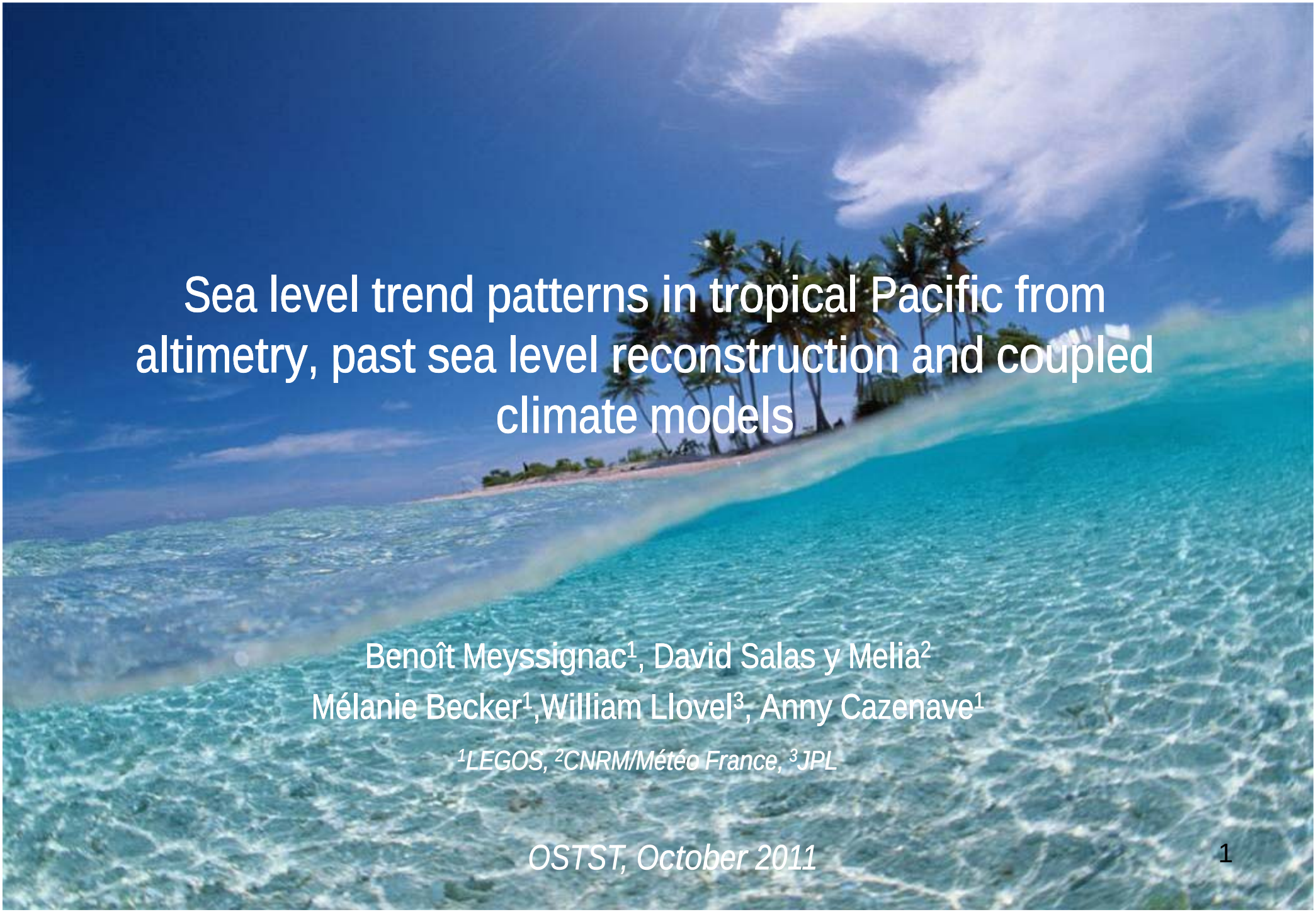


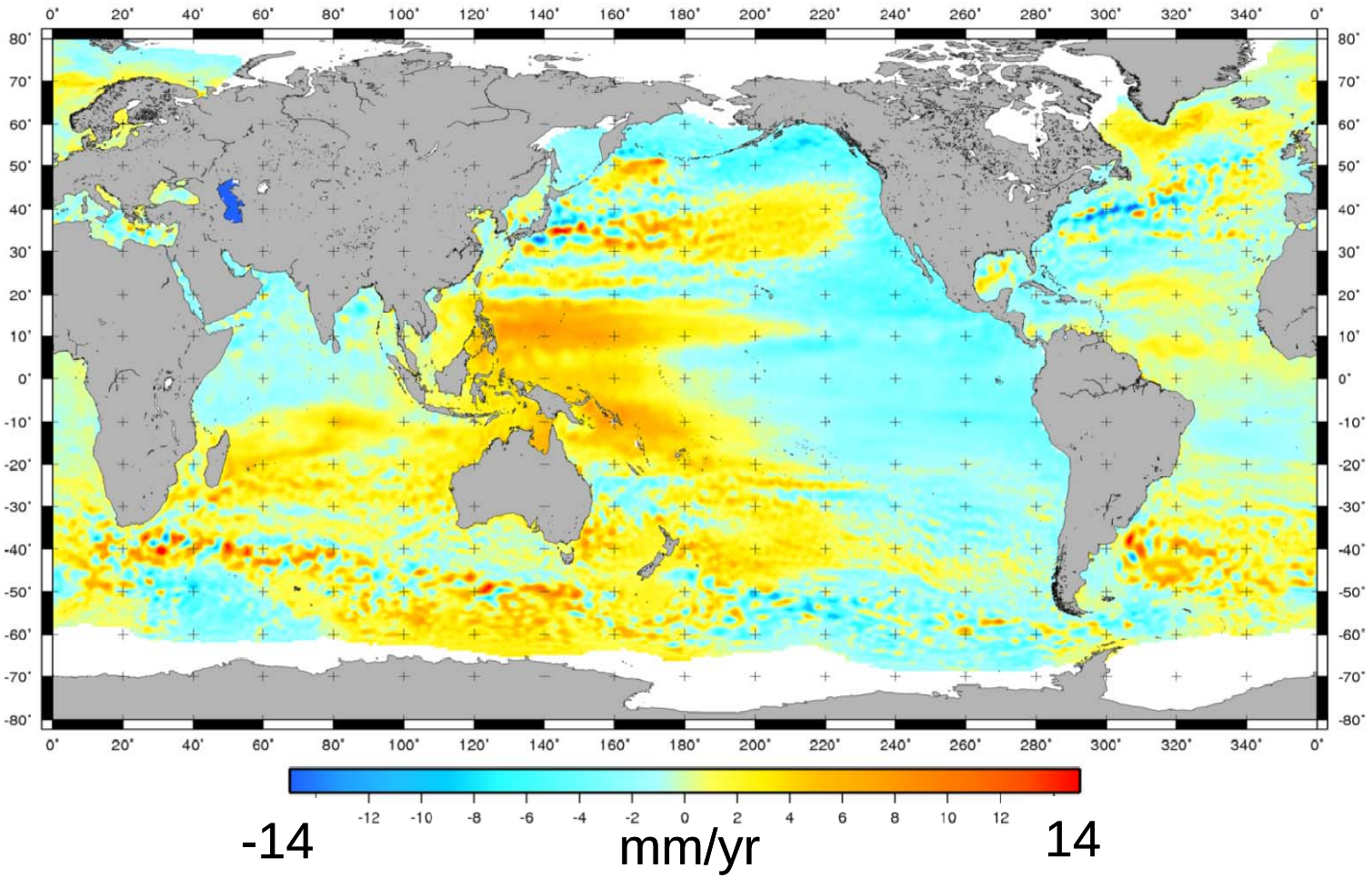
Sea level trend patterns in tropical Pacific from altimetry, past sea level reconstruction and coupled climate models

Benoît Meyssignac[1], David Salas y Melia[2]
Mélanie Becker[1],William Llovel[3], Anny Cazenave[1]

[1]LEGOS, [2]CNRM/Météo France, [3]JPL

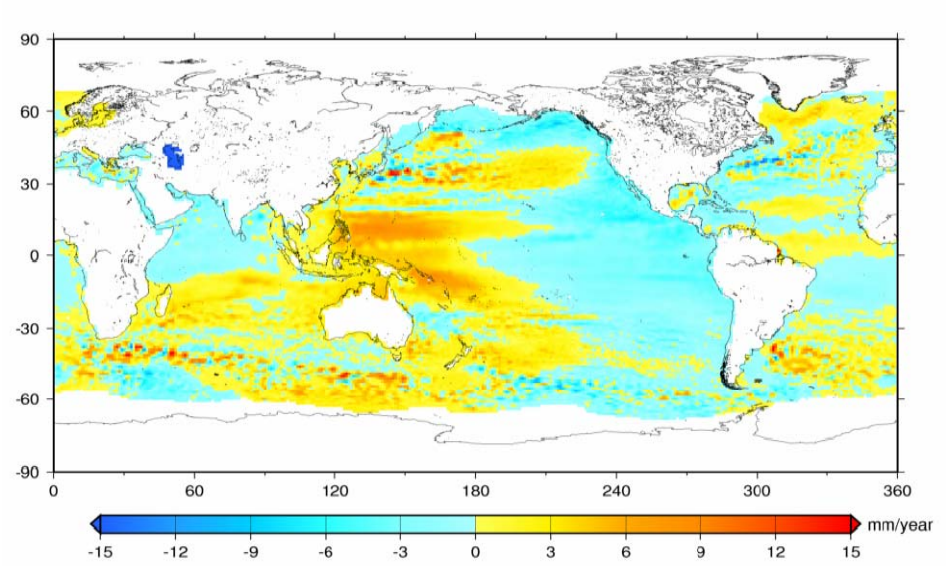
OSTST, October 2011

Observed Sea Level Trend Patterns from Jan. 1993 to Dec. 2009 *(global trend removed)*



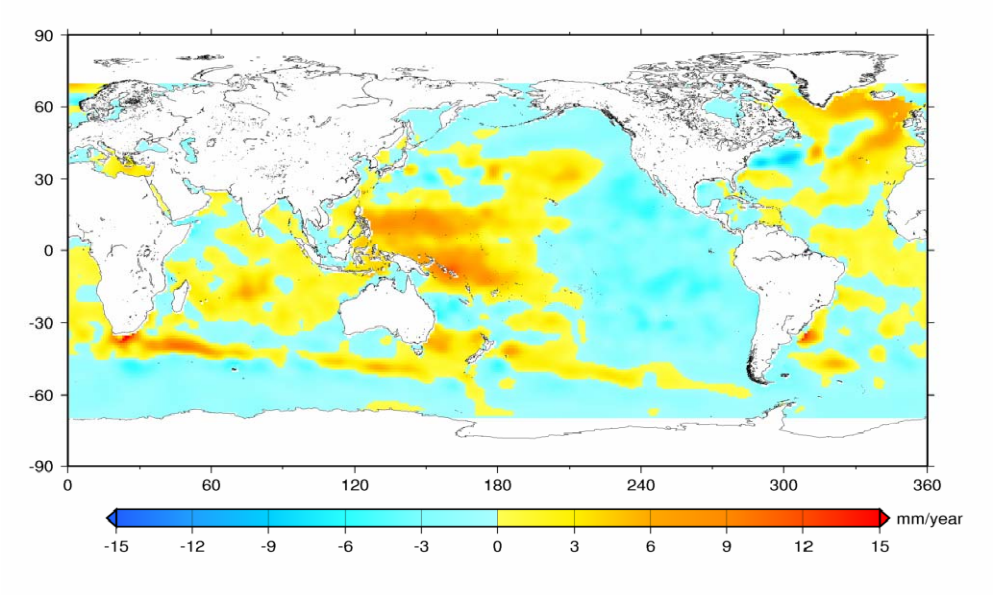
- Are the observed trend patterns stationnary?
- Are they linked to internal variability only?
- Is there some imprint of external forcings (anthropogenic, solar, volcanic)?

Observed Sea Level Trend Patterns from Jan. 1993 to Dec. 2009 *(global trend removed)*



Satellite Altimetry measurement

Observed Thermal Expansion Trend Patterns from Jan. 1993 to Dec. 2009 *(global trend removed)*



In situ hydrographic measurement

(Levitus et al.,2009)

Cazenave & Llovel, 2010
Lombard et al. 2009
Kohl & Stammer 2008
Wunsch et al. 2007

- Observed sea level grids
  - satellite altimetry (since 1993)
  - reconstruction (since 1950)

- 8 coupled climate models (CMIP3):

GFDL cm2.1, CNRM-cm3, GISS model-er, IAP fgoals g1.0,
IPSL-cm4, MIROC 3.2 medres, NCAR ccsm3 and UKMO hadcm3

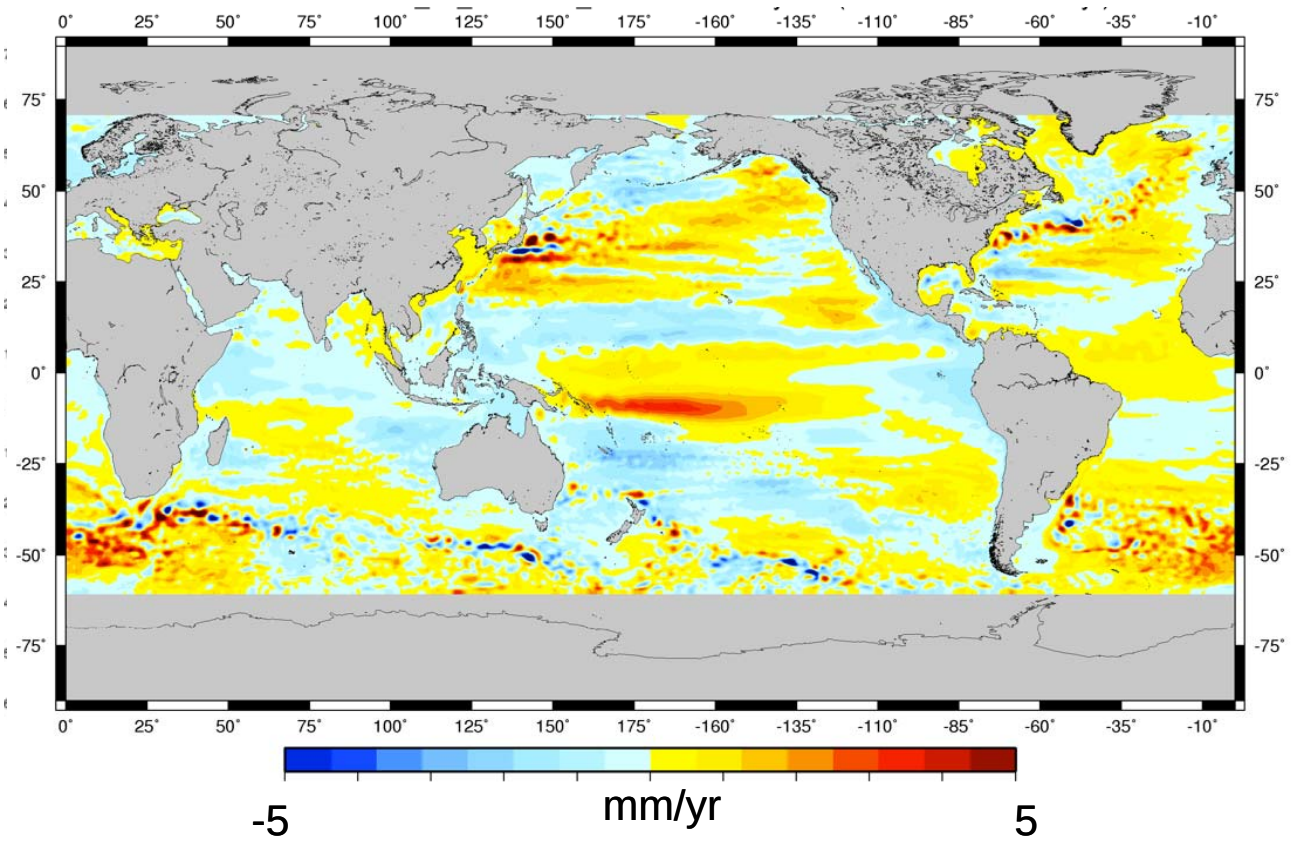
- **500 year long control runs (constant external forcing)**
- **20th century runs (solar+volacanic+anthropogenic var)**

Reconstructed sea level trend patterns (1950-2009) from reduced optimal interpolation

(Kaplan et al 2000)

→ 99 long tide gauges records + spatial EOFs from 47-years of the DRAKKAR/NEMO ocean model SSH

(new version of Llovel et al. 2009's reconstruction)

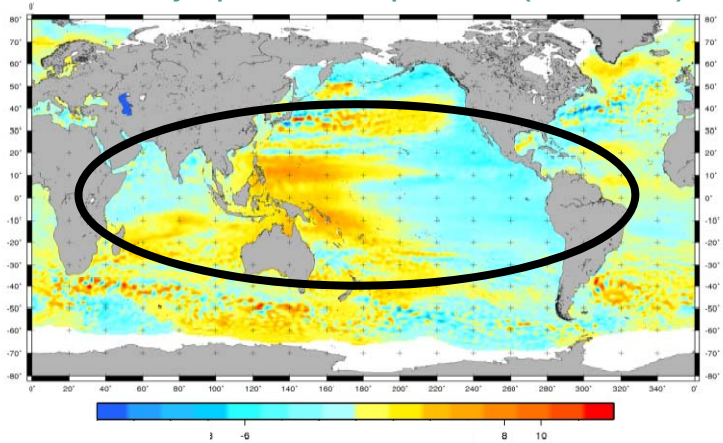


1950-2009 spatial patterns (global trend removed)

Meyssignac et al. Under review
Ray and Douglas 2011
Llovel et al. 2009
Berge Nguyen et al. 2008
Church et al. 2004

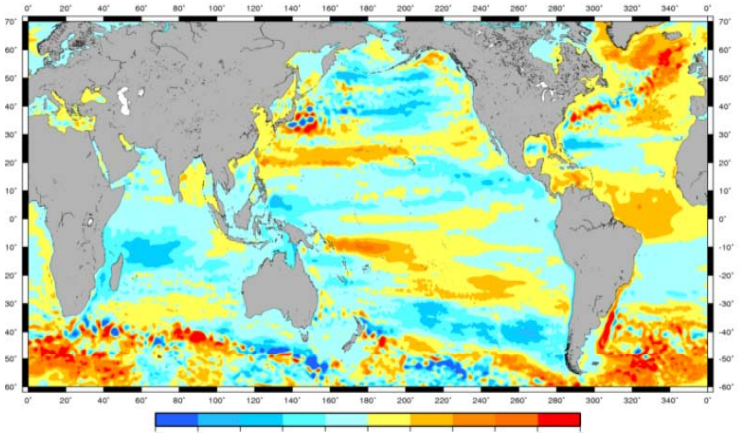
Spatial trend patterns of the sea level reconstruction computed over successive 17-year windows

Altimetry spatial trend patterns (1993-2010)



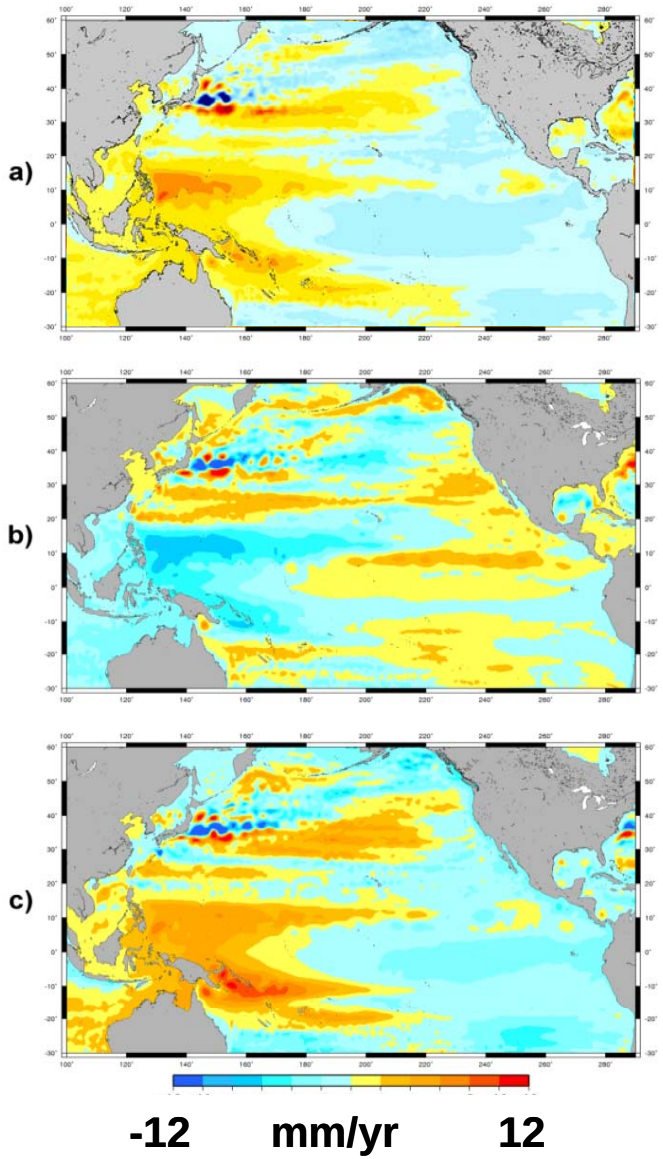
-14 mm/yr 14

Reconstructed spatial trend patterns (1950-2009)



-5 mm/yr 5

Reconstructed trends in successive 17-year windows



1992-2009

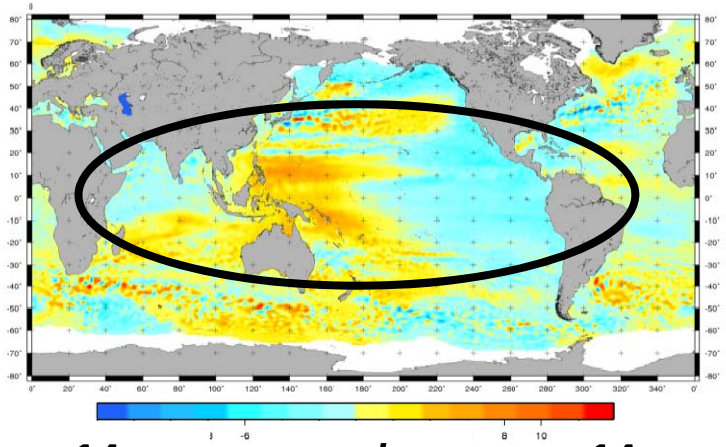
1971-1989

1958-1975

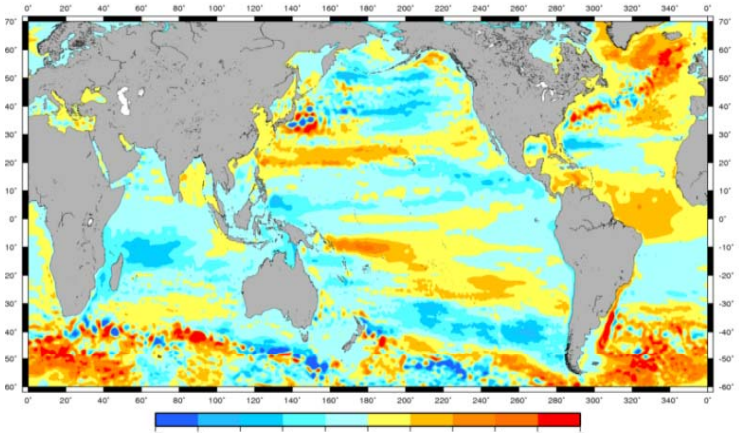
-12 mm/yr 12

Spatial trend patterns of the sea level reconstruction computed over successive 17-year windows

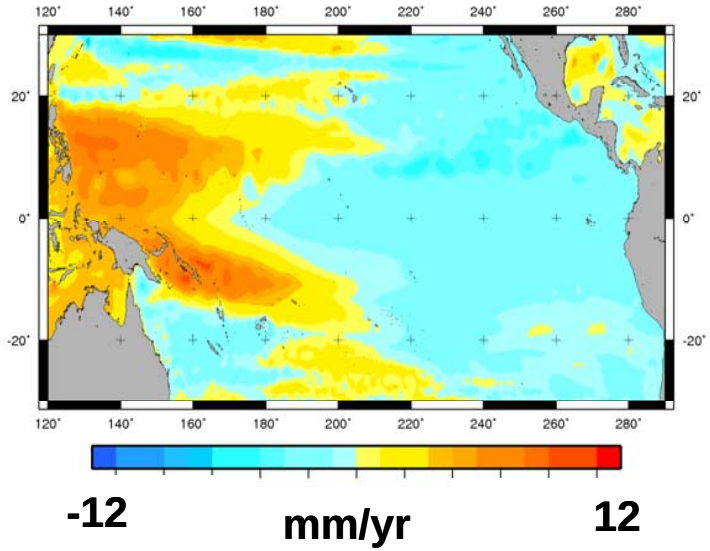
Altimetry spatial trend patterns (1993-2010)

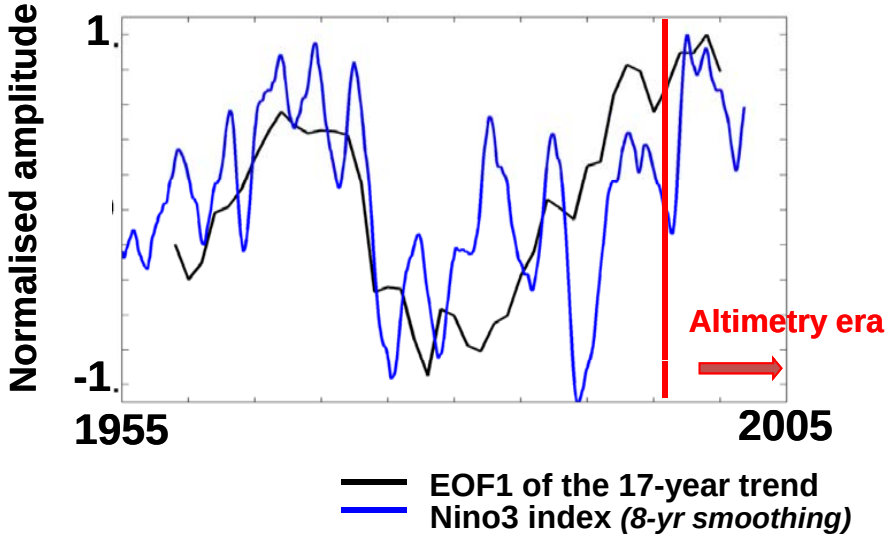


Reconstructed spatial trend patterns (1950-2009)



EOF1 of Reconstructed trends in successive 17-year windows
36.6 % of the total variance

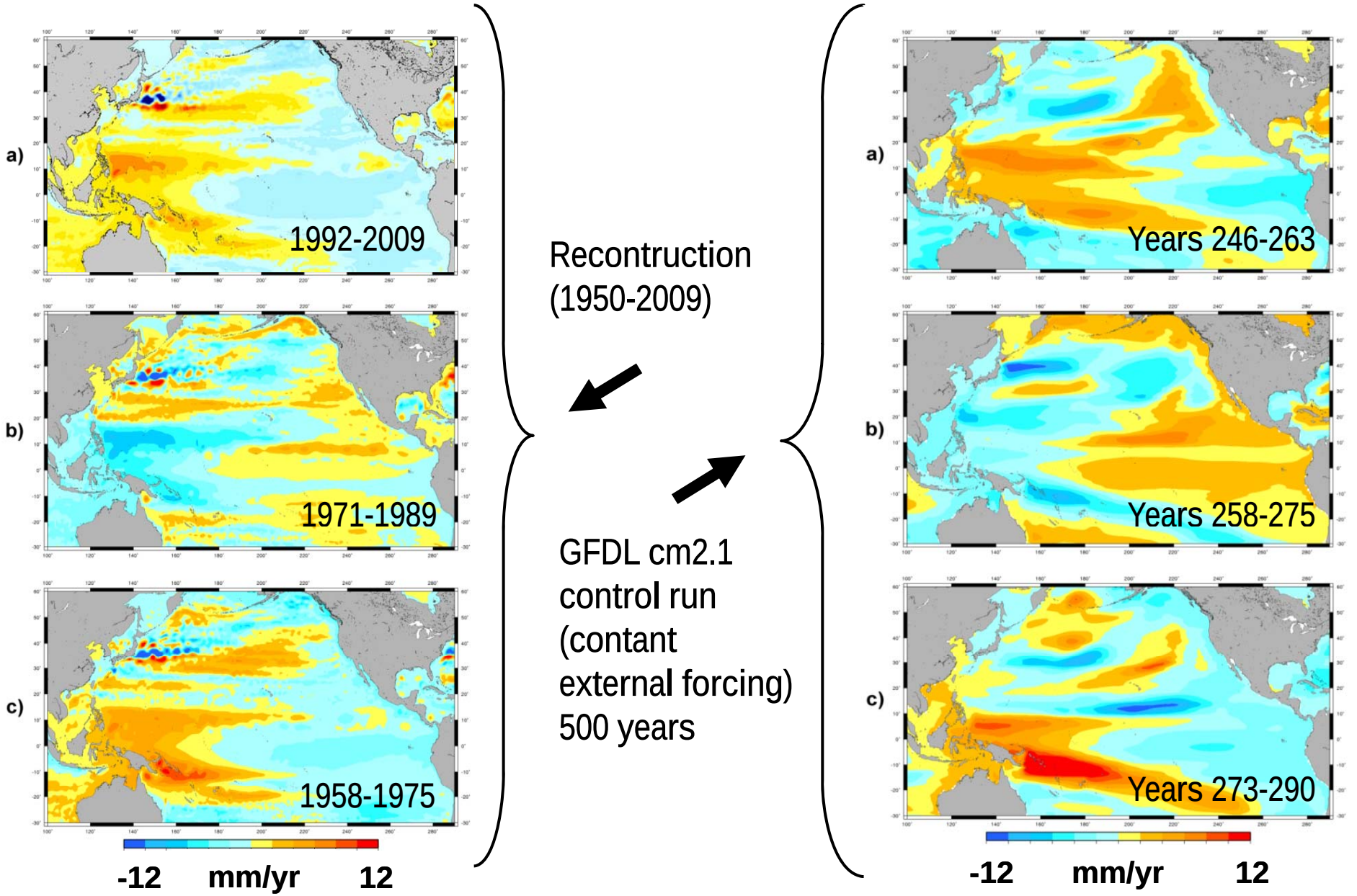




- Coupled Climate models control runs:

500-yr long control runs with
constant, preindustrial external forcing

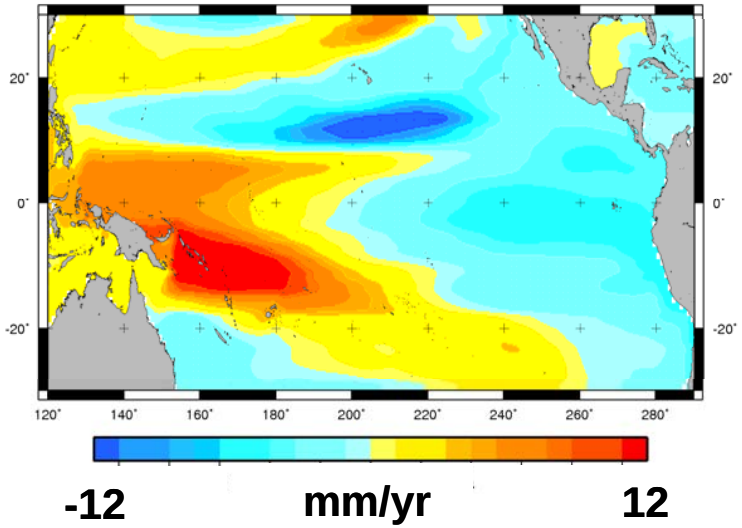
Spatial trend patterns of the GFDL control run computed over successive 17-year windows

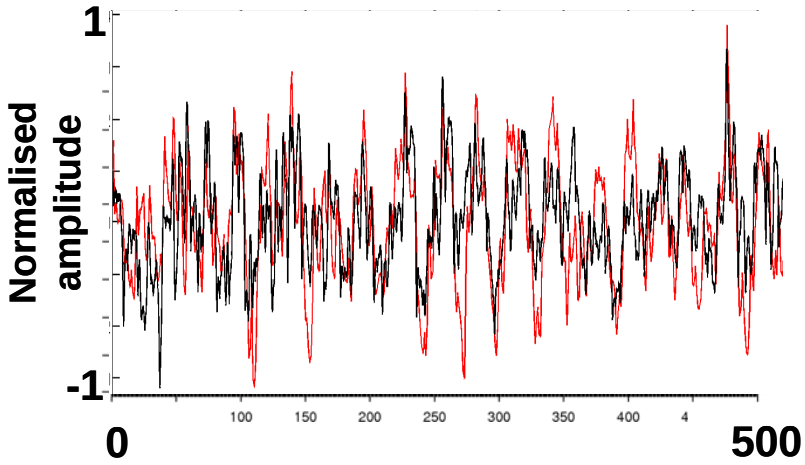


Spatial trend patterns of the GFDL control run computed over successive 17-year windows

GFDL control run

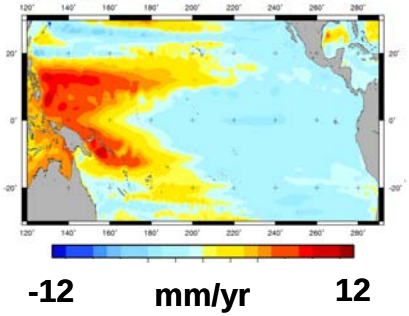
EOF1 of trends in successive 17-year windows
35.0 % of the total variance

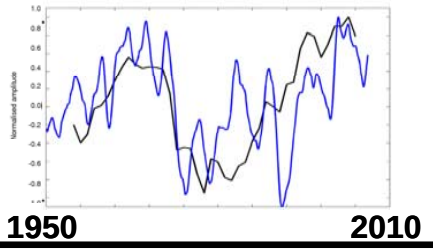




2-D reconstruction 1950-2009

EOF1 of trends in successive 17-year windows. 36.6% of the total variance

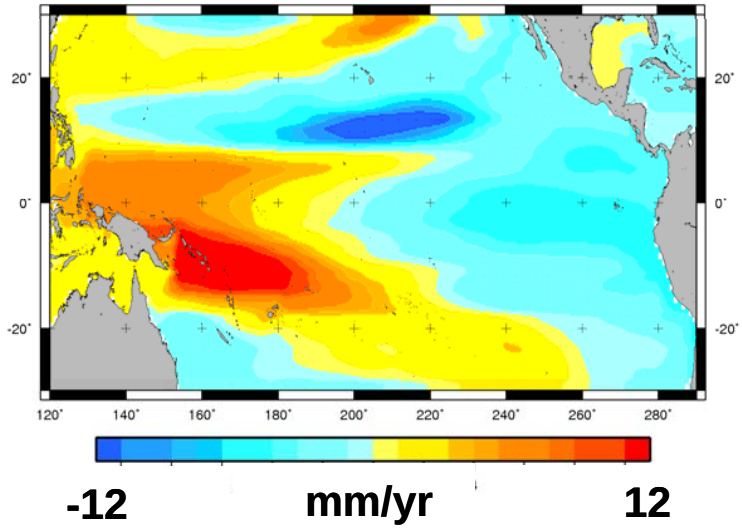


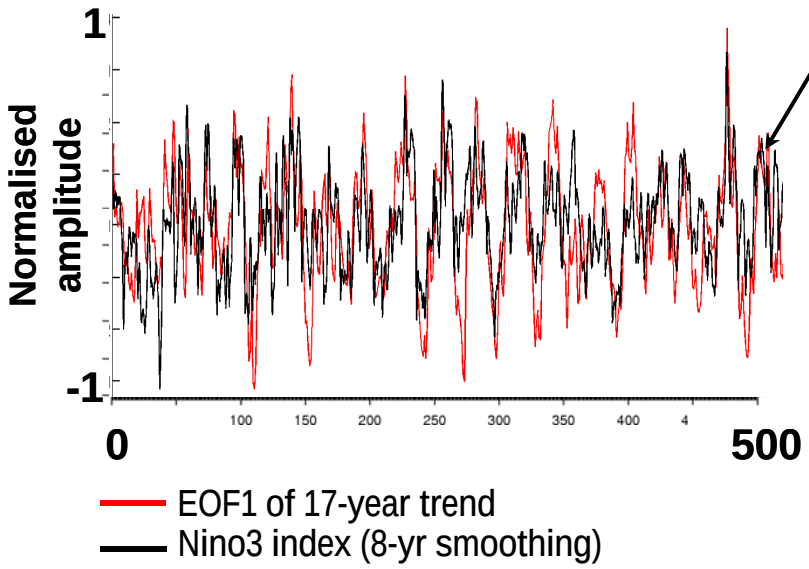


Spatial trend patterns of the GFDL control run computed over successive 17-year windows

GFDL control run

EOF1 of trends in successive 17-year windows
35.0 % of the total variance



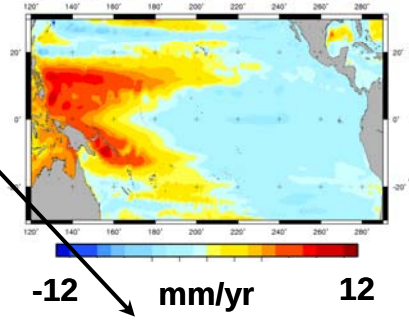


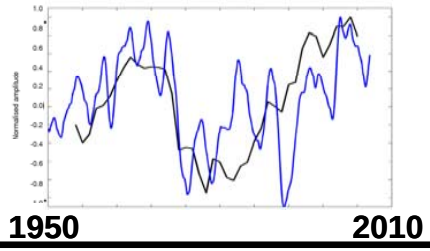
Similar patterns in observations (reconstruction) and GFDL control run, which fluctuate with periods (25-30 years) of sea level acceleration/deceleration

~25-30 yr^{-1}

2-D reconstruction

EOF1 of trends in successive 17-year windows. 36.6% of the total variance

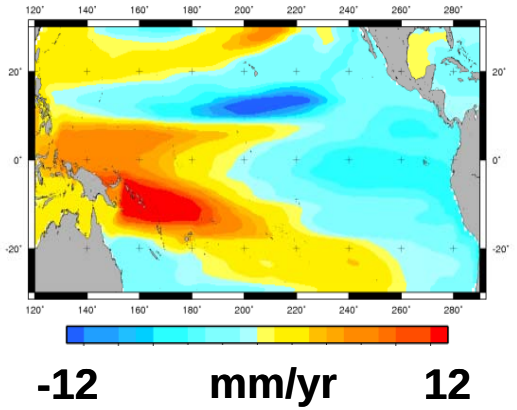


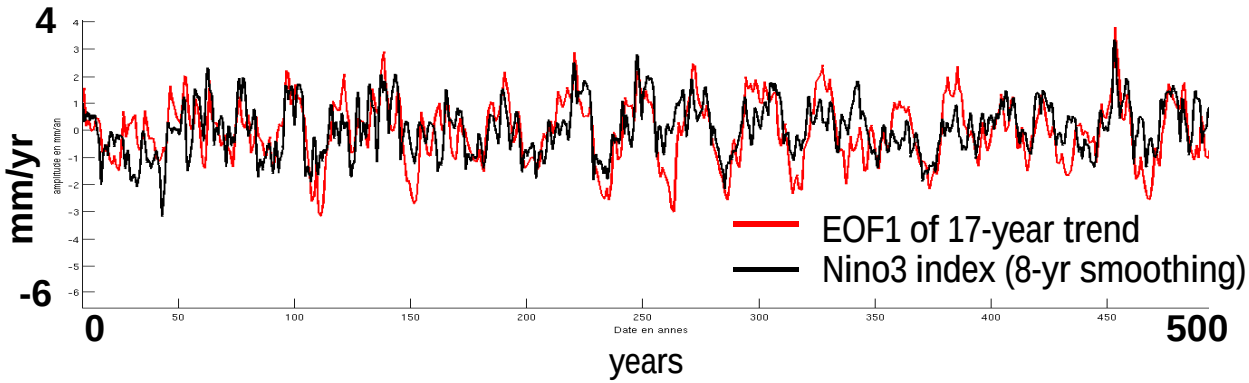


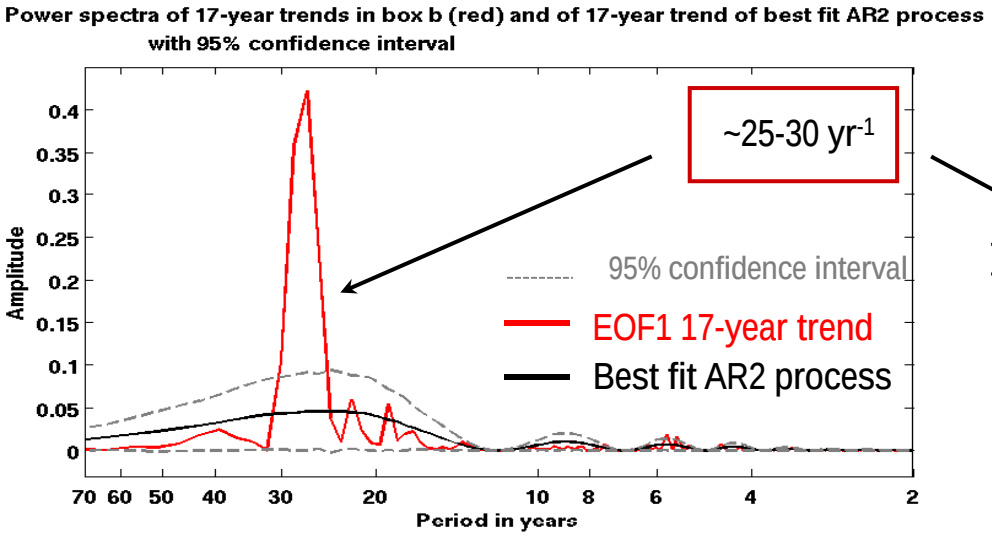
EOF1 of 17-year trend
Nino3 index (8-yr smoothing)

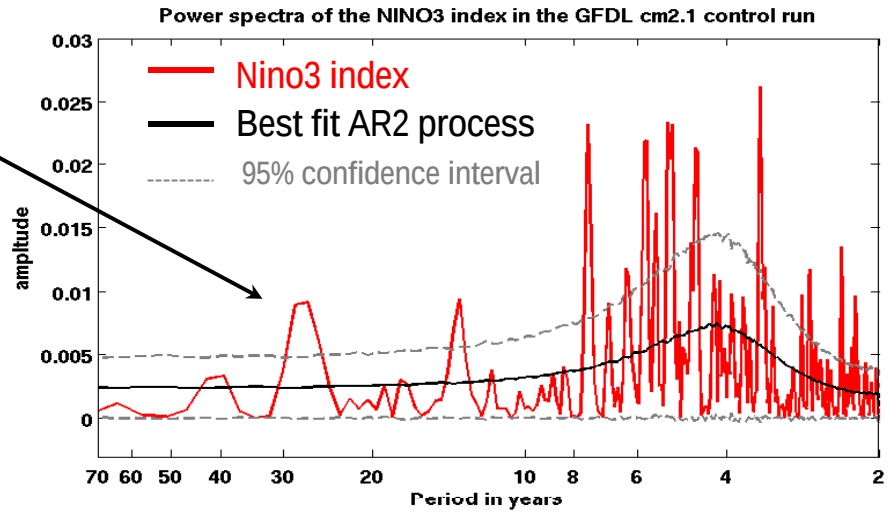
Spatial trend patterns of the GFDL control run computed over successive 17-year windows

EOF1 of 17-yr windows trends from GFDL control run and Fourier analysis



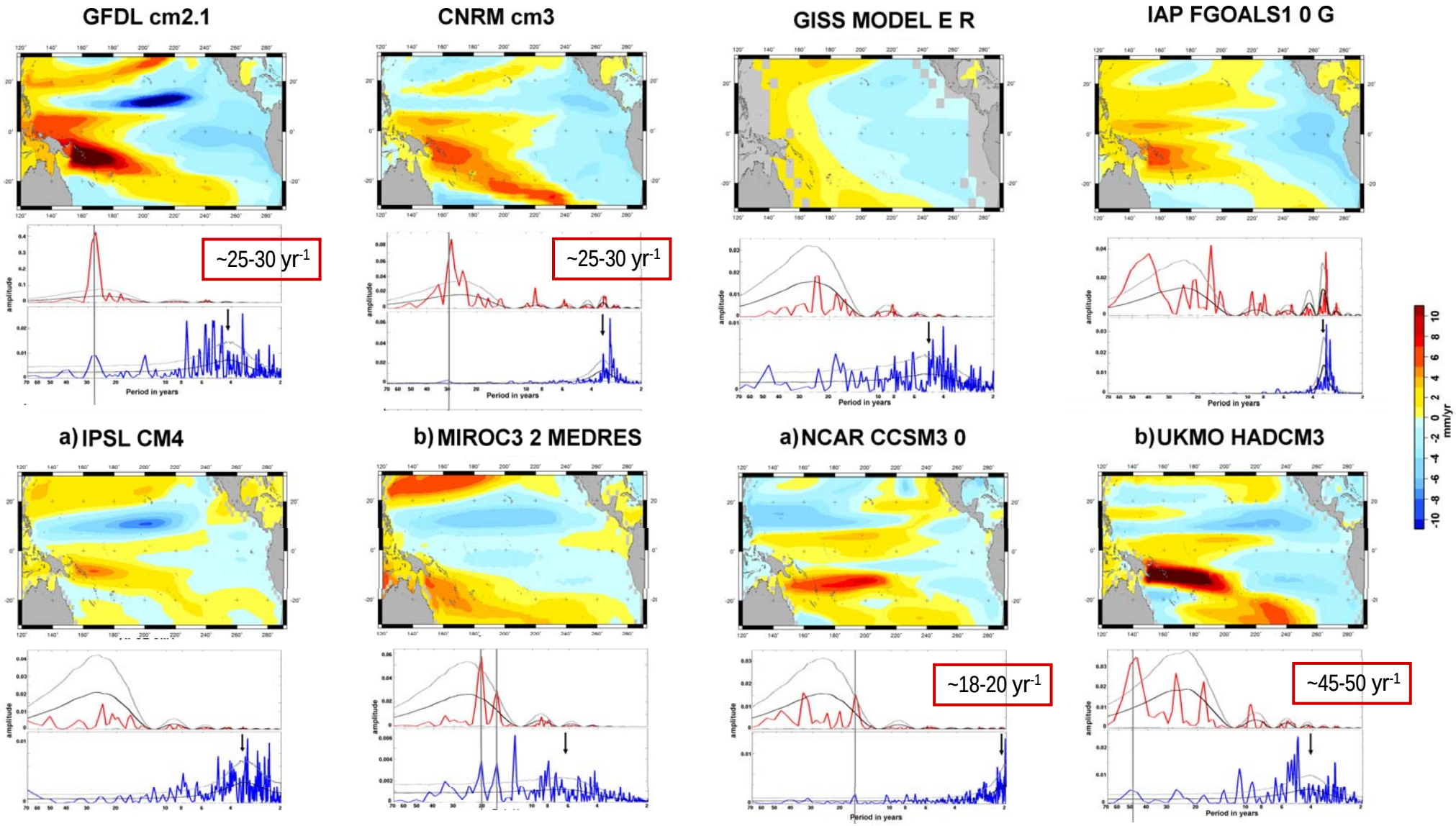






Periods of increased/decreased intensity of the trend patterns (sea level acceleration/deceleration) linked to internal low- frequency variability of ENSO

Spatial trend patterns of the AOCGCM control run computed over successive 17-year windows



Periods of increased/decreased intensity of the trend patterns (sea level acceleration/deceleration) linked to internal low- frequency variability of ENSO

- Coupled Climate models control runs:

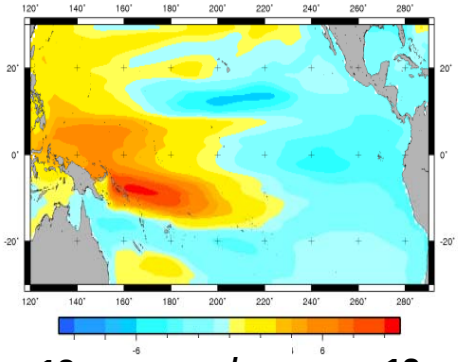
20th century experiment with
Volcanic+Sun variability and GHG+ Aerosols

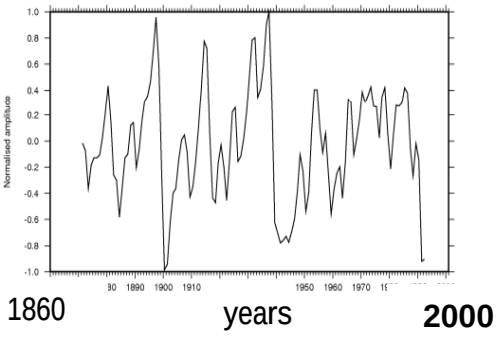
20th Century GFDL runs with Volcanic+Sun variability and GHG+ Aerosols emissions

EOF1 of GFDL 20c3m runs' trends in successive 17-year windows

run1

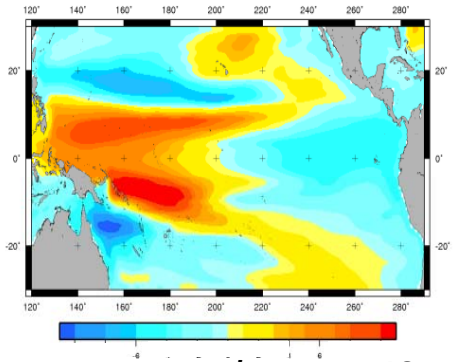
31.7 % of variance

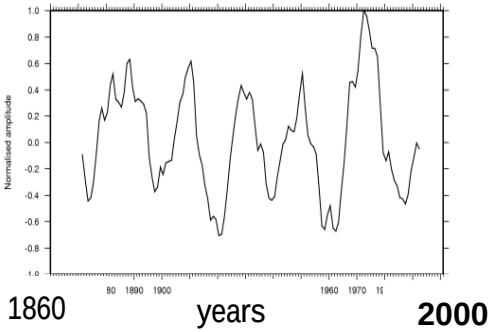




run2

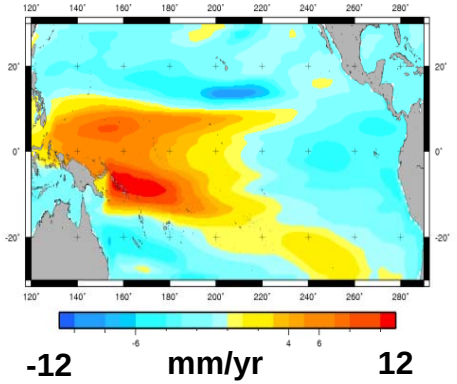
44.8% of variance

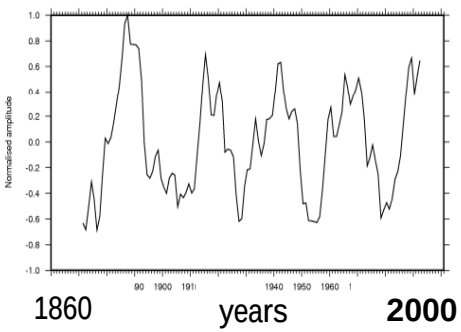




run3

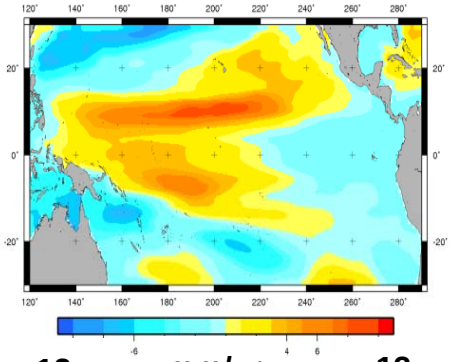
39.3% of variance

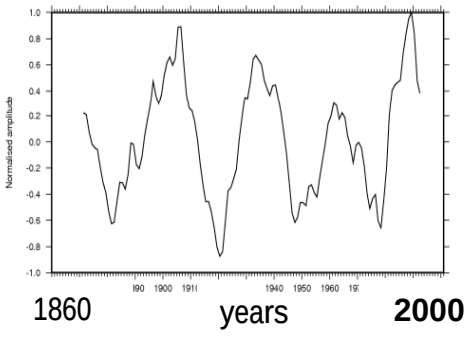




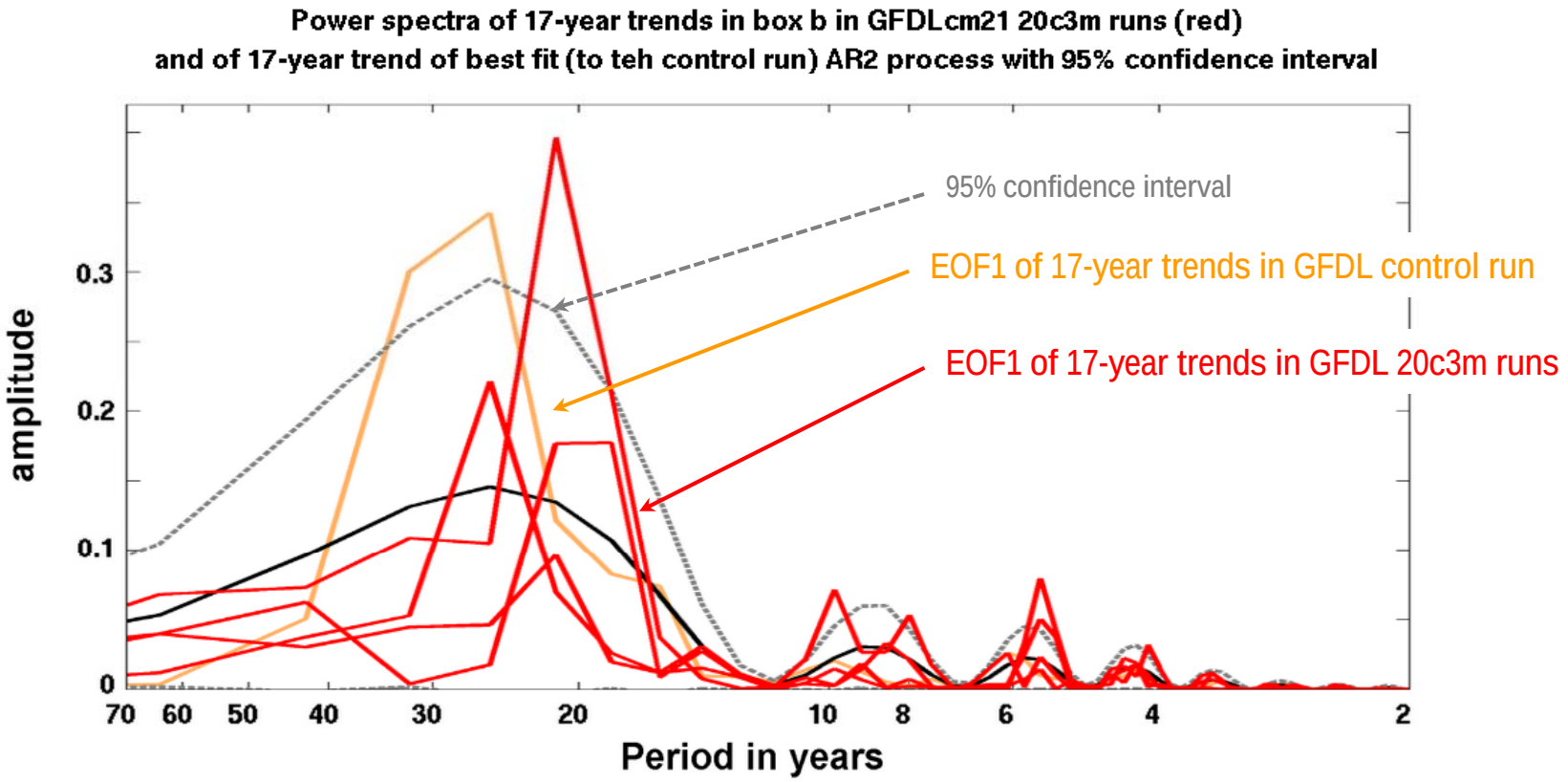
run4

30.9% of variance



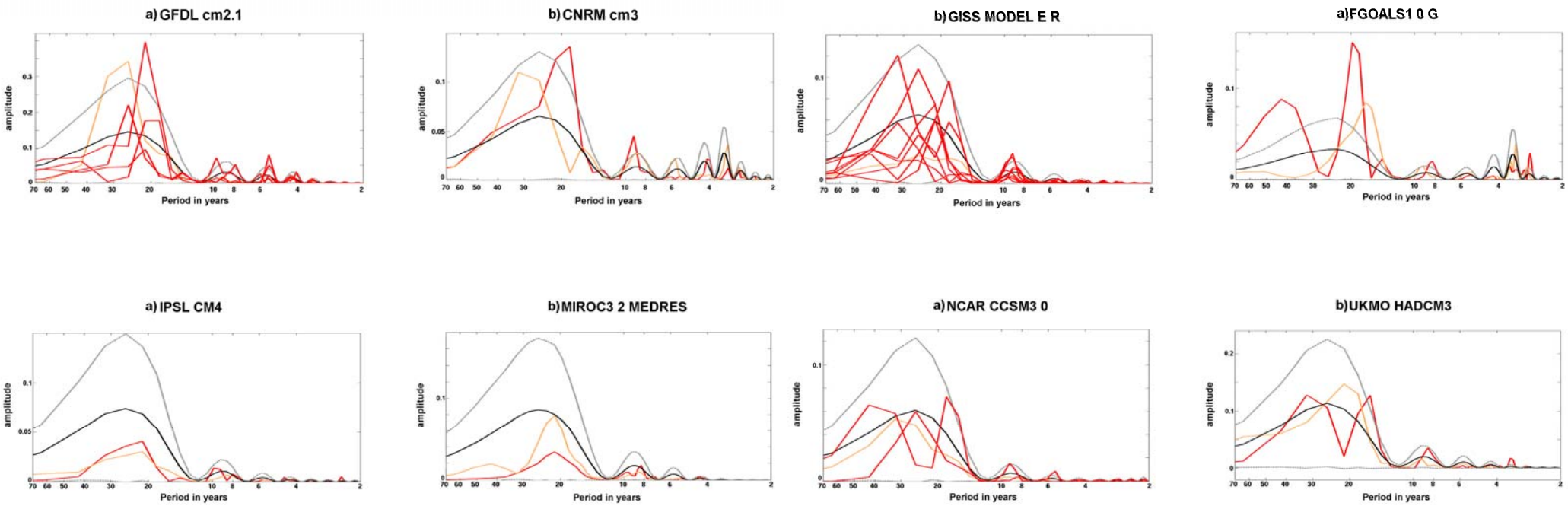


20th Century GFDL runs with Volcanic+Sun variability and GHG+ Aerosols emissions



The fluctuations of the trend patterns in the GFDL 20c3m run is **undistinguishable** from fluctuations of the trend patterns in the GFDL control run

20th Century GFDL runs with Volcanic+Sun variability and GHG+ Aerosols emissions



The fluctuations of the trend patterns in 13 out of 19 20c3m runs is undistinguishable from fluctuations of the trend patterns in the control runs

Conclusions

-The past sea level reconstruction suggests that the observed spatial trend patterns over the altimetry era (~17 years) in the tropical Pacific have oscillated in the past following a low frequency ENSO modulation

-AOGCM runs with constant, preindustrial external forcing show similar low-frequency modulation, during which sea level accelerates/decelerates (or equivalently trend patterns of increasing/decreasing intensity)
(but with different characteristic periods: 25-30yr, 18-20yr or 45-50yr)

-20th Century AOGCM runs with complete external forcing (including anthropogenic) show spatial trend patterns in sea level similar to those observed in control runs and observations. Their temporal variability is undistinguishable from their temporal variability in control runs.

- Internal modes of the climate system are mostly responsible for the observed spatial trend patterns during the altimetry era in the tropical Pacific
- This study (based on CMIP3 AOGCMs) suggests that it is not yet possible to detect any anthropogenic forcing signature in the tropical Pacific