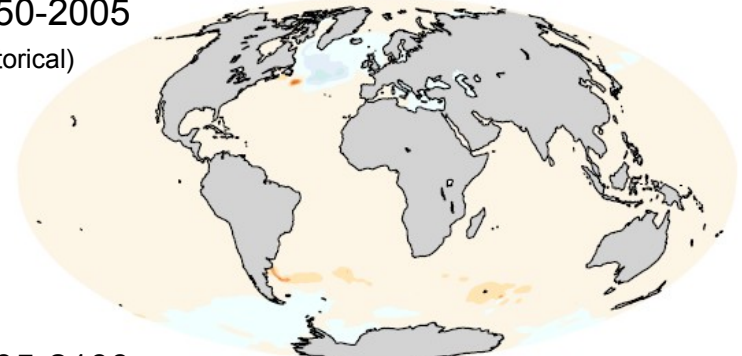
# RESULTS

- Mean States: SST

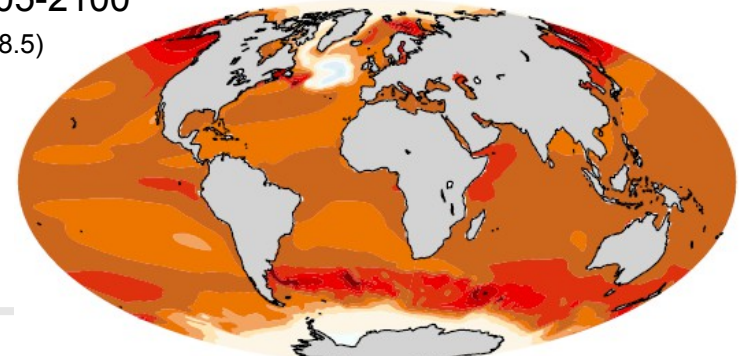
1645-1715  
(maunder)



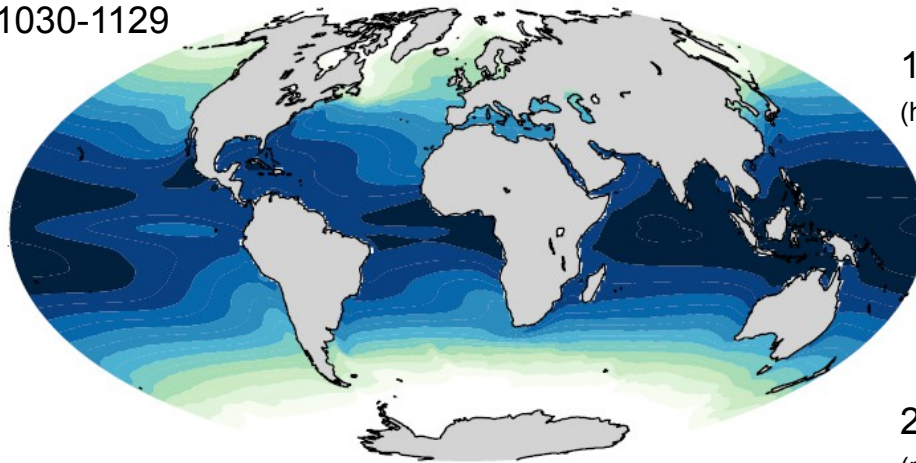
1850-2005  
(historical)



2005-2100  
(rcp8.5)



1030-1129

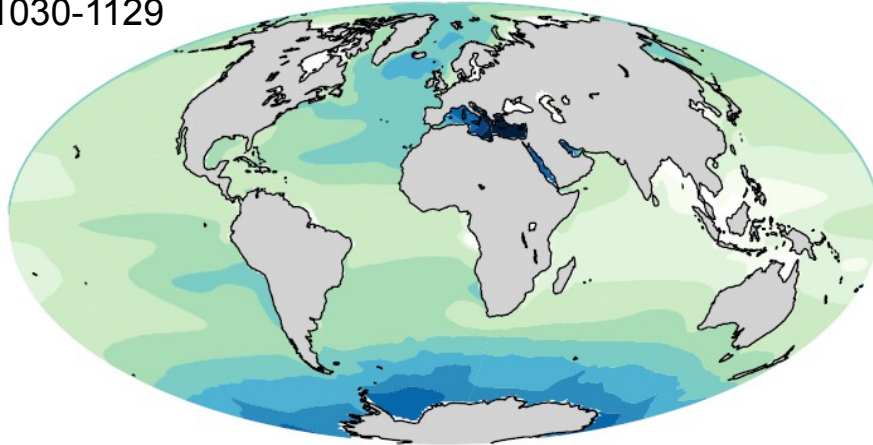


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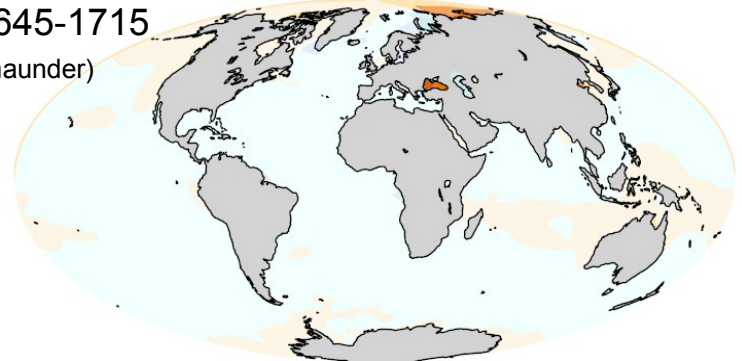
# RESULTS

- Mean States: DIC

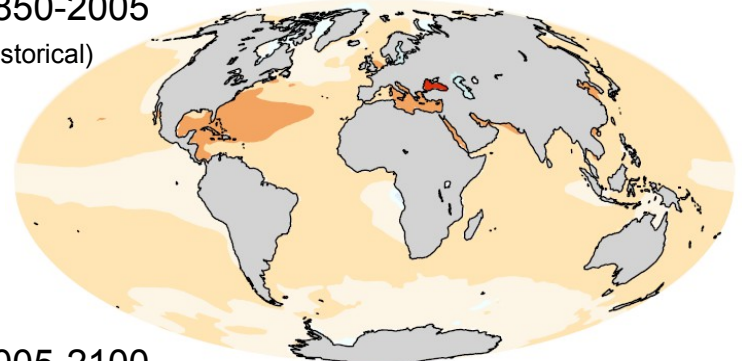
1030-1129



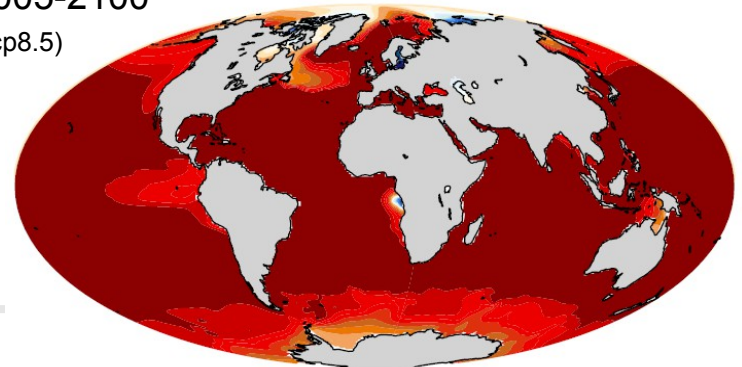
1645-1715  
(maunder)



1850-2005  
(historical)



2005-2100  
(rcp8.5)



2400  
2300  
2200  
2100  
2000  
1900  
1800

mmol m<sup>3</sup>

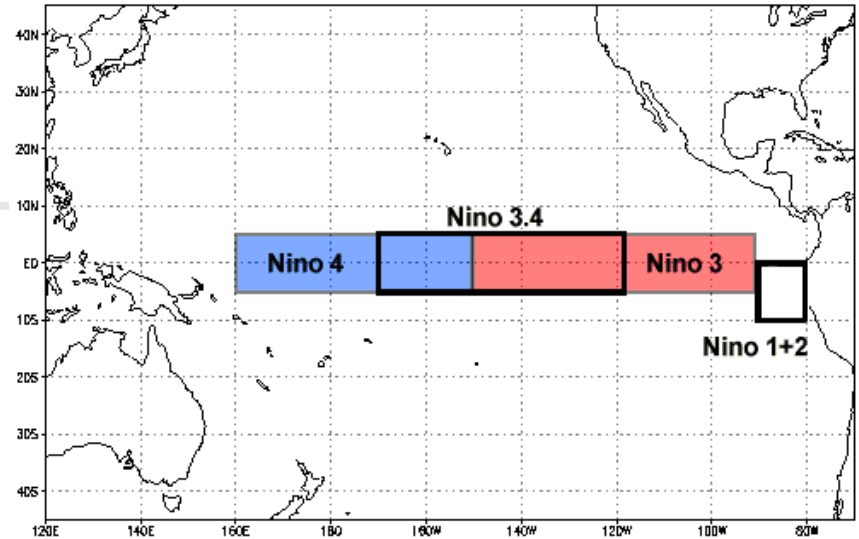
100  
80  
60  
40  
20  
0  
-20  
-40  
-60  
-80  
-100

$u^b$

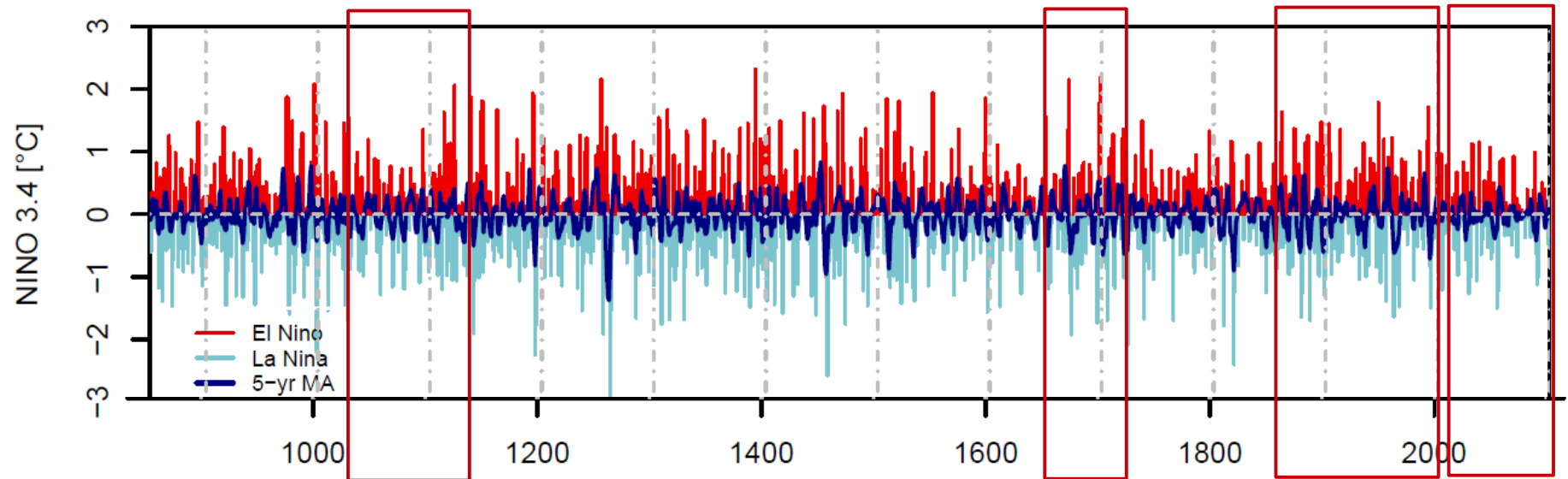
# RESULTS

## - ENSO

- **Niño 3.4**  
→ mean SST (5°S-5°N, 120-170°W)
- annual



MARCH



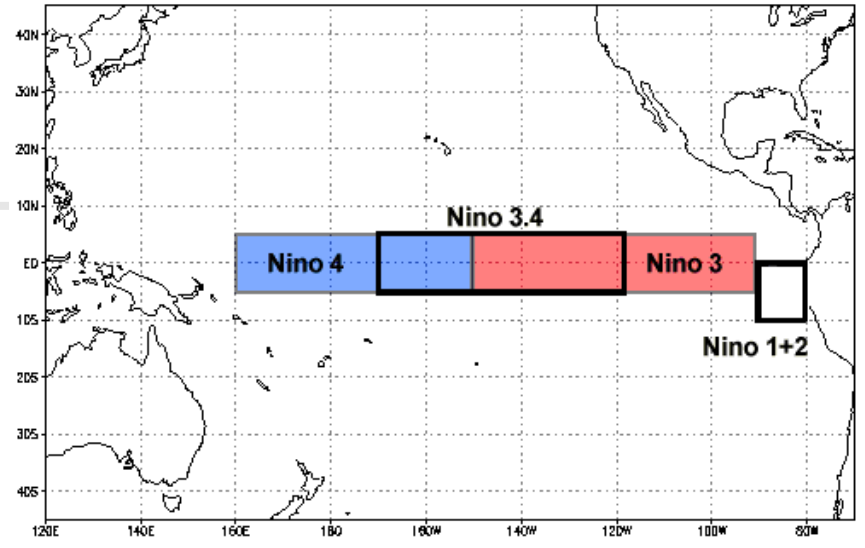


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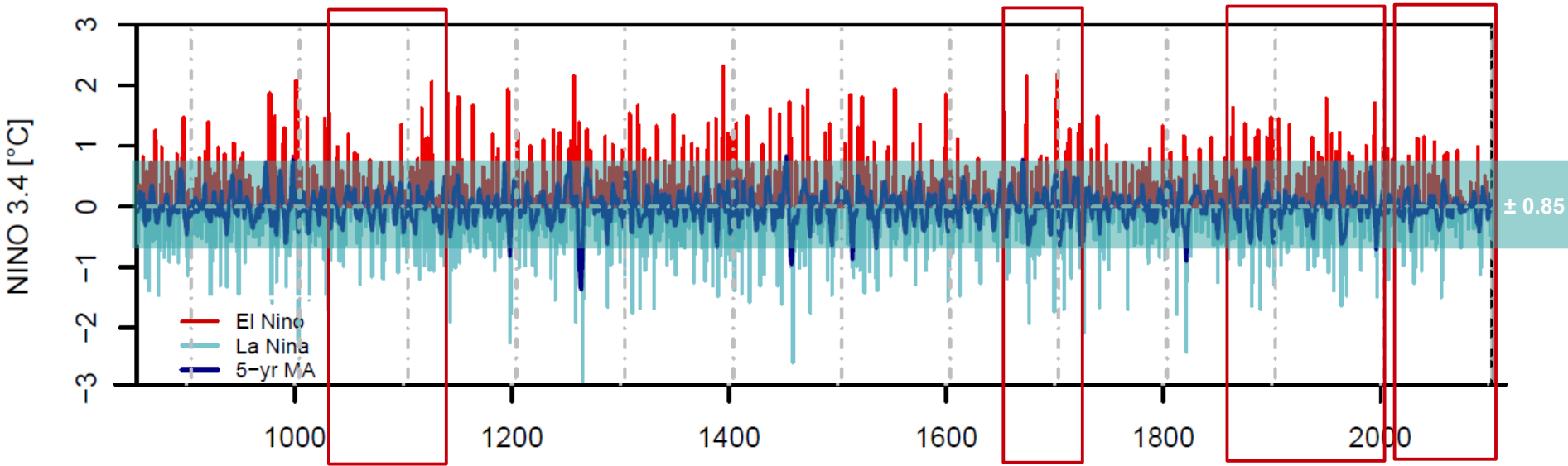
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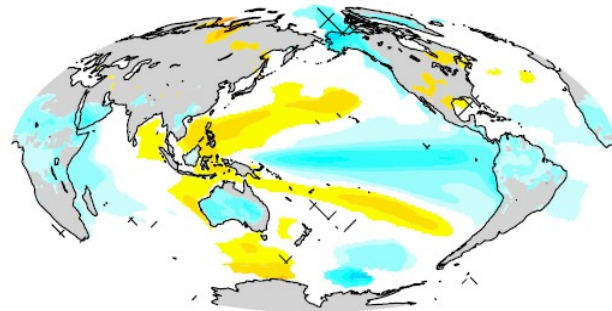
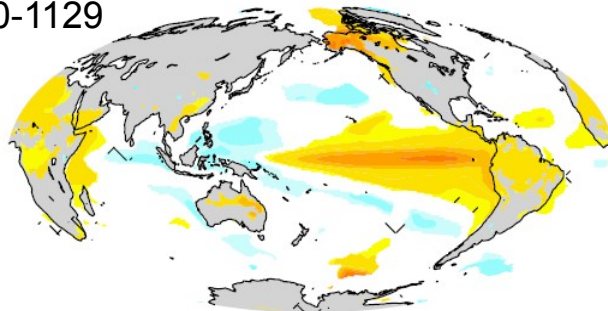
# RESULTS

- ENSO vs  
Surface Temperature

El Niño

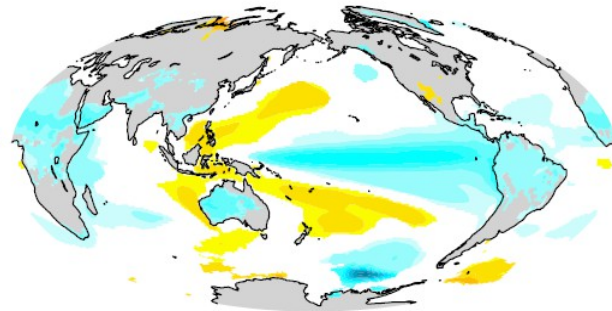
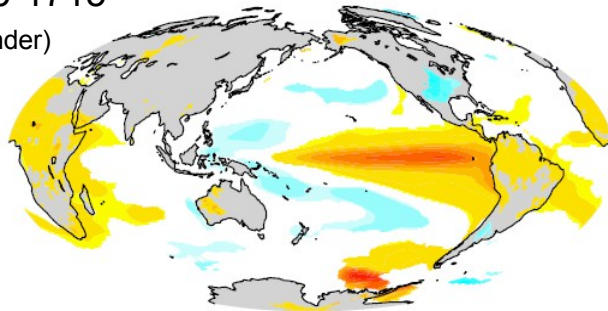
La Niña

1030-1129



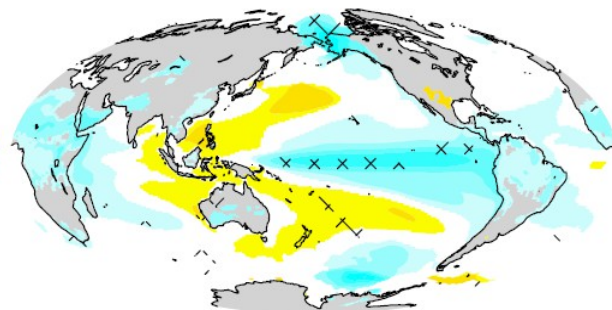
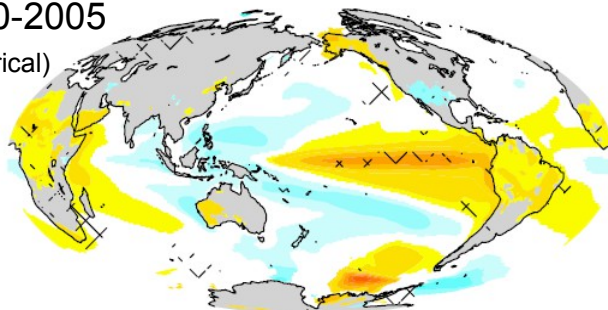
1645-1715

(maunder)



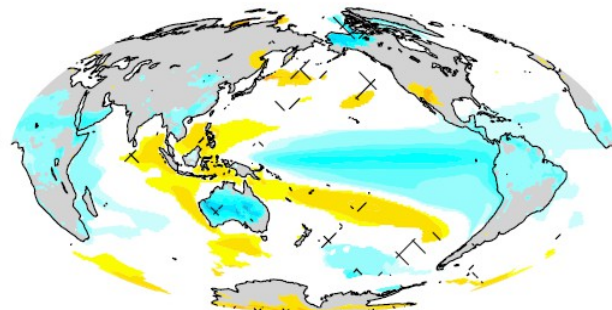
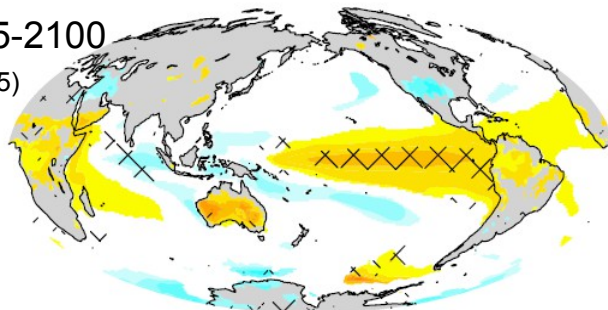
1850-2005

(historical)



2005-2100

(rcp8.5)



3

2.4

1.8

1.2

0.6

0

-0.6

-1.2

-1.8

-2.4

-3

K

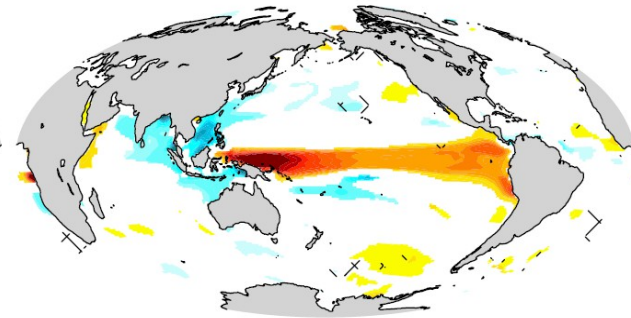
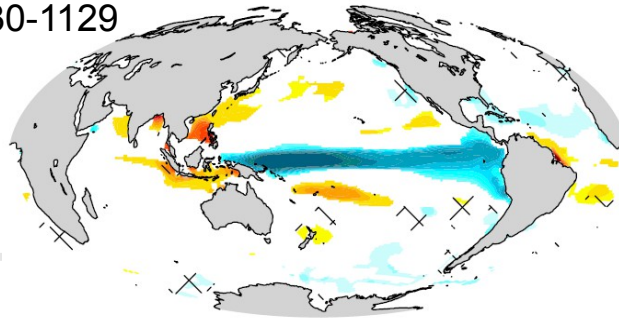
# RESULTS

- ENSO vs DIC

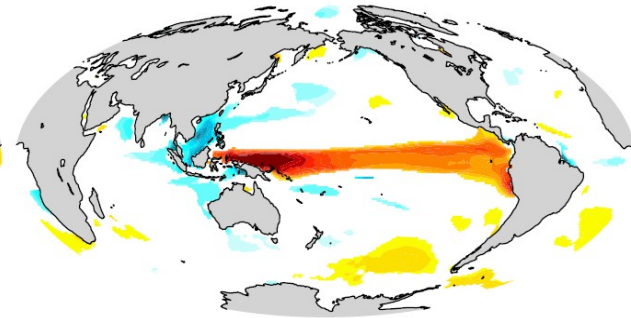
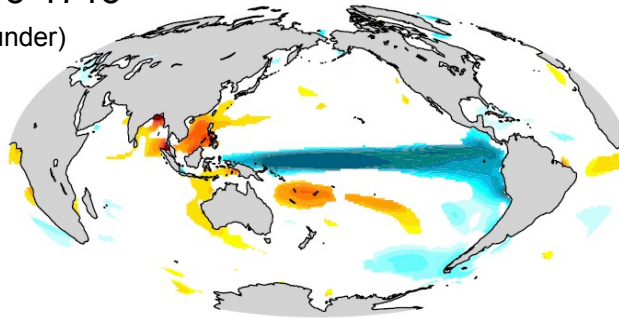
El Niño

La Niña

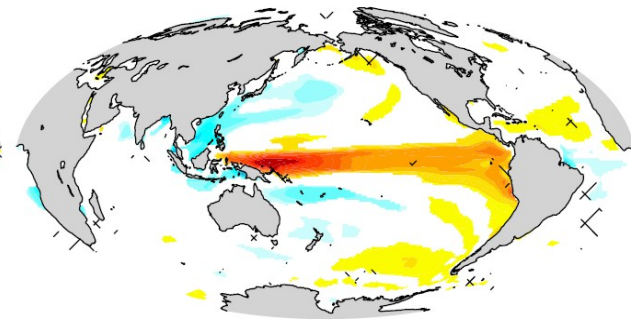
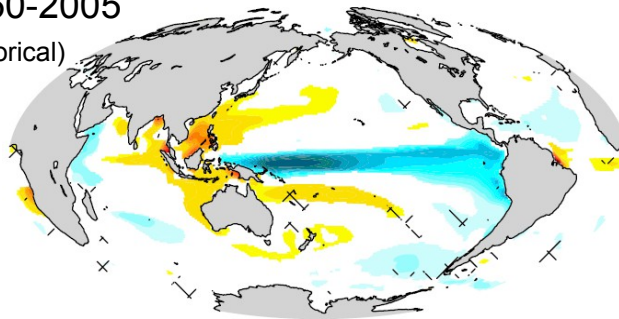
1030-1129



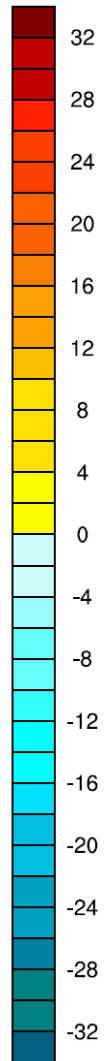
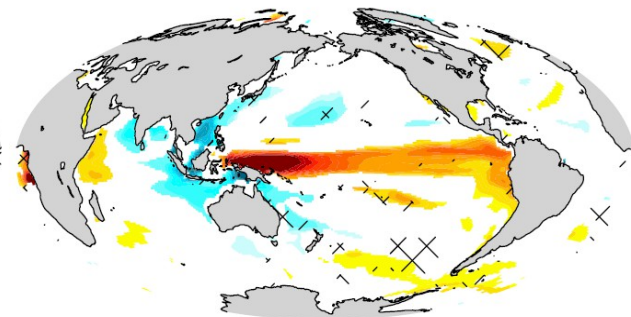
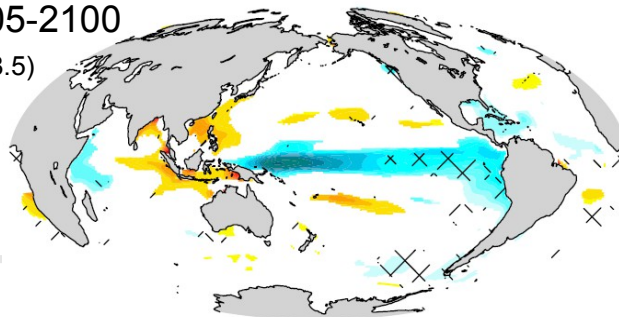
1645-1715  
(maunder)



1850-2005  
(historical)



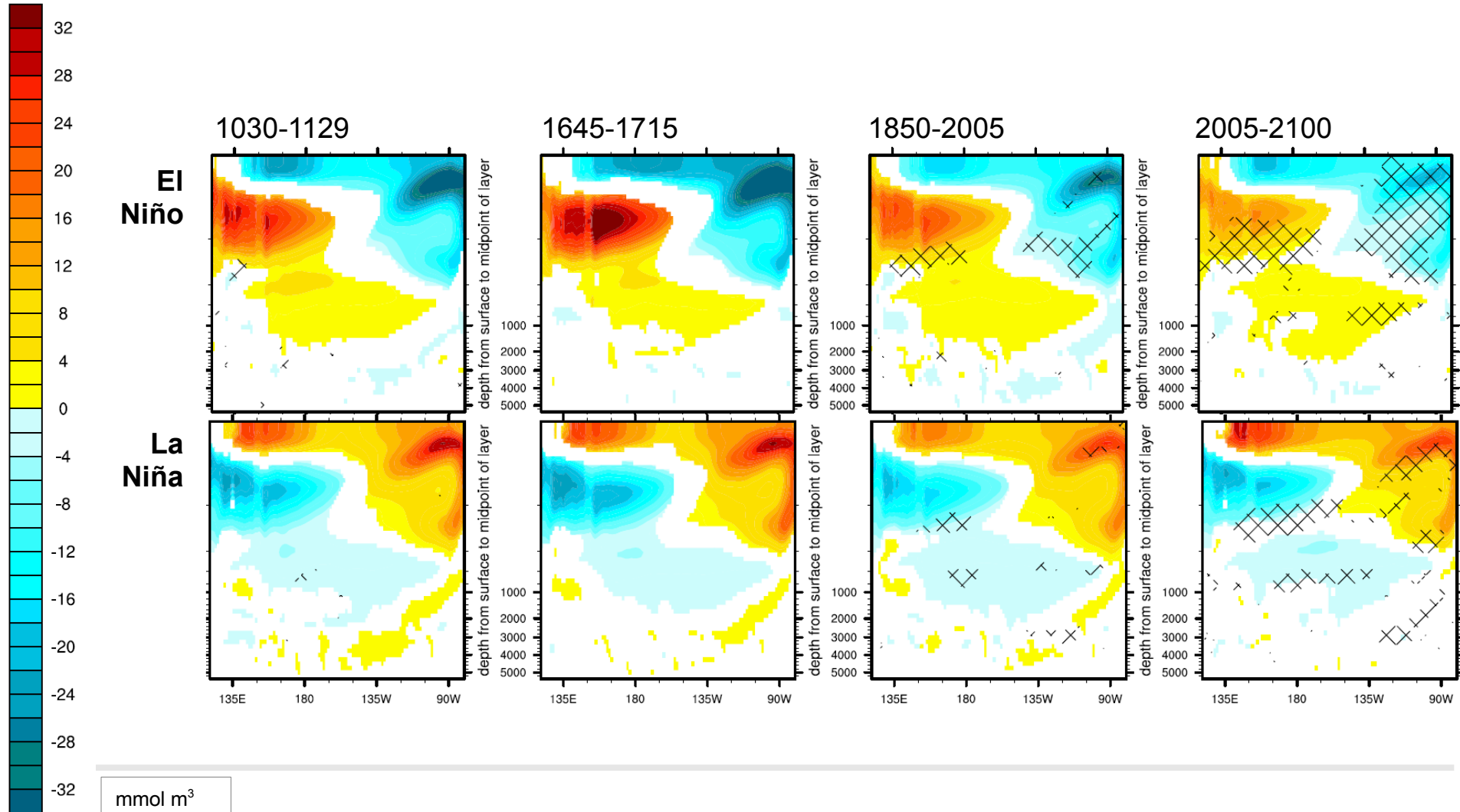
2005-2100  
(rcp8.5)



mmol m<sup>-3</sup>

# RESULTS

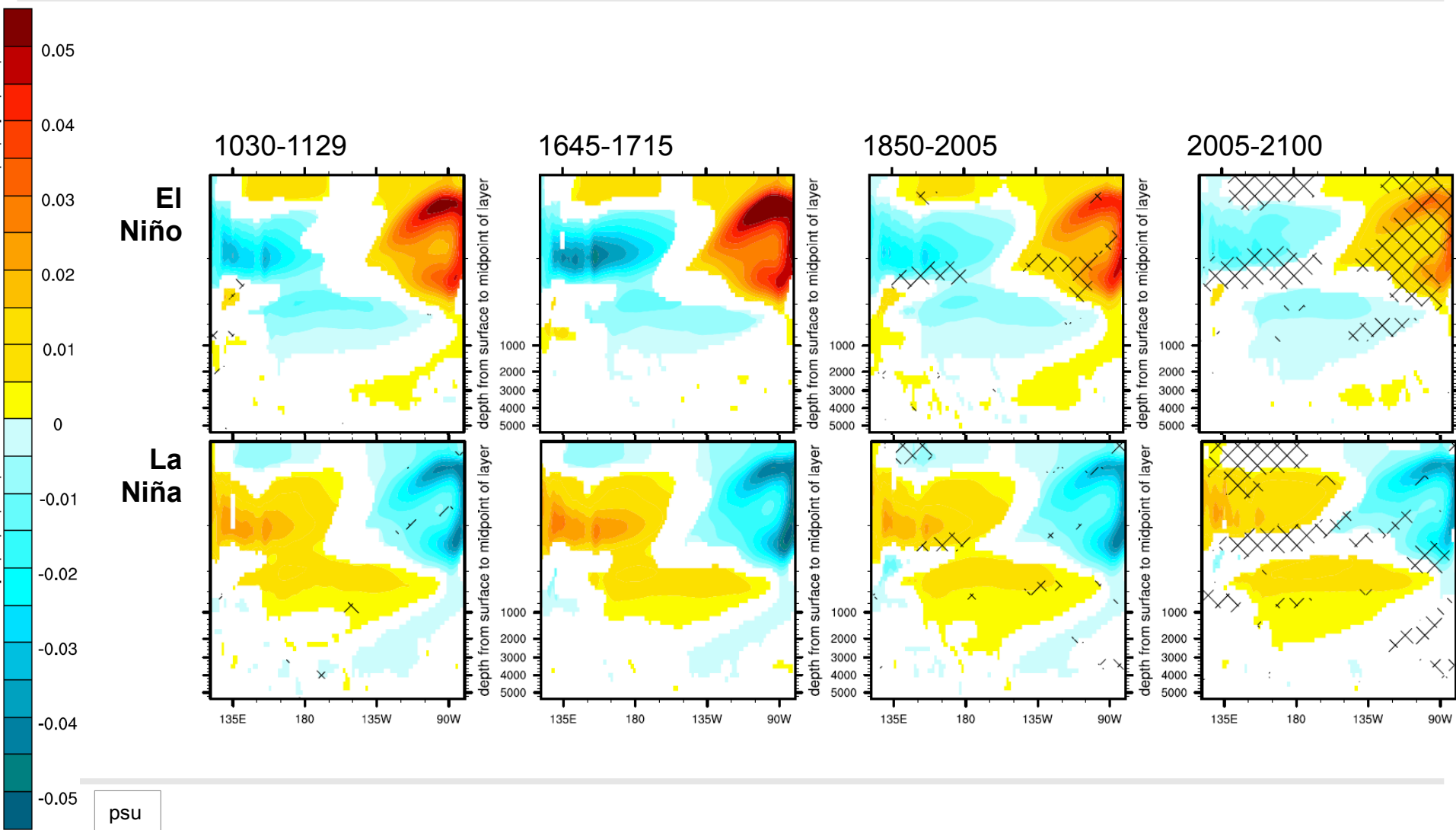
- ENSO vs DIC



$\text{mmol m}^{-3}$

# RESULTS

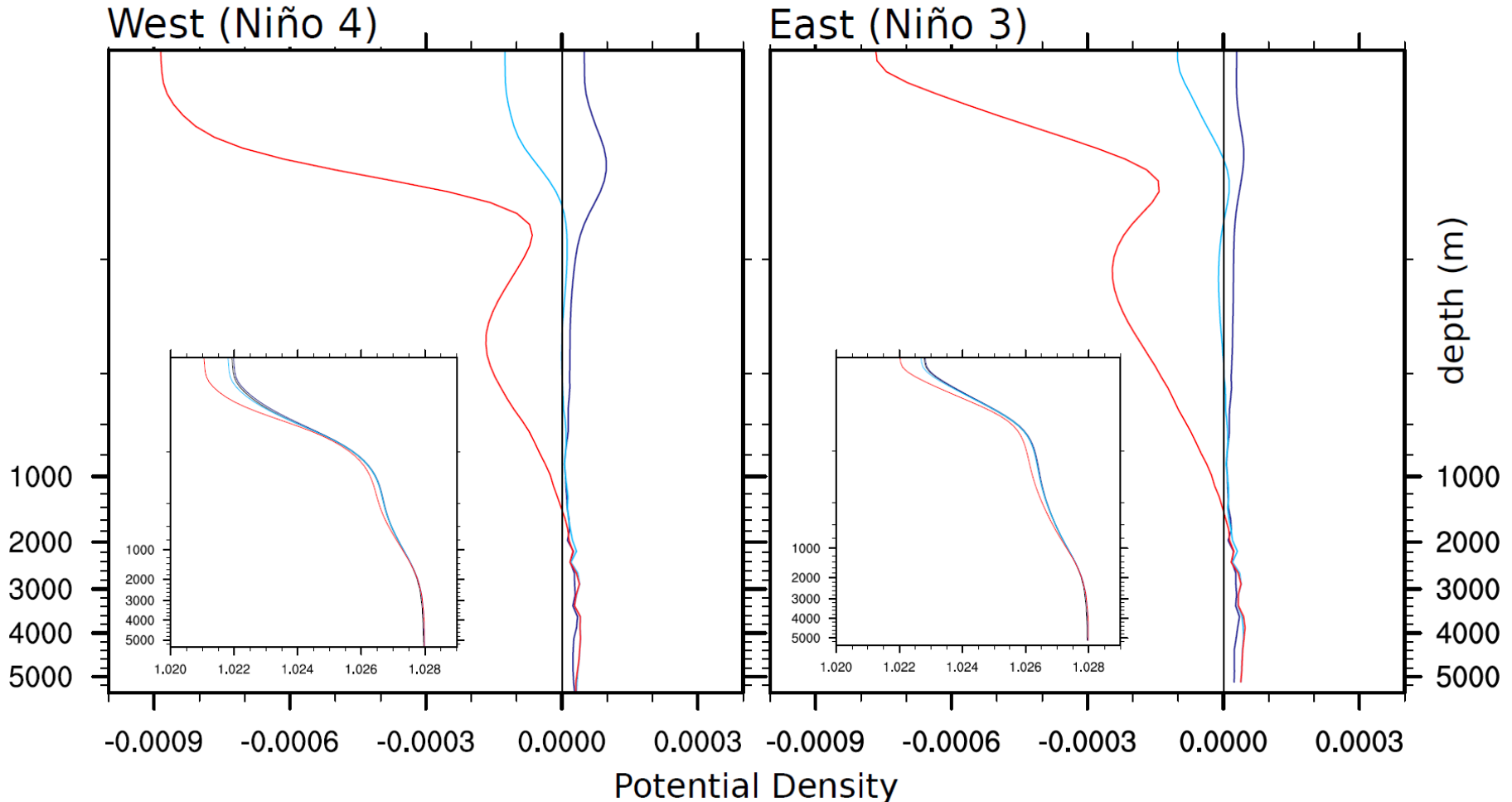
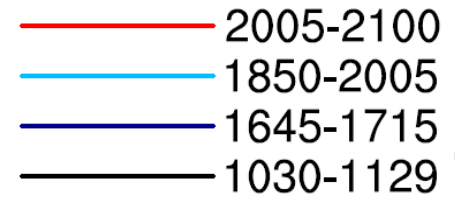
- ENSO vs pH



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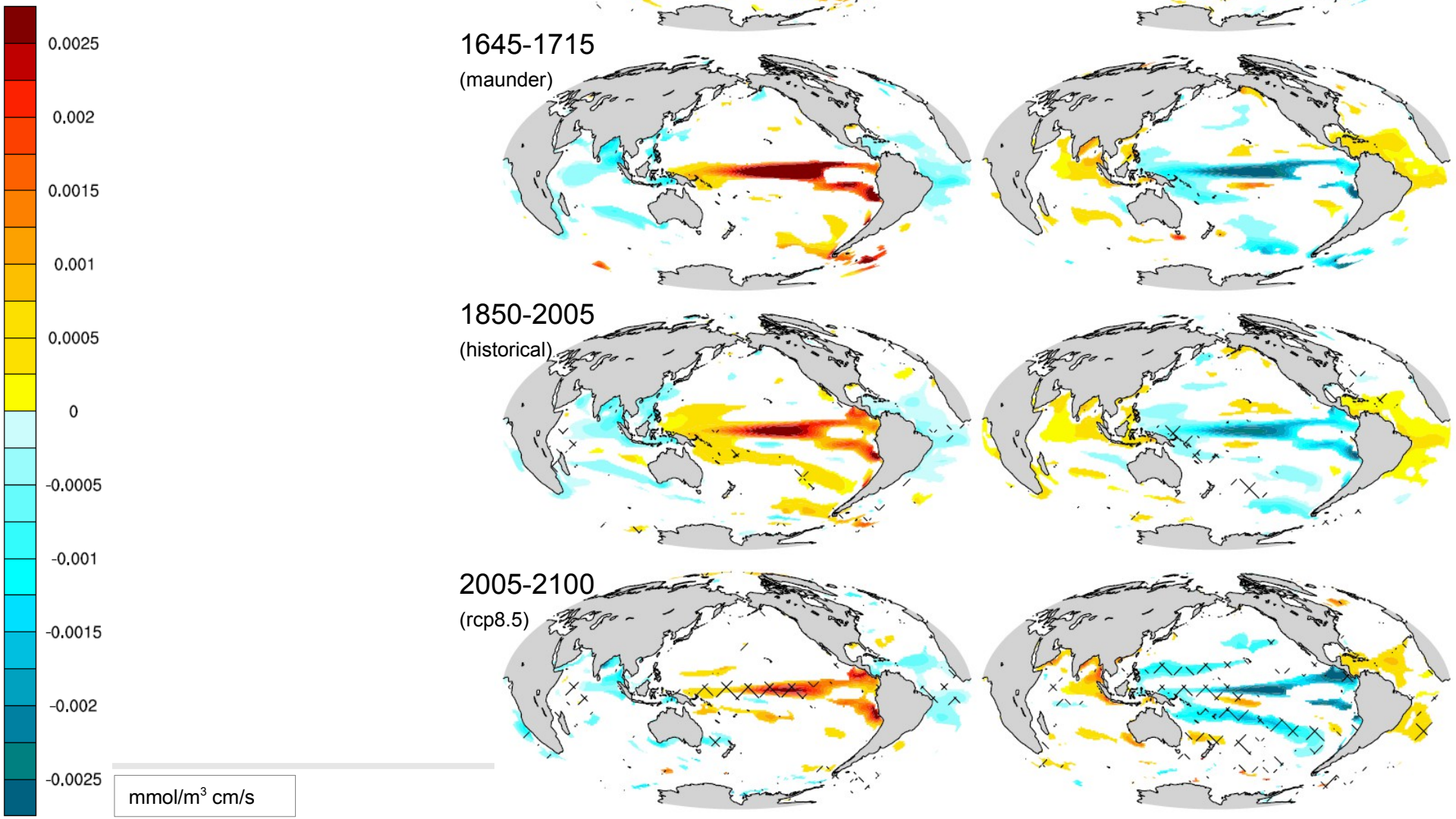
# RESULTS

- Mean states: potential density



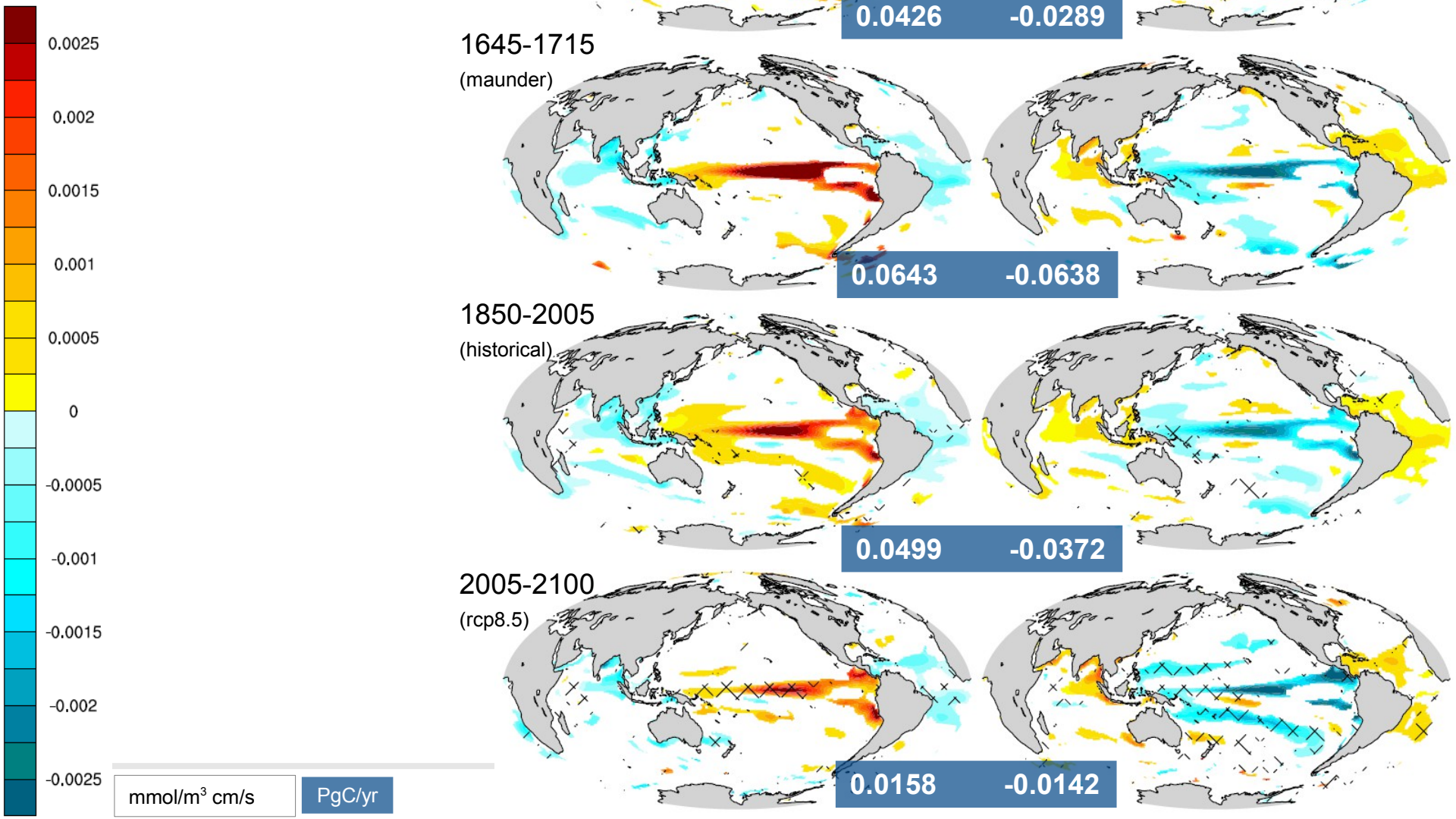
# RESULTS

- ENSO vs  
air-sea flux of CO<sub>2</sub>



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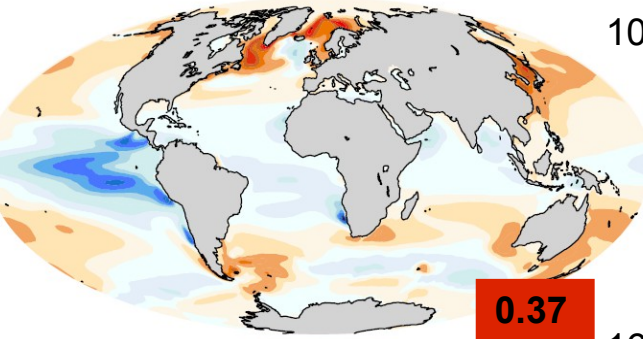




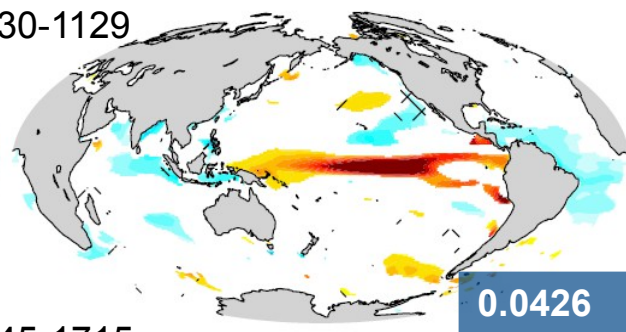
El Niño

La Niña

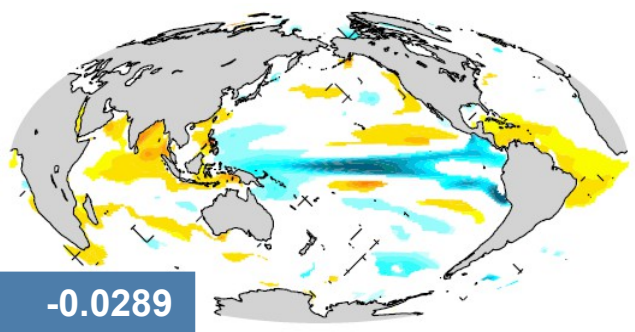
1030-1129



0.37



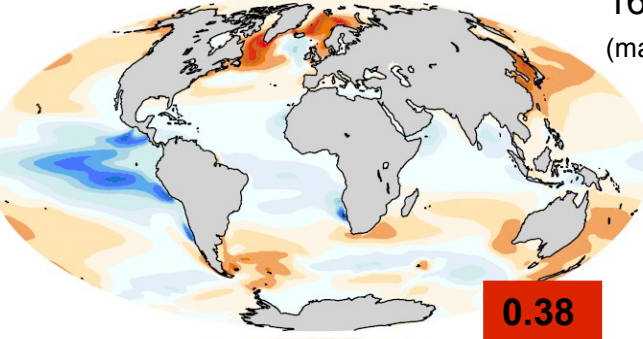
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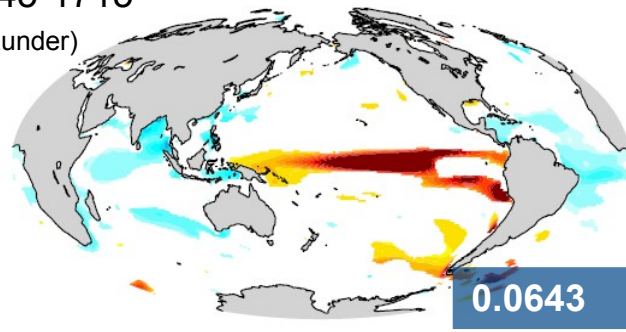
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1645-1715

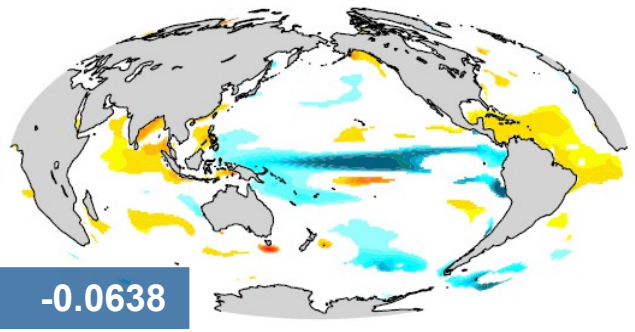
(maunder)



0.38



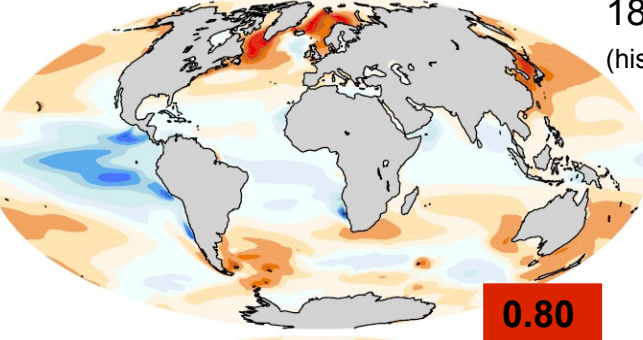
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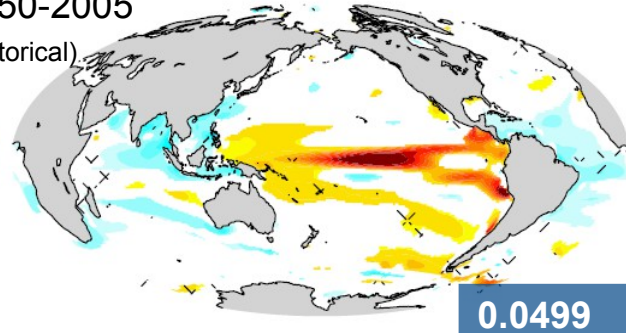
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1850-2005

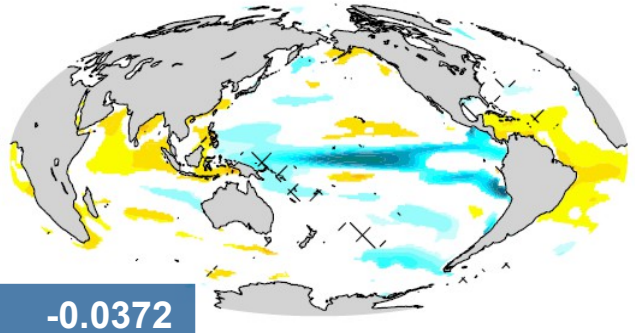
(historical)



0.80



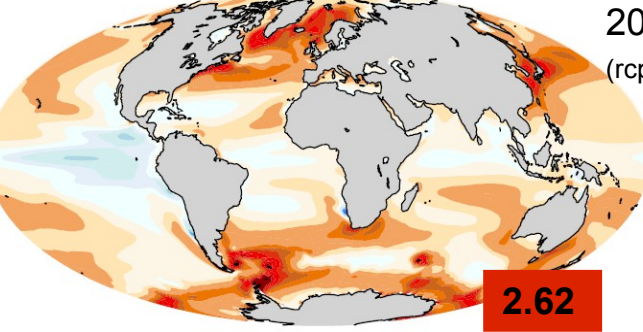
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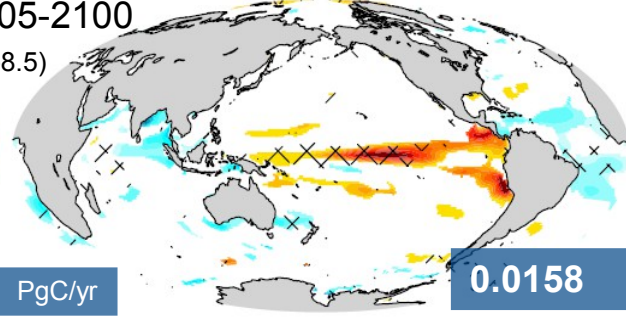
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2005-2100

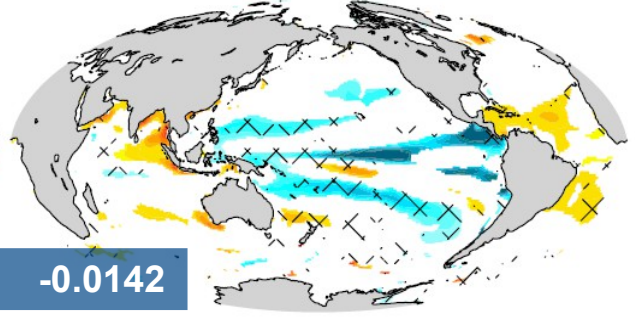
(rcp8.5)



2.62



0.0158



-0.0142

PgC/yr

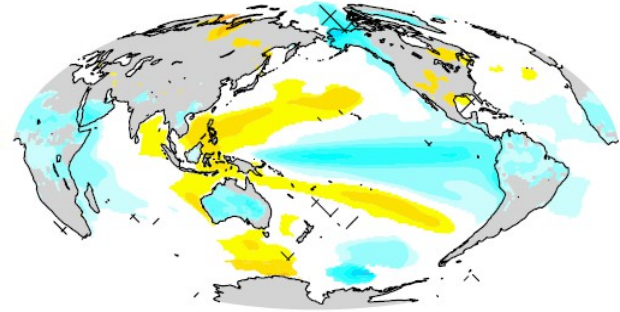
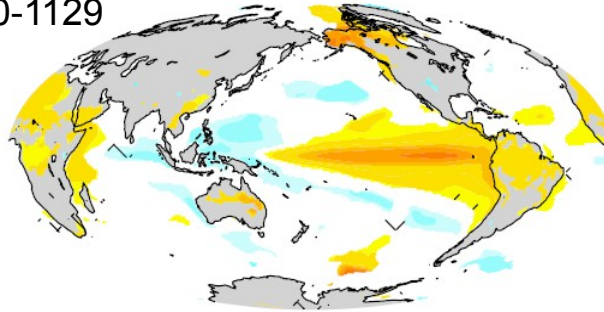
# RESULTS

- Nonlinearity

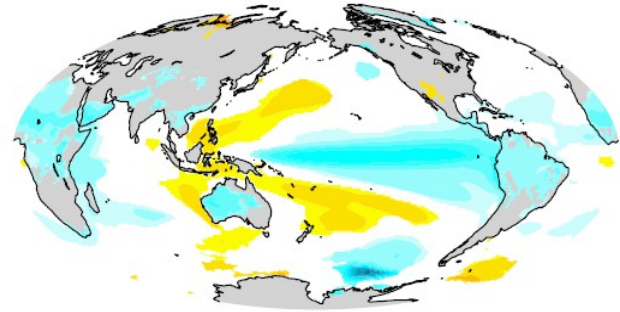
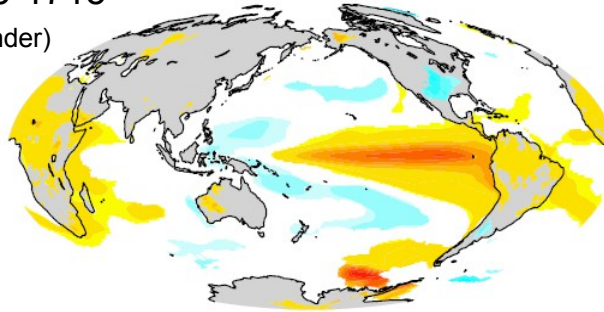
El Niño

La Niña

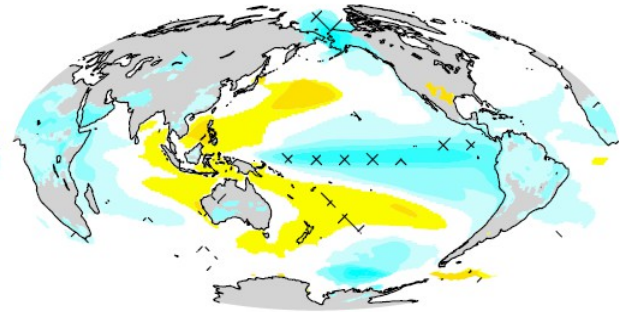
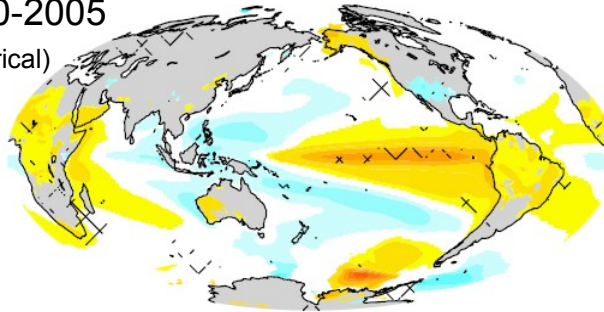
1030-1129



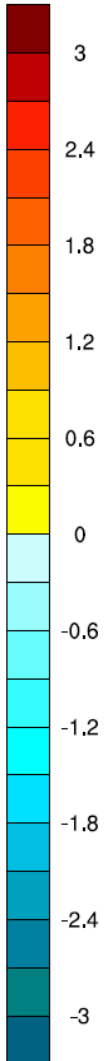
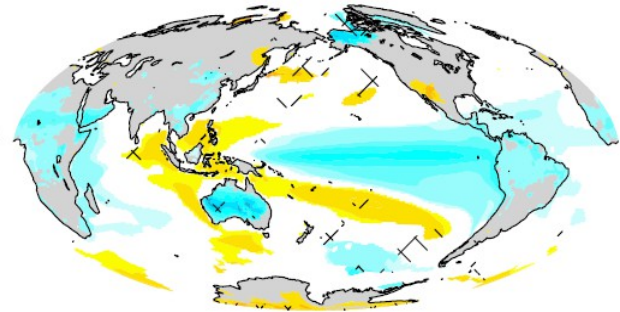
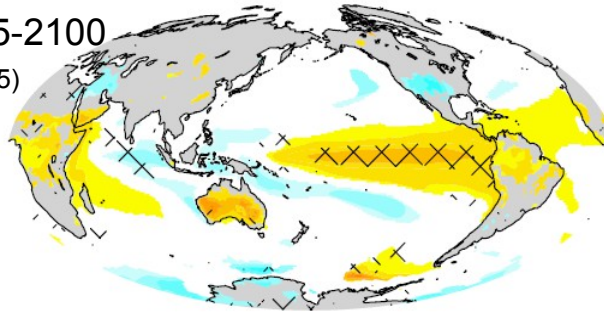
1645-1715  
(maunder)



1850-2005  
(historical)



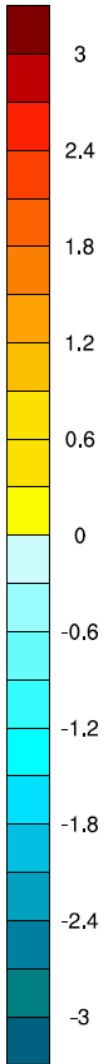
2005-2100  
(rcp8.5)



K

# RESULTS

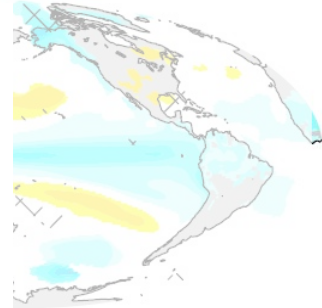
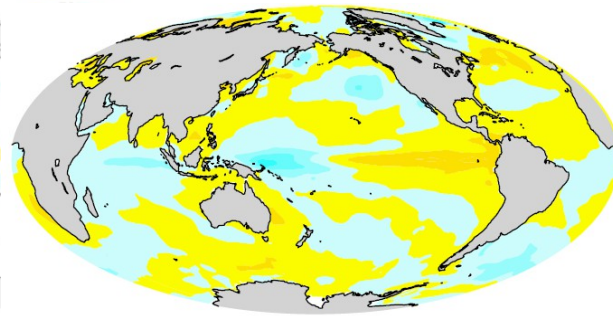
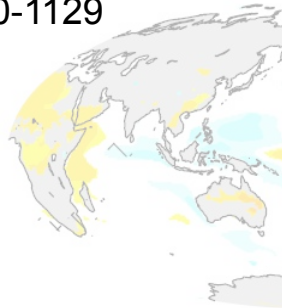
- Nonlinearity



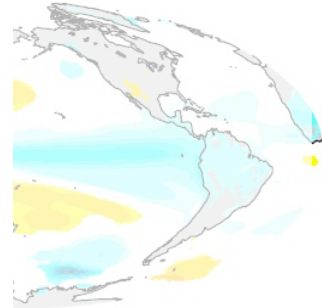
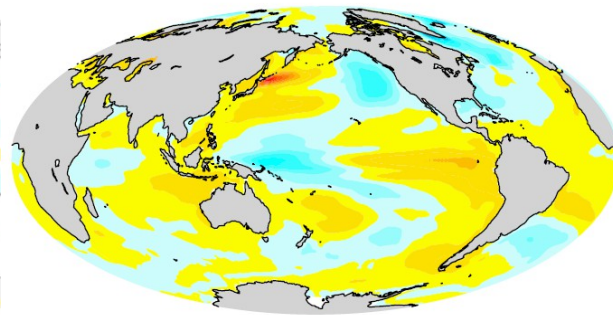
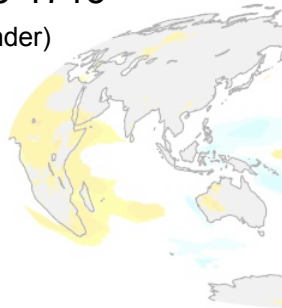
El Niño

La Niña

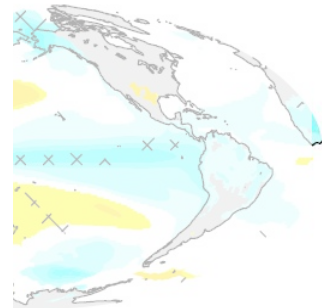
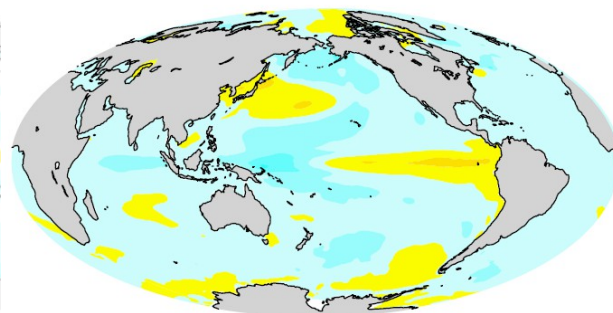
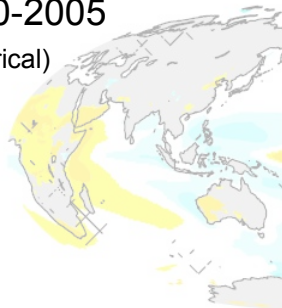
1030-1129



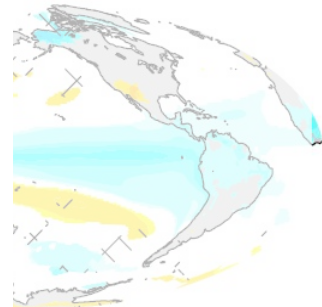
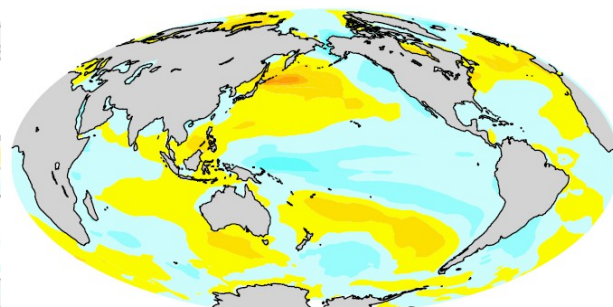
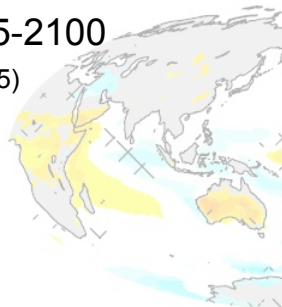
1645-1715  
(maunder)



1850-2005  
(historical)



2005-2100  
(rcp8.5)



# CONCLUSION & OUTLOOK

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- significant response > 2000 m depth
  - response weaker and more shallow in warmer climate
  - air-sea CO<sub>2</sub> flux: less relevant for inter-annual variability of atm. CO<sub>2</sub>
  - El Niño and La Niña not exactly linear
  
  - different mean states → differences of intra- & inter-annual variability?
  - different ENSO types (canonical vs Modoki)
  - more models
  
  - ...
-

# References

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