Pacific CO_2 fluxes pattern analysis through SST clustering

Pradeebane VAITTINADA AYAR
Jerry TJIPUTRA

NORCE

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Outline

1. Context
2. Data & Methods
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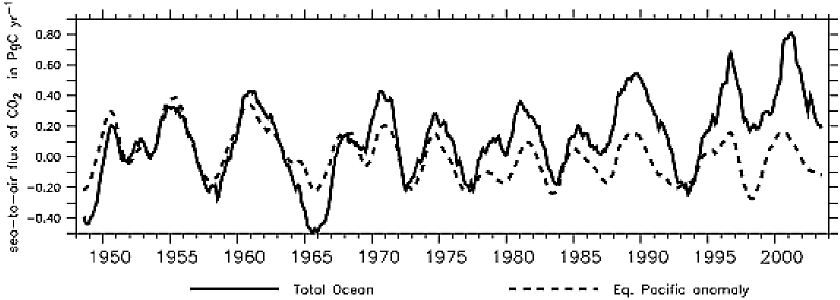
[WETZEL *et al., 2005*]



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Constraint the **VARIABILITY** of CMIP6 models carbon uptake by using its the relationship with ENSO [FEELY *et al., 2006*].

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One way to study spatial pattern thanks to **STATISTICAL CLUSTERING**.

Aim : analyse carbon uptake pattern thanks SST clustering.

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Monthly **OBSERVATIONS** over pacific basin

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Clustering (regrouping) applied to SST-based NINO3, NINO4 and PDO.

Gaussian mixture model

Approximate the distribution of a datafield x as a weighted sum of K (the number of cluster or groups) Gaussian distribution f_k [PEARSON, *1894 ;* MCLACHLAN *&* PEEL, *2000*] :

$$f(x) = \sum_{k=1}^{K} \pi_k f_k(x; \alpha_k)$$

where π_k is the mixture ratio.

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Each monthly field is assigned to one cluster C_k (represented by f_k) by applying the principle of *posterior* maximum :

$$C_k = \{\boldsymbol{x}; \pi_k f_k(\boldsymbol{x}, \boldsymbol{\alpha}_k) \geqslant \pi_j f_j(\boldsymbol{x}, \boldsymbol{\alpha}_j), \forall j = 1, \ldots, K\}.$$

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The BIC to be minimised to determine K : $BIC = -2\log(L) + p\log(n)$, with p the number of free parameters, n the sample's size, L the likelihood.

Expectation-Maximization (EM) algorithm [Dempster *et al.*, 1977]

Successive iterations (i) of the E and M steps :

Expectation (E) step : for each C_k $k \in [1, \cdots, K]$, and month $j \in [1, \cdots, n]$:

$$\tau_k^i(x_j) = \frac{\pi_k^i f_k(x_j \mid \alpha_j^i)}{\sum_{k=1}^{K} \pi_k^i f_k(x_j \mid \alpha_j^i)};$$

where $\tau_k^i(x_j)$ is the posterior probability that x_j belongs to C_k at iteration i.

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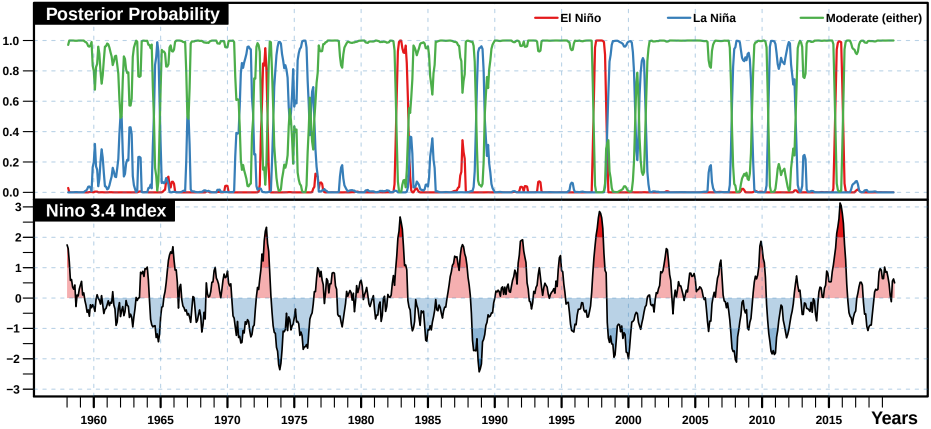
MAXIMIZATION (M) step : for each C_k $k \in [1, \cdots, K]$:

$$\pi_k^{i+1} = \frac{1}{n} \sum_{j=1}^{n} \tau_k^i(x_j);$$

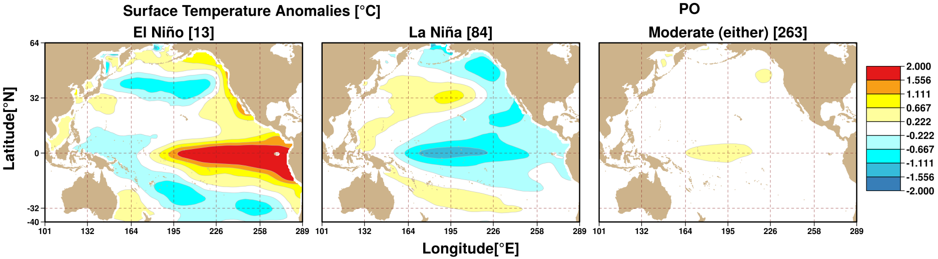
which is the Maximum likelihood of the ratios.

Outline

Clustering results



Observed patterns (1985-2014)



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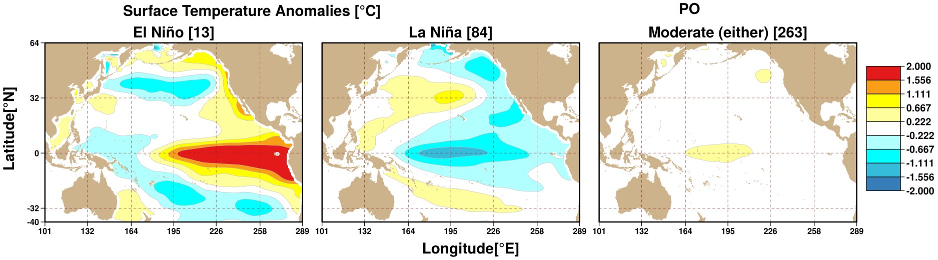
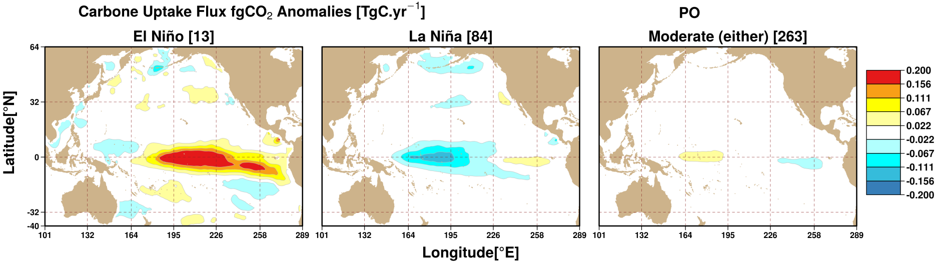
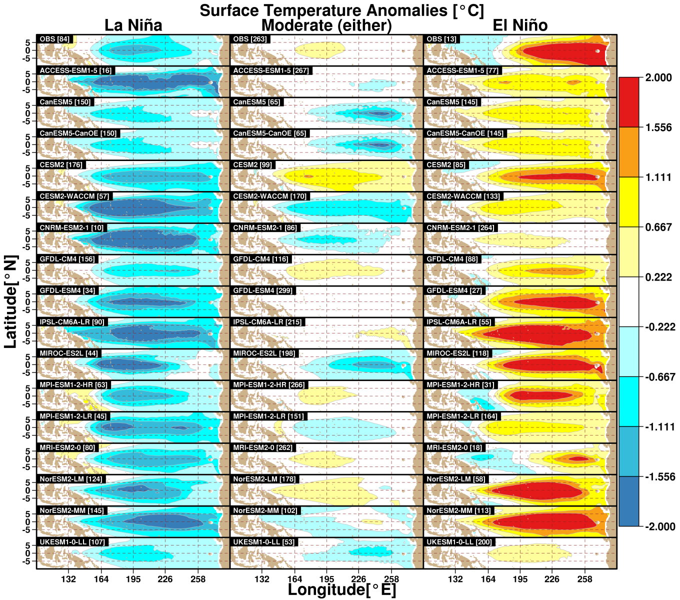
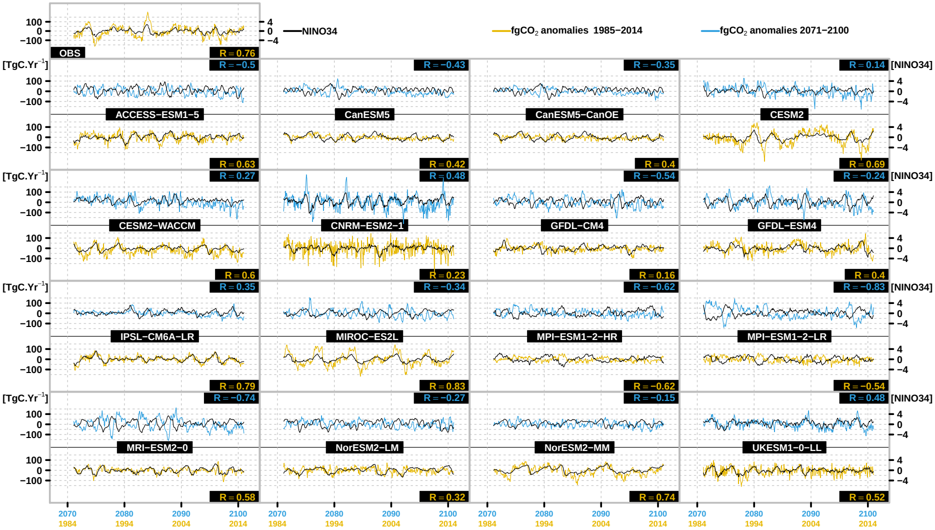




CMIP6 patterns (1985-2014)



Results for CMIP6 : NINO34 vs. $fgCO_2$ anomalies



CMIP6 NINO34 vs. $fgCO_2$ anomalies

	Correlation $fgCO_2$ vs. NINO3.4	
	1985-2014	2071-2100
OBS	.76	-
ACCESS-ESM1-5	.63	-.5
CanESM5-CanOE	.42	-.43
CanESM5	.40	-.35
CESM2	.69	.14
CESM2-WACCM	.60	.27
CNRM-ESM2-1	.23	.48
GFDL-CM4	.16	-.54
GFDL-ESM4	.40	-.24
IPSL-CM6A-LR	.79	.35
MIROC-ES2L	.83	- .34
MPI-ESM1-2-HR	-.62	-.62
MPI-ESM1-2-LR	-.54	-.83
MRI-ESM2-0	.58	-.74
NorESM2-LM	.32	-.27
NorESM2-MM	.74	-.15
UKESM1-0-LL	.52	.48

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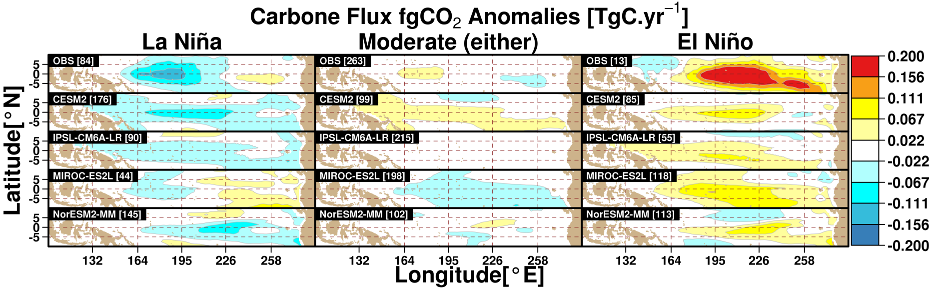
CMIP6


Carbone Flux fgCO2 Anomalies [TgC.yr−1]
La Niña
Moderate (either)
El Niño
OBS [84]
CESM2 [176]
IPSL-CM6A-LR [90]
MIROC-ES2L [44]
NorESM2-MM [145]
OBS [263]
CESM2 [99]
IPSL-CM6A-LR [215]
MIROC-ES2L [198]
NorESM2-MM [102]
OBS [13]
CESM2 [85]
IPSL-CM6A-LR [55]
MIROC-ES2L [118]
NorESM2-MM [113]
Latitude[°N]
5
0
-5
132
164
195
226
258
Longitude[°E]
0.200
0.156
0.111
0.067
0.022
-0.022
-0.067
-0.111
-0.156
-0.200

CMIP6 **fgCO_2** anomalies vs. NINO3.4/$P^{nt}_{CO_2}$ anomalies

NON-THERMAL $P^{nt}_{CO_2} = P_{CO_2} \exp\left(\gamma_T(< SST > - SST)\right)$,
γ_T : CO_2 temperature sensitivity (4.23%$\cdot^{\circ}C^{-1}$), $< SST >$: long-term mean SST [LANDSCHÜTZER *et al., 2018*].

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CMIP6 **$fgCO_2$** anomalies vs. NINO3.4/$P^{nt}_{CO_2}$ anomalies

	Correlation $fgCO_2$ vs.			
	NINO3.4		Non-thermal $P^{nt}_{CO_2}$	
	1985-2014	2071-2100	1985-2014	2071-2100
OBS	.76		-.85	
ACCESS-ESM1-5	.63	-.5	-.38	.37
CanESM5-CanOE	.42	-.43	-.33	.18
CanESM5	.40	-.35	-.34	.14
CESM2	.69	.14	-.3	-.28
CESM2-WACCM	.60	.27	-.28	-.29
CNRM-ESM2-1	.23	.48	-.01	-.60
GFDL-CM4	.16	-.54	-.02	.38
GFDL-ESM4	.40	-.24	-.16	-.04
IPSL-CM6A-LR	.79	.35	-.24	-.28
MIROC-ES2L	.83	- .34	-.36	.31
MPI-ESM1-2-HR	-.62	-.62	.20	.17
MPI-ESM1-2-LR	-.54	-.83	.09	.31
MRI-ESM2-0	.58	-.74	-.54	.31
NorESM2-LM	.32	-.27	-.09	.02
NorESM2-MM	.74	-.15	-.27	.05
UKESM1-0-LL	.52	.48	-.32	-.29

Thank you for your attention!!

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