

Macro-scale patterns in upwelling/downwelling activity at North American west coast

¹Saldívar-Lucio, R., ²E. Di Lorenzo, ³M. Nakamura,

¹H. Villalobos, ⁴D. ¹Lluch-Cota and ¹P. Del Monte-Luna





periods

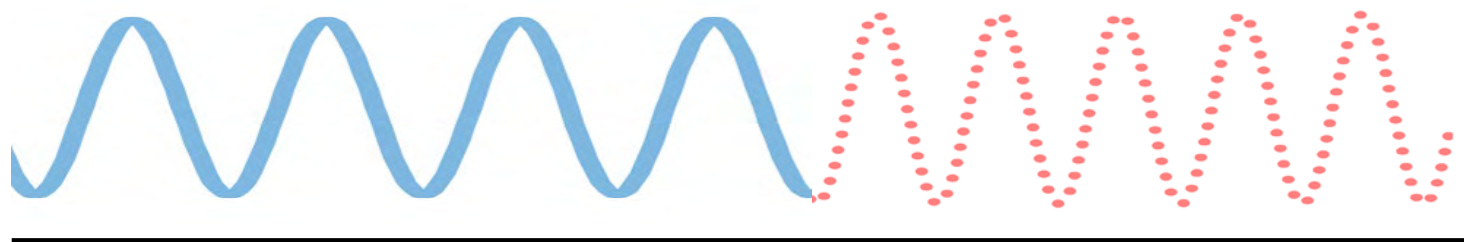
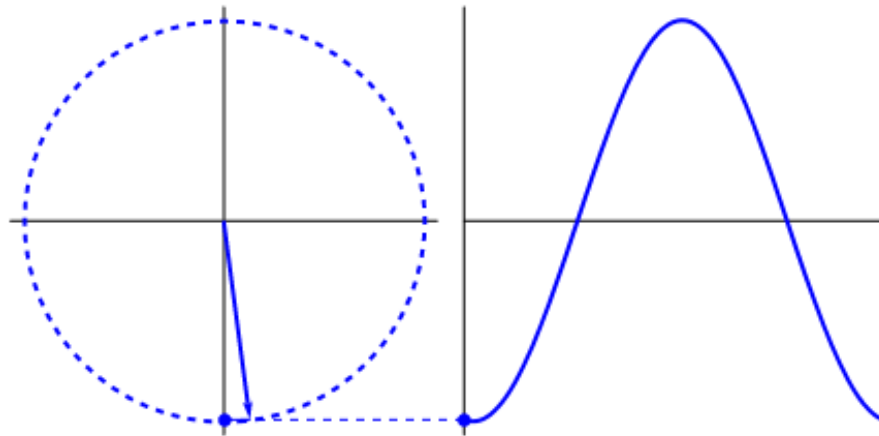
Warming /
cooling

Pacific
sardine

Expansion / contraction
process ~30 years

Lindegren *et al.*, 2013
Rodríguez-Sánchez *et al.*, 2009;
Lluch-Belda *et al.*, 1992



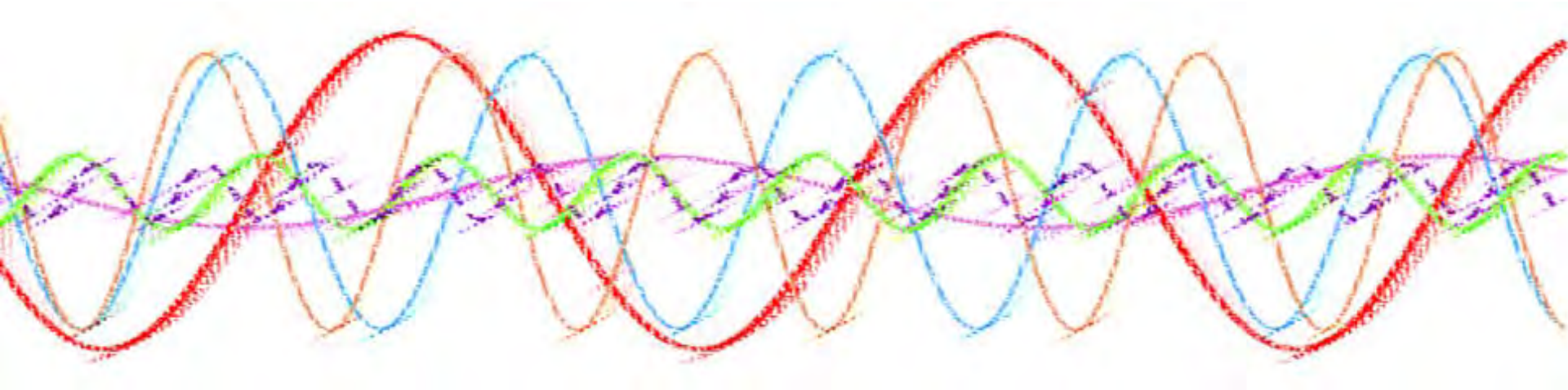


Past

Future

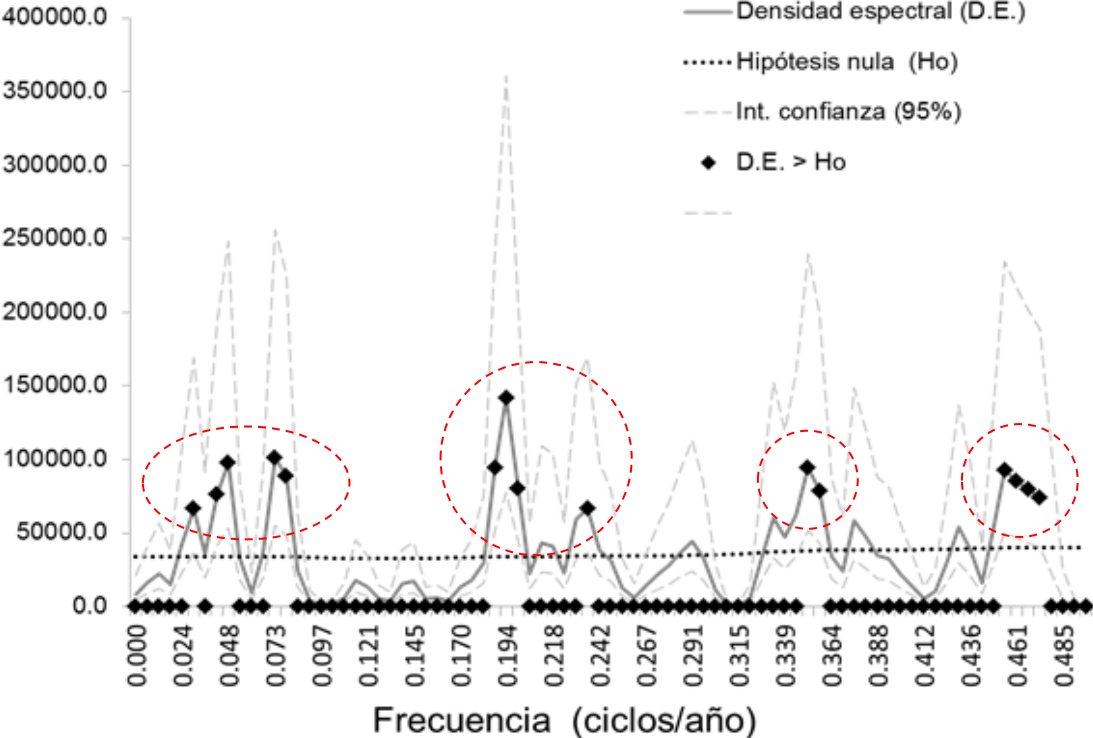


Low-frequency
Vs
specific periodic signals



AUTOCORRELATION DILEMMA

Not correct for running
projections



The inclusion of each signal...



1) impact on
signal projection
(e.g. Amplitude and phase)

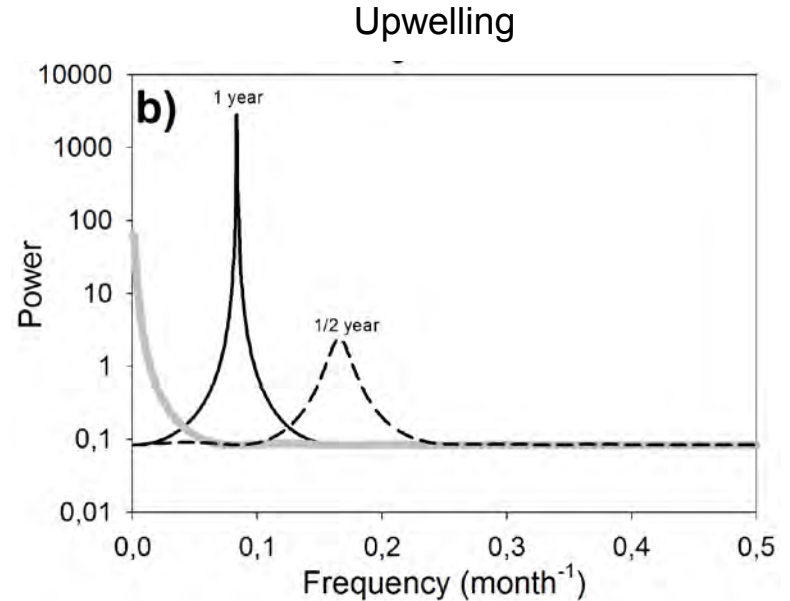
2) affects statistical confidence
& complicates interpretation

Ocean Physics

Multi-scale variability

Low-
frequency

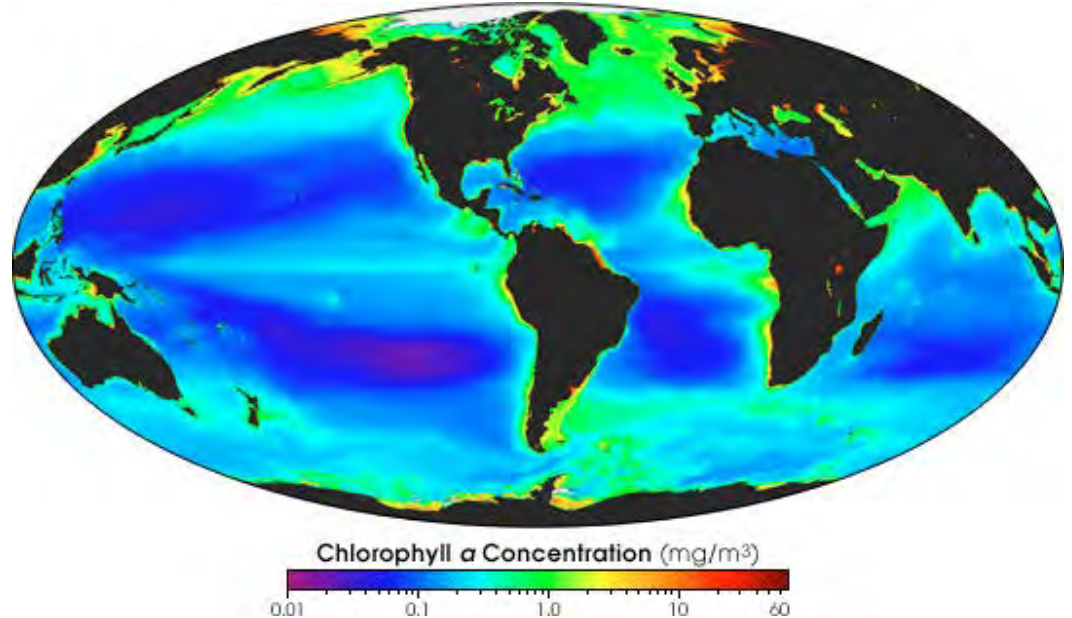
- Stochastic variability & feedback
- Periodic changes





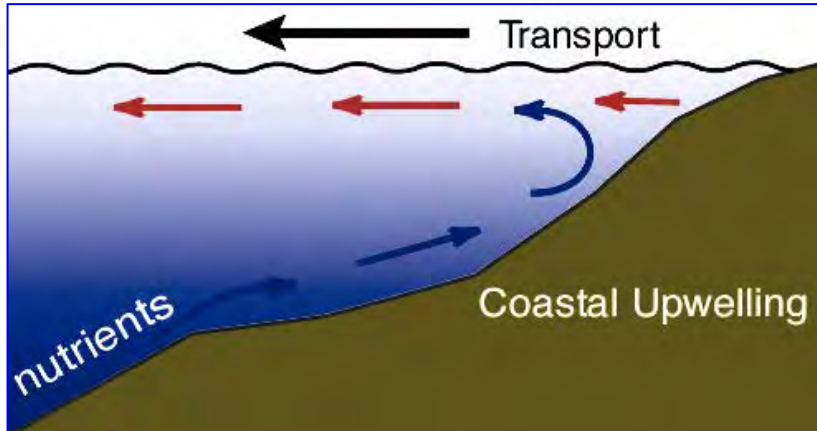
Upwelling activity

- Ocean productivity
- Pelagic habitats
- Ecological interactions
- Biomass fluctuations



>20% of the global fishery catches

Upwelling activity



Economy

Food security

General Strategy

- A) Worked on **clean signal**(s), obtained from original time series (upwelling index).
- B) **Converging results** from different techniques & analysed different **temporal resolutions**.
- C) **Compared** identified periodicities to those described in (scientific) literature.
- D) Tested **forecasting skill** of selected periodicities.



General Strategy

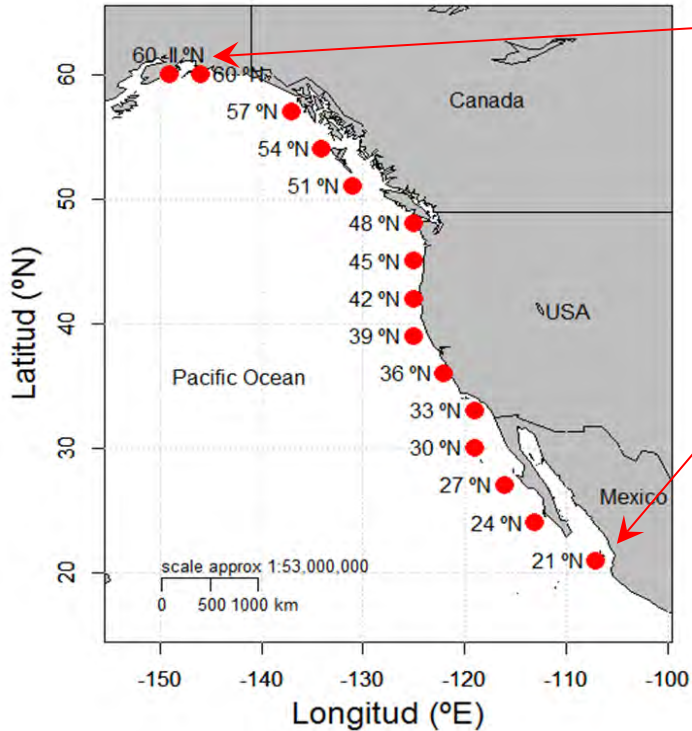
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15th Stations

21 – 60° N

From 1946 to 2012

Atmospheric pressure fields



Geostrophic winds



Ekman transport

Total upwelled water per year
($\text{m}^3 \cdot \text{s}^{-1} / 100 \text{ m coastline}$)

<http://www.pfeg.noaa.gov/>

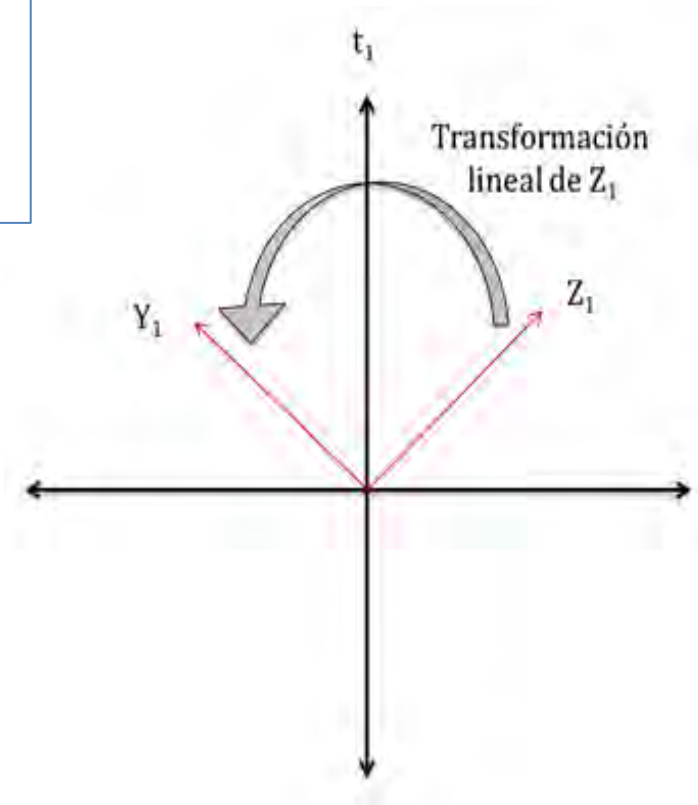


**MAXIMUM
AUTOCORRELATION
FACTOR ANALYSIS
(MAFA)**

AUTOCORRELATION



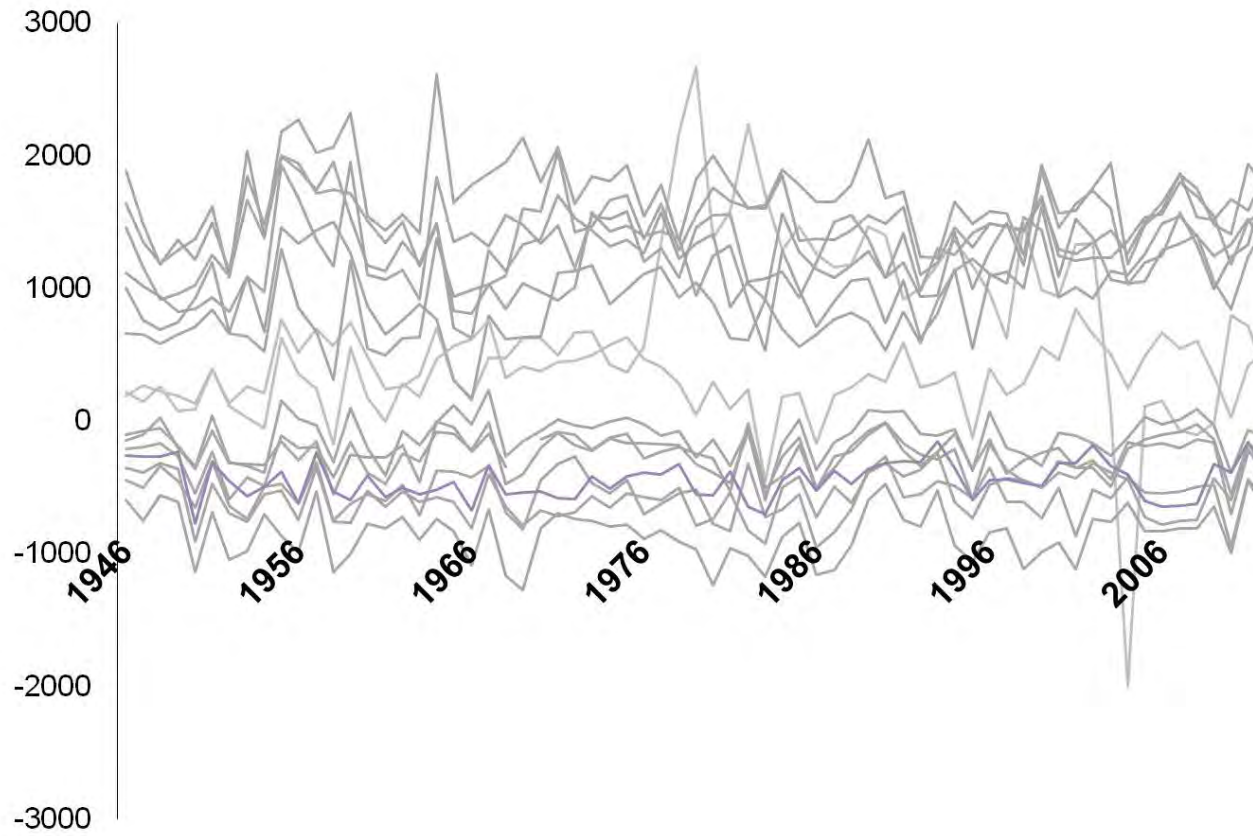
Structure of data in time



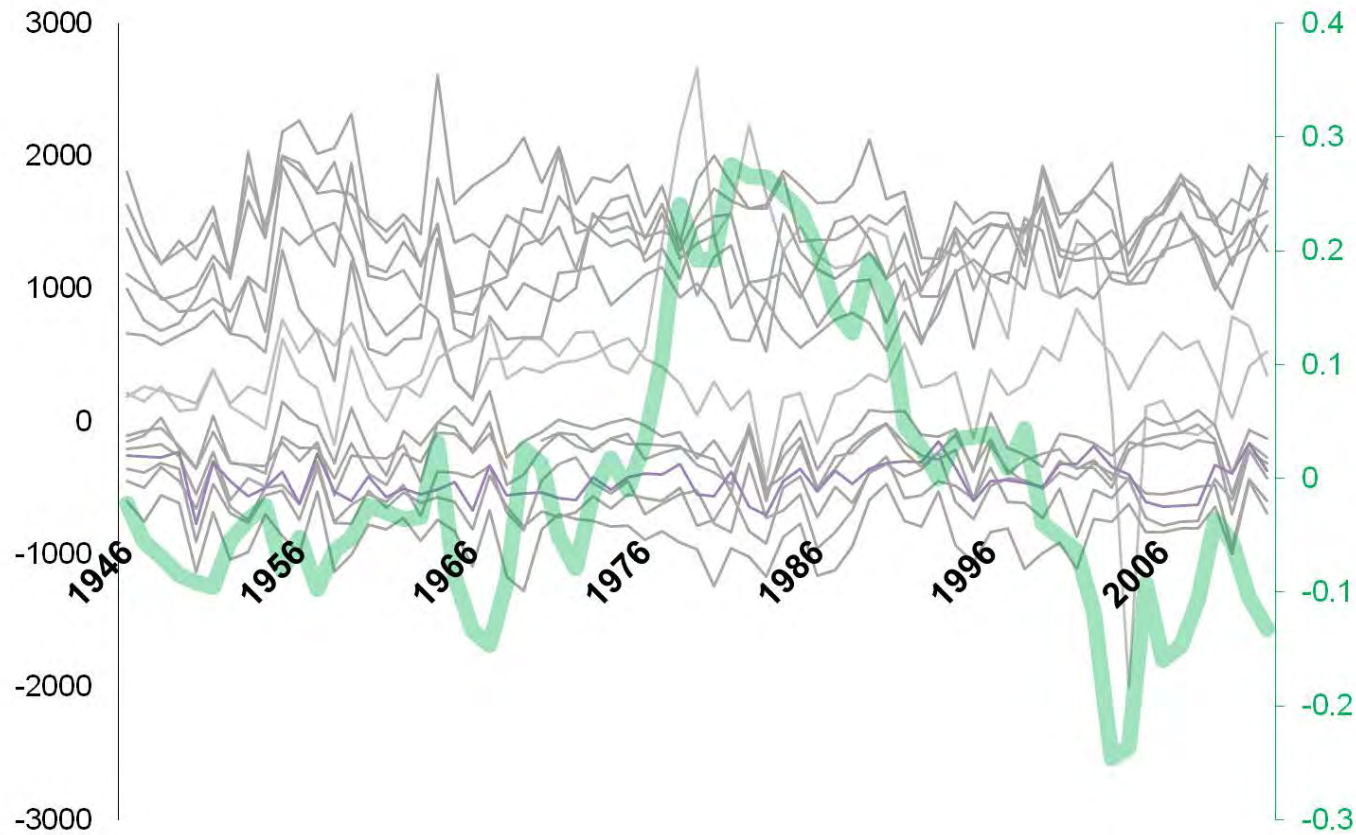
Signal



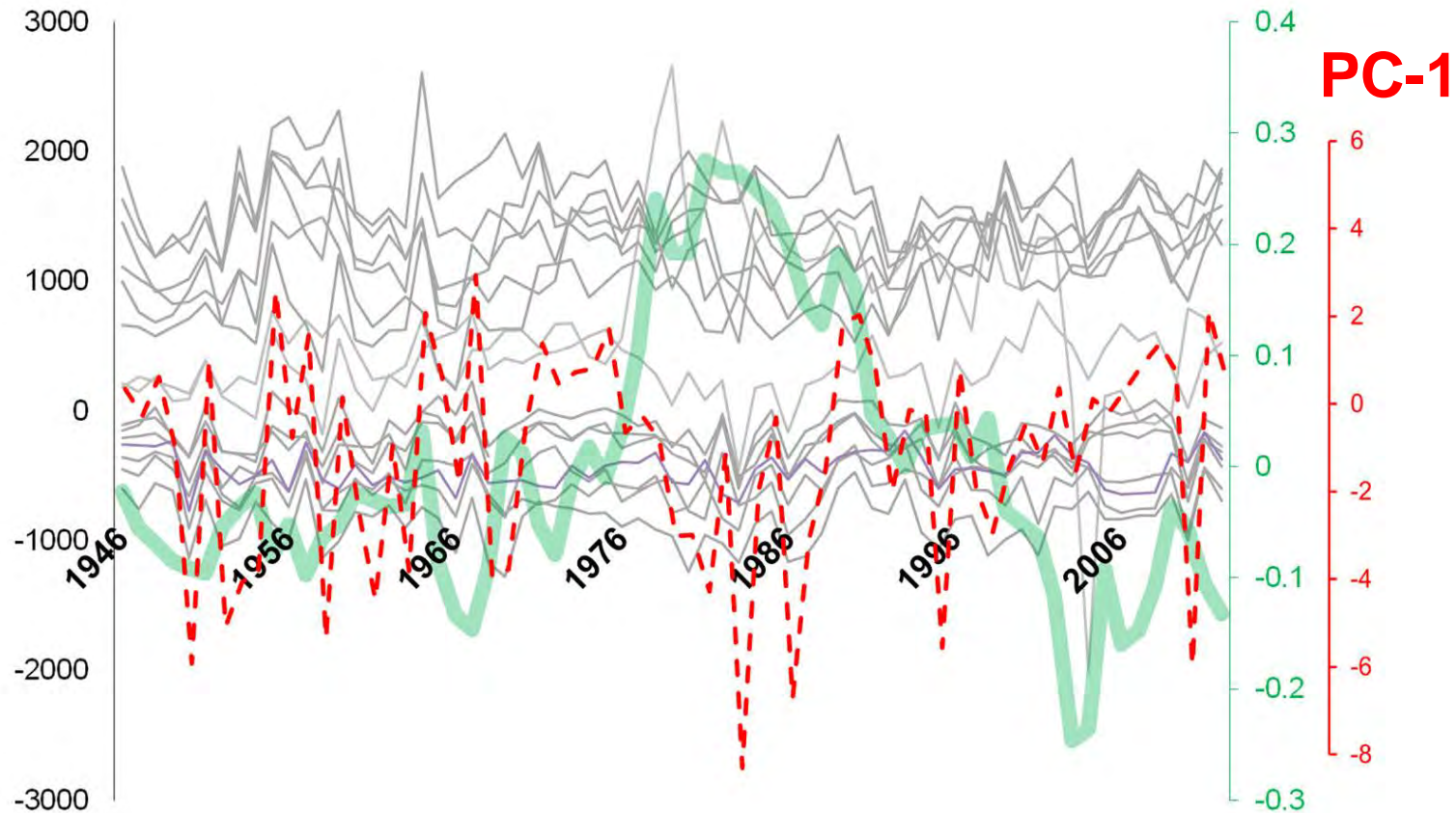
Noise



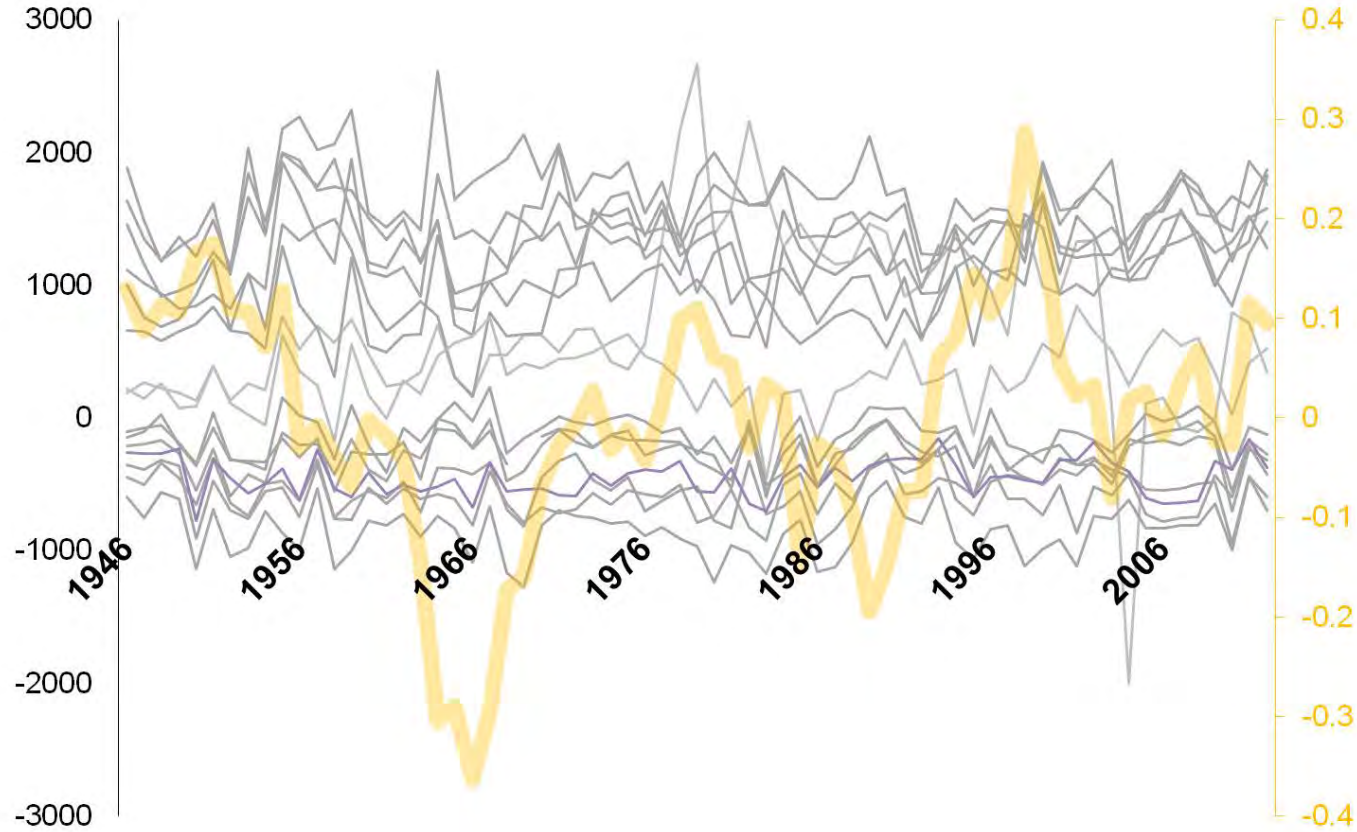
MAF-1



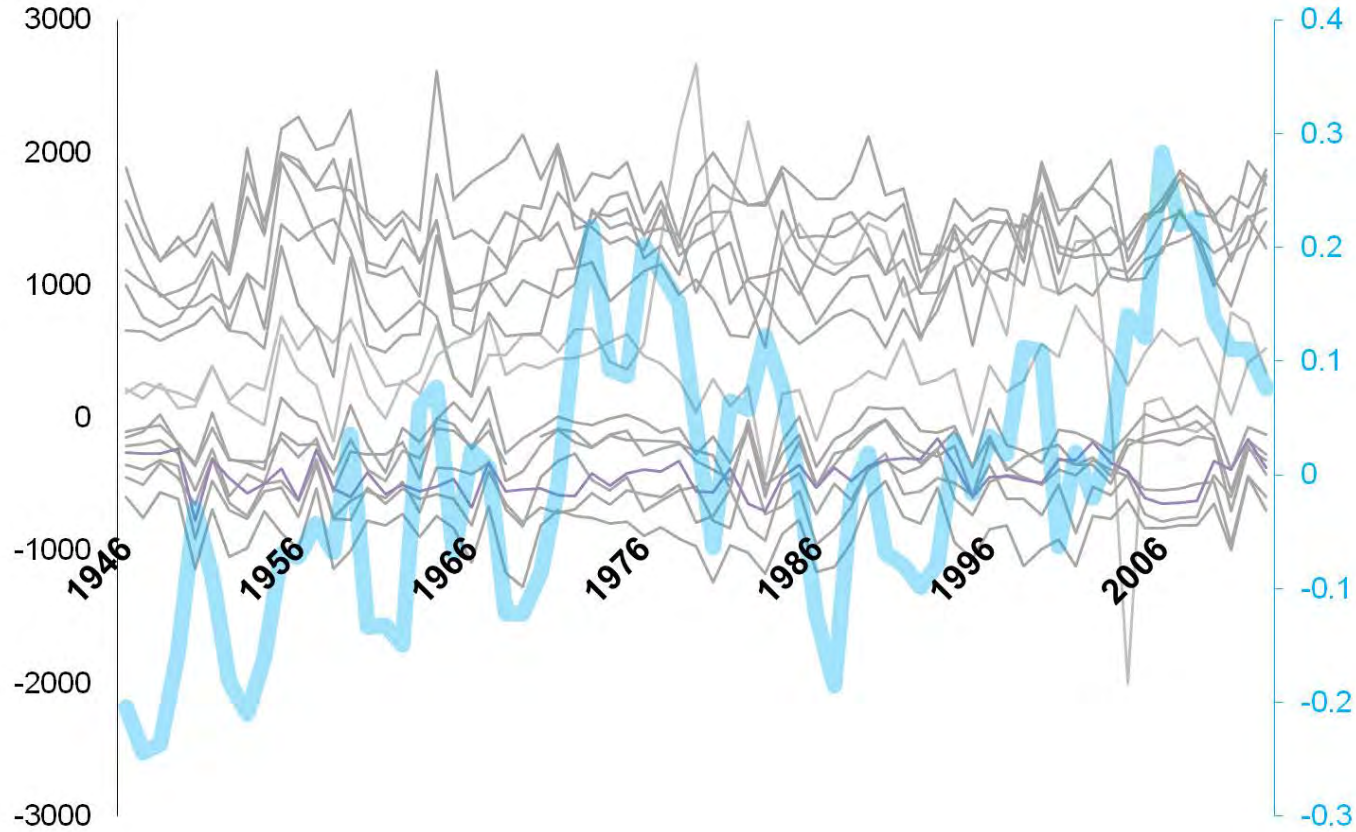
MAF-1



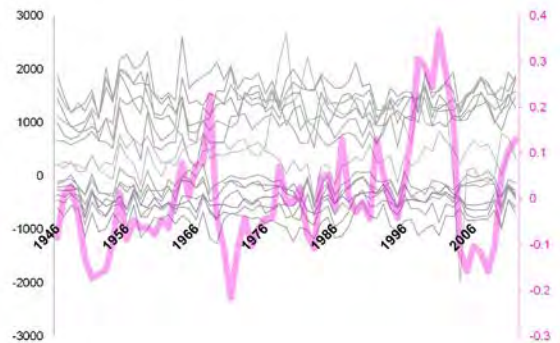
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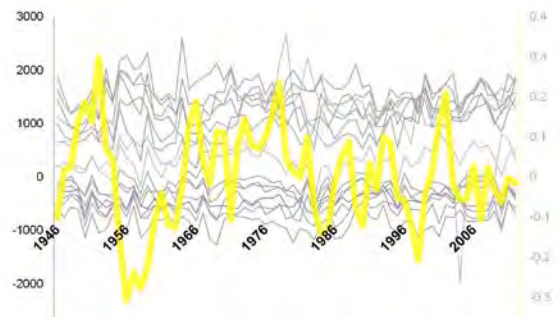
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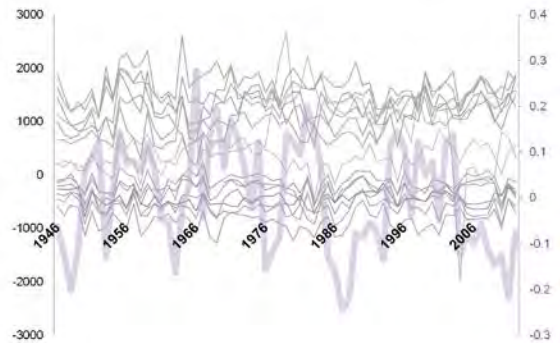
MAF-4

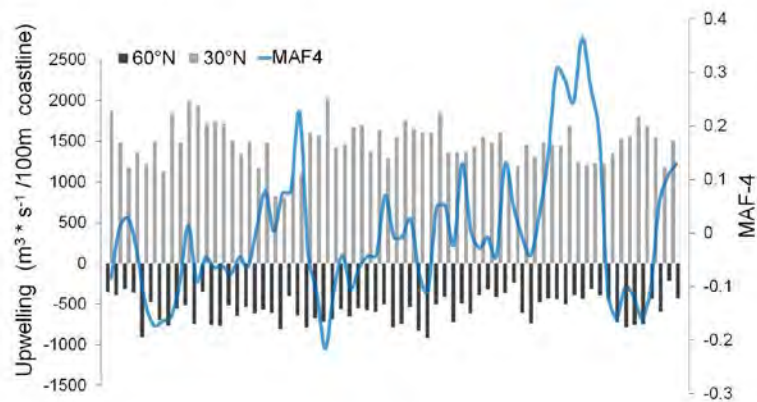


MAF-5

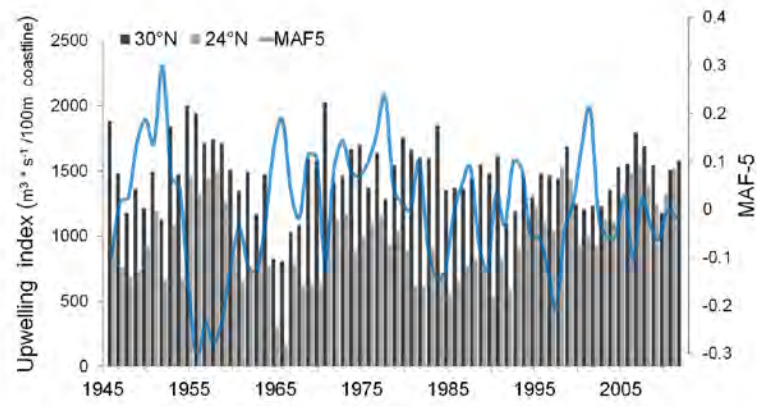


MAF-6

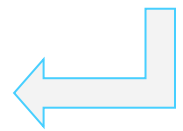




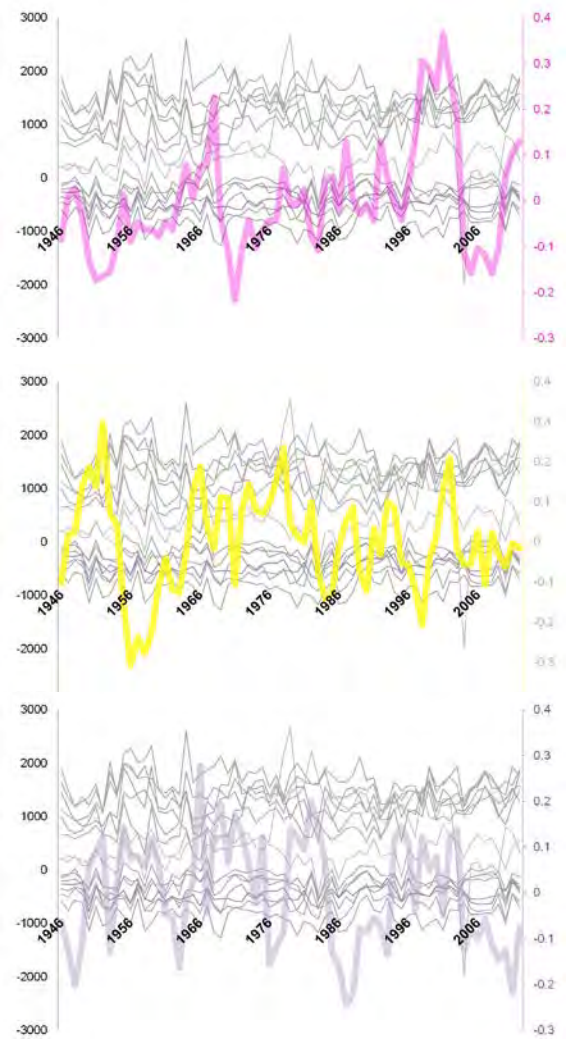
MAF-4



MAF-5

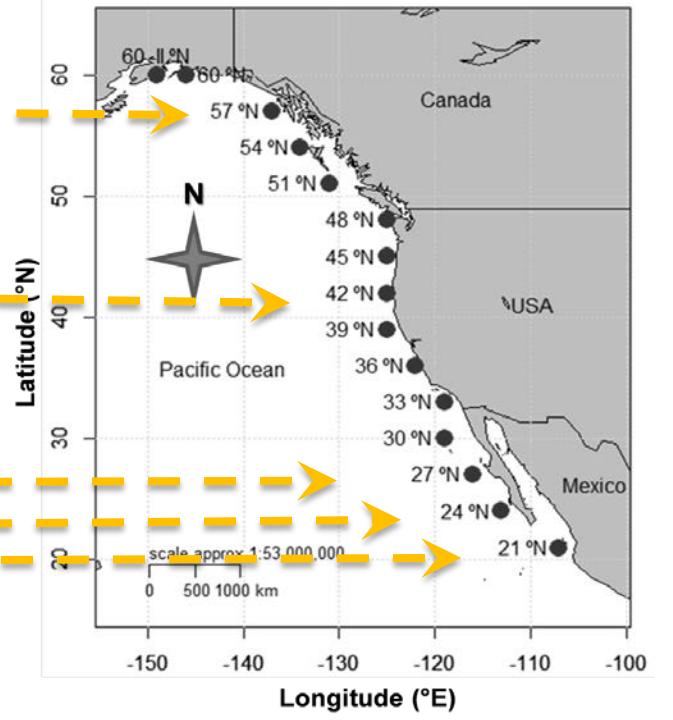
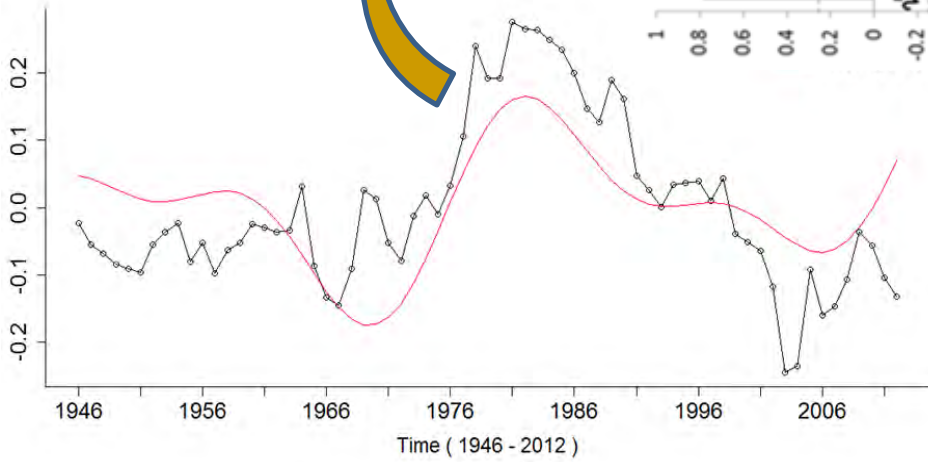


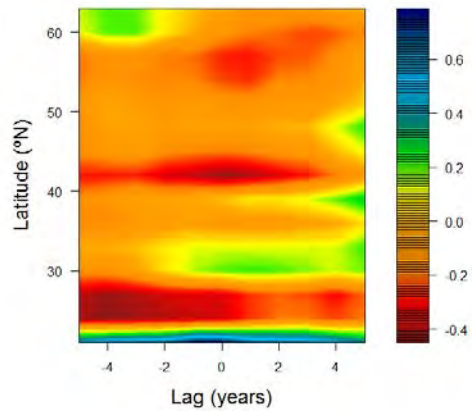
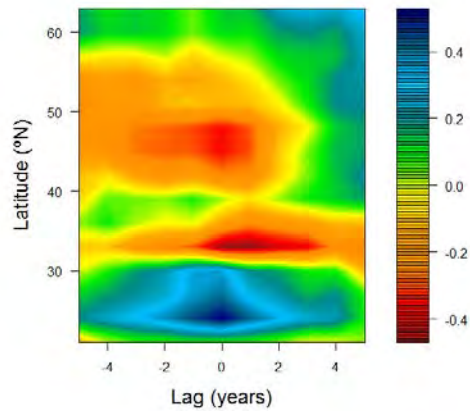
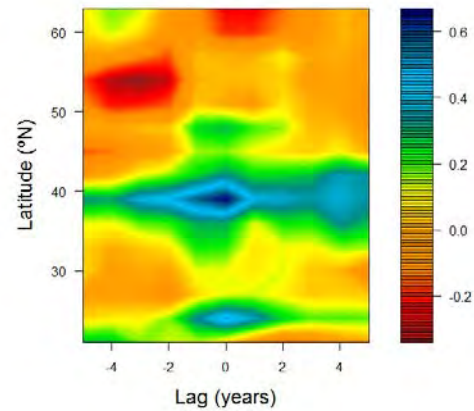
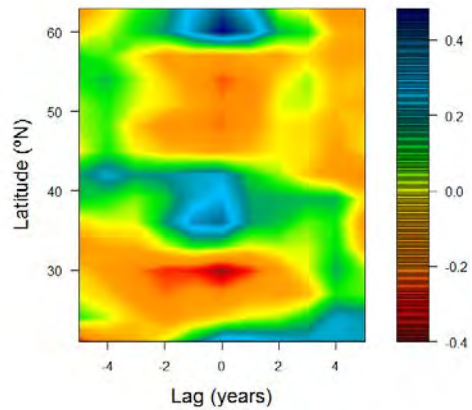
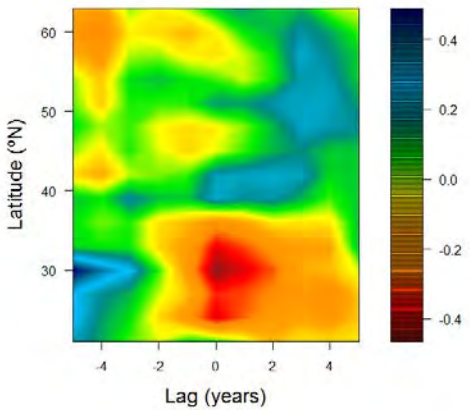
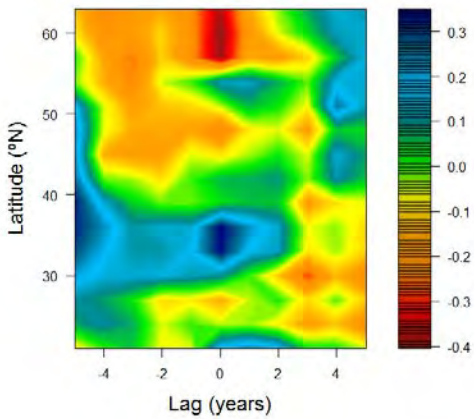
MAF-6





MAF-1



MAF1**MAF2****MAF3****MAF4****MAF5****MAF6**

DECISION
(selecting single periodicities)



All available analytical tools are imperfect in this point

General Strategy

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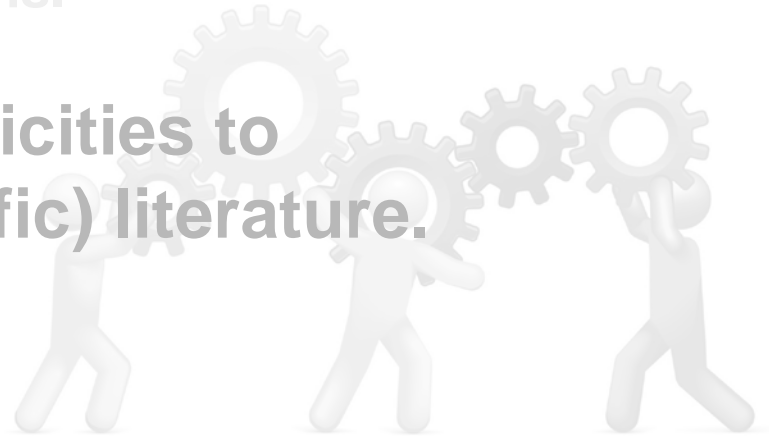


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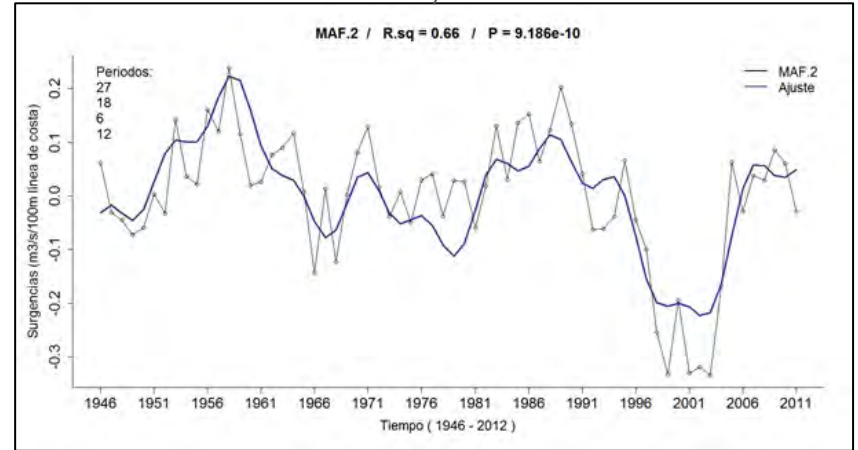
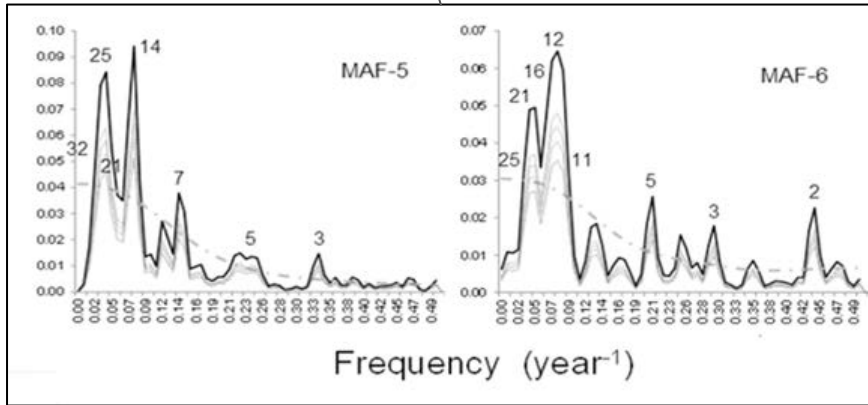
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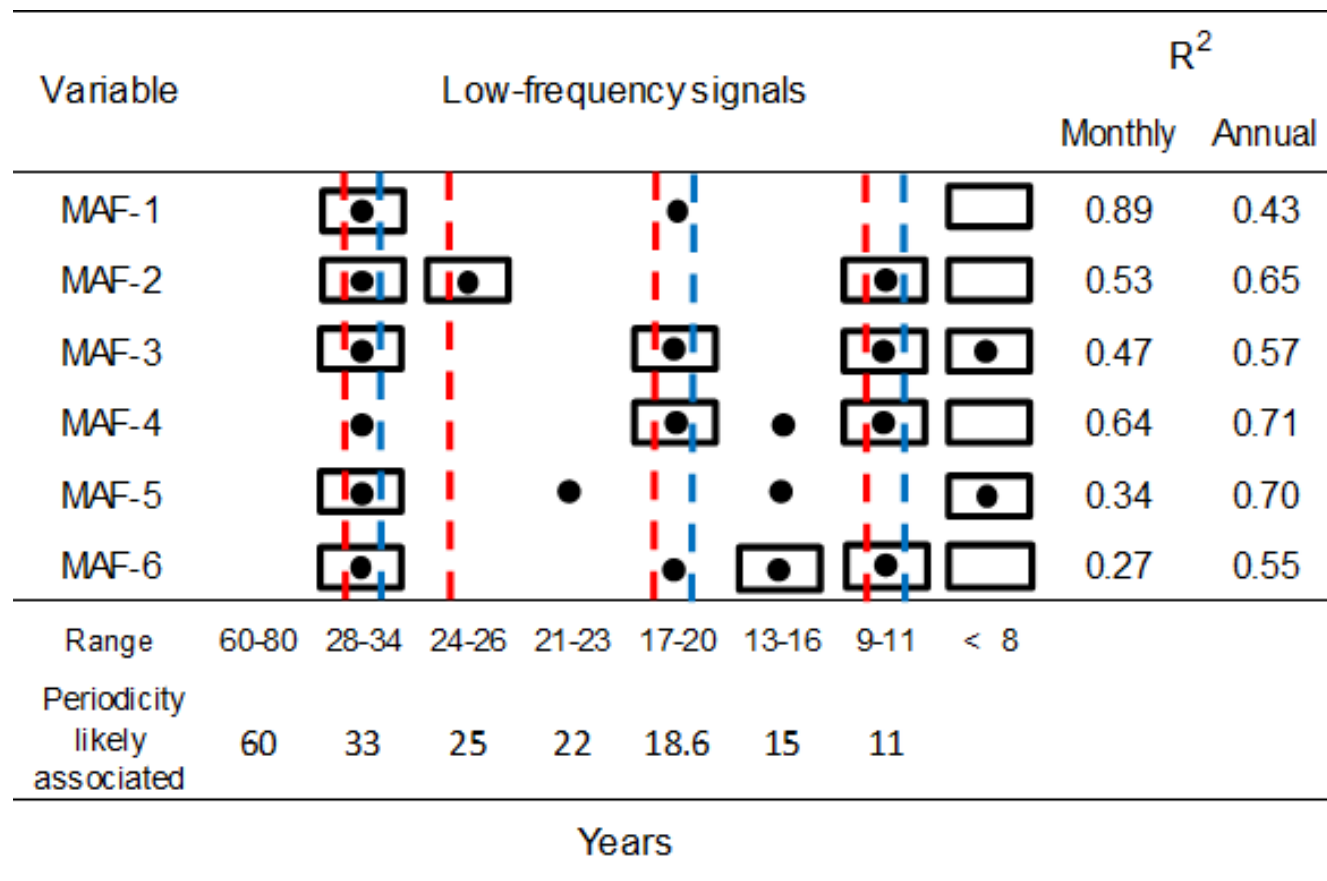


Spectral Density

&

Cyclic Descend + Periodic regression

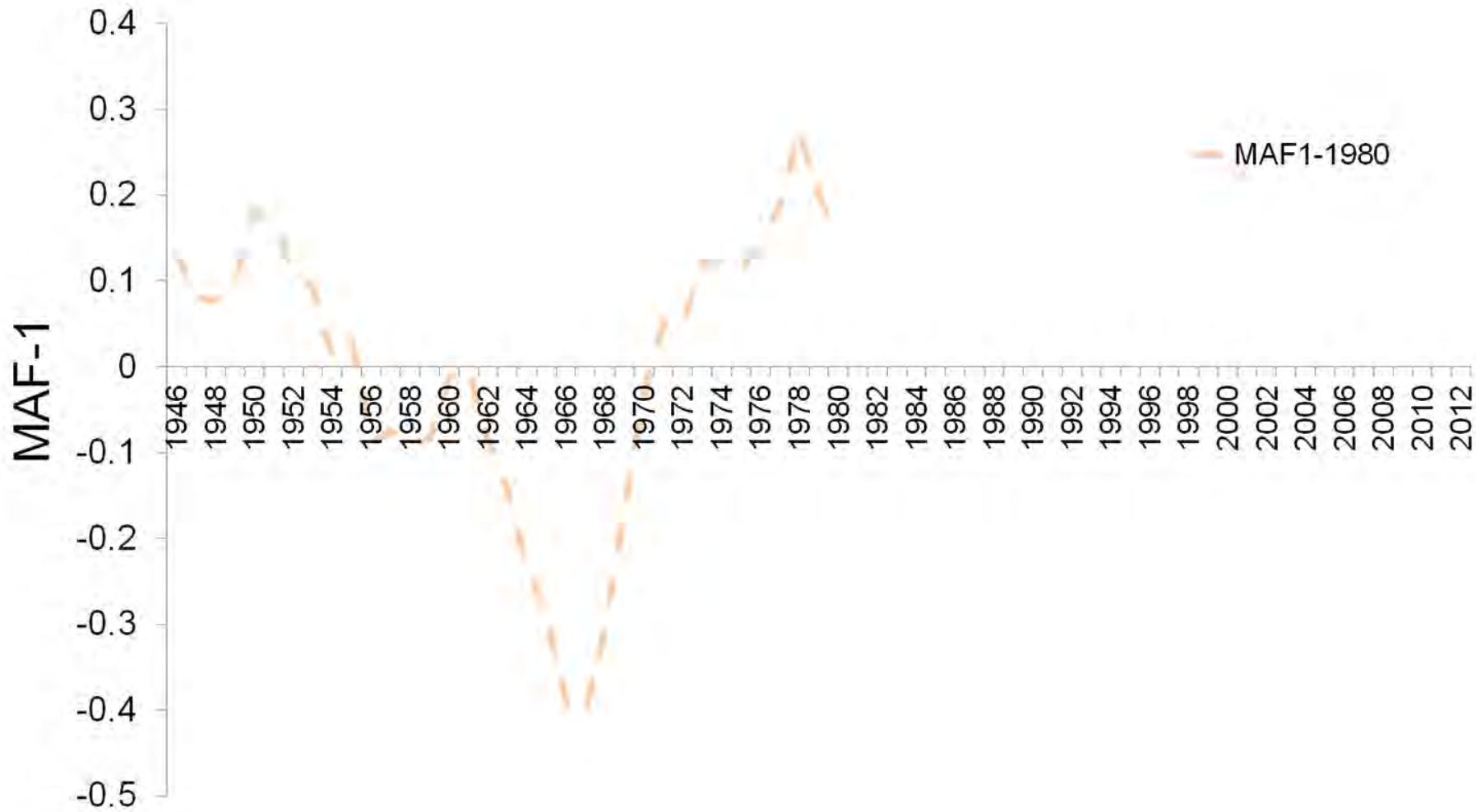


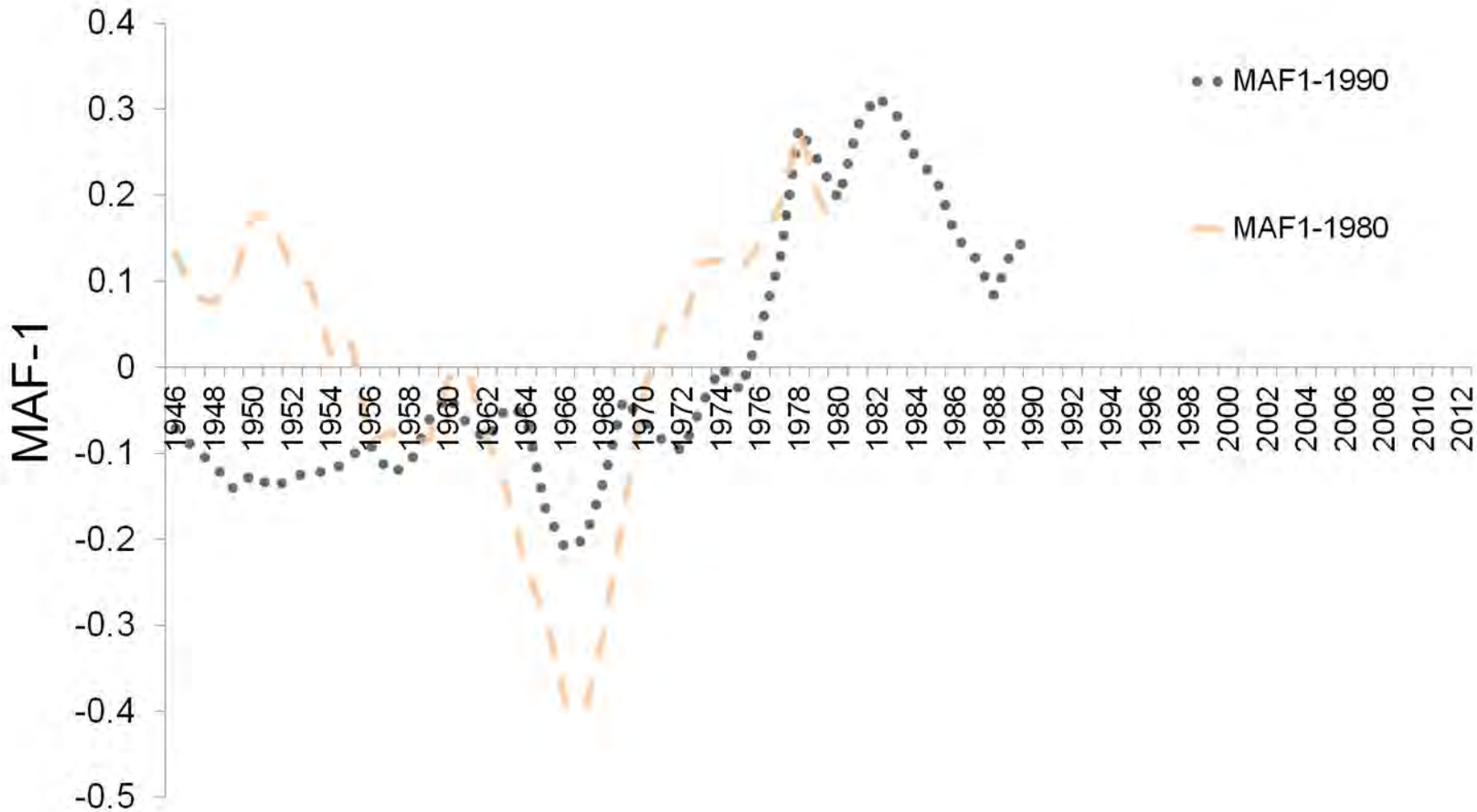


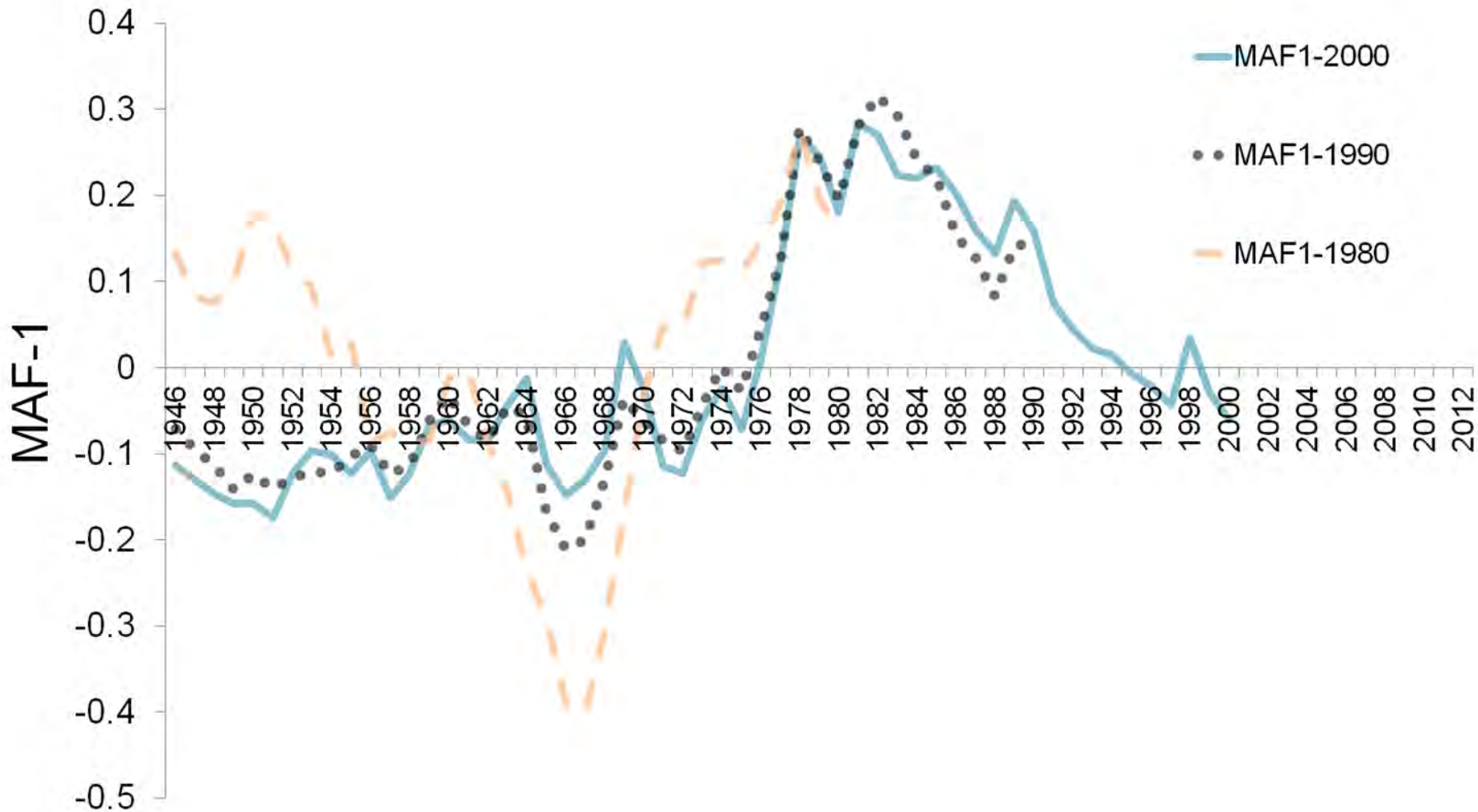
General Strategy

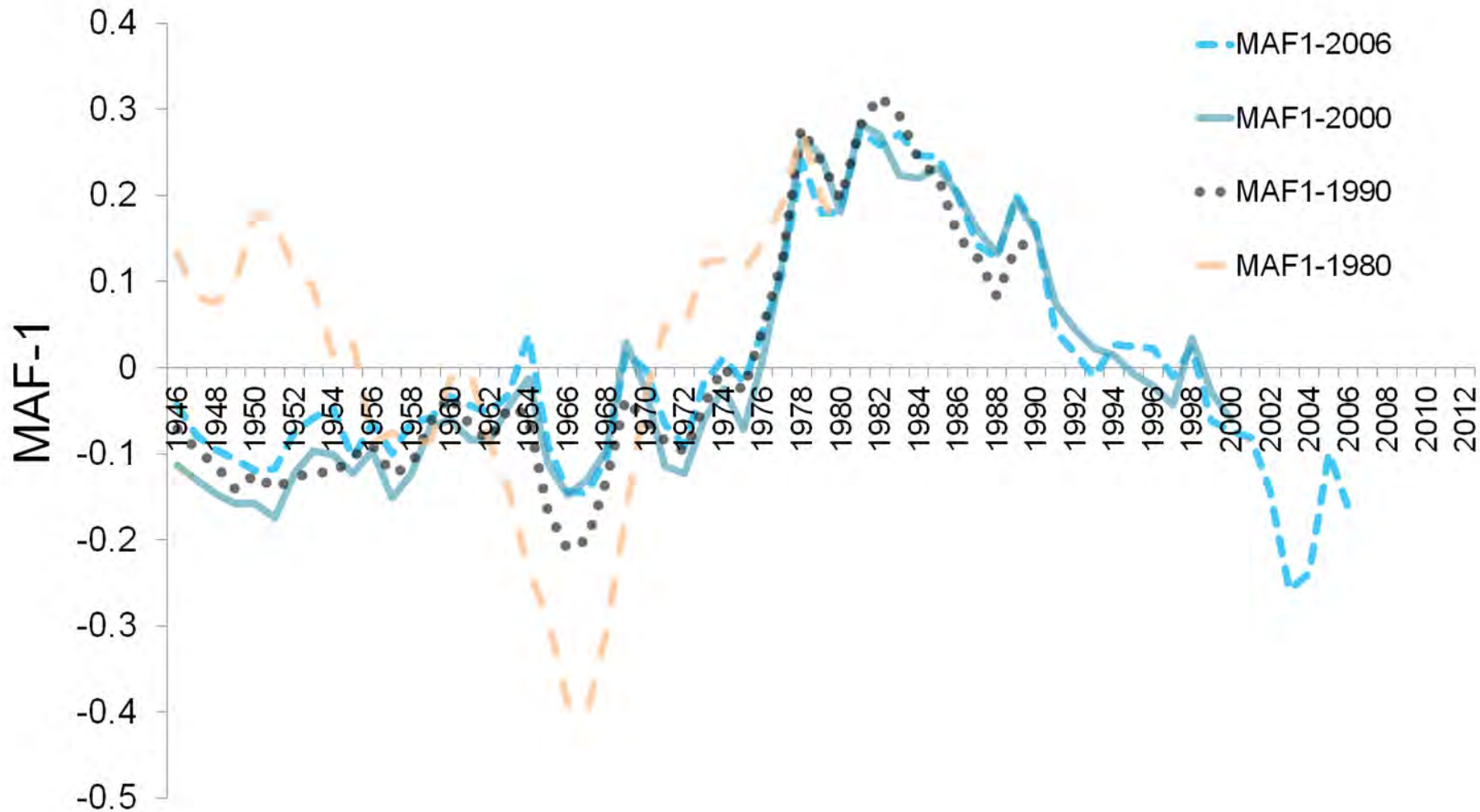
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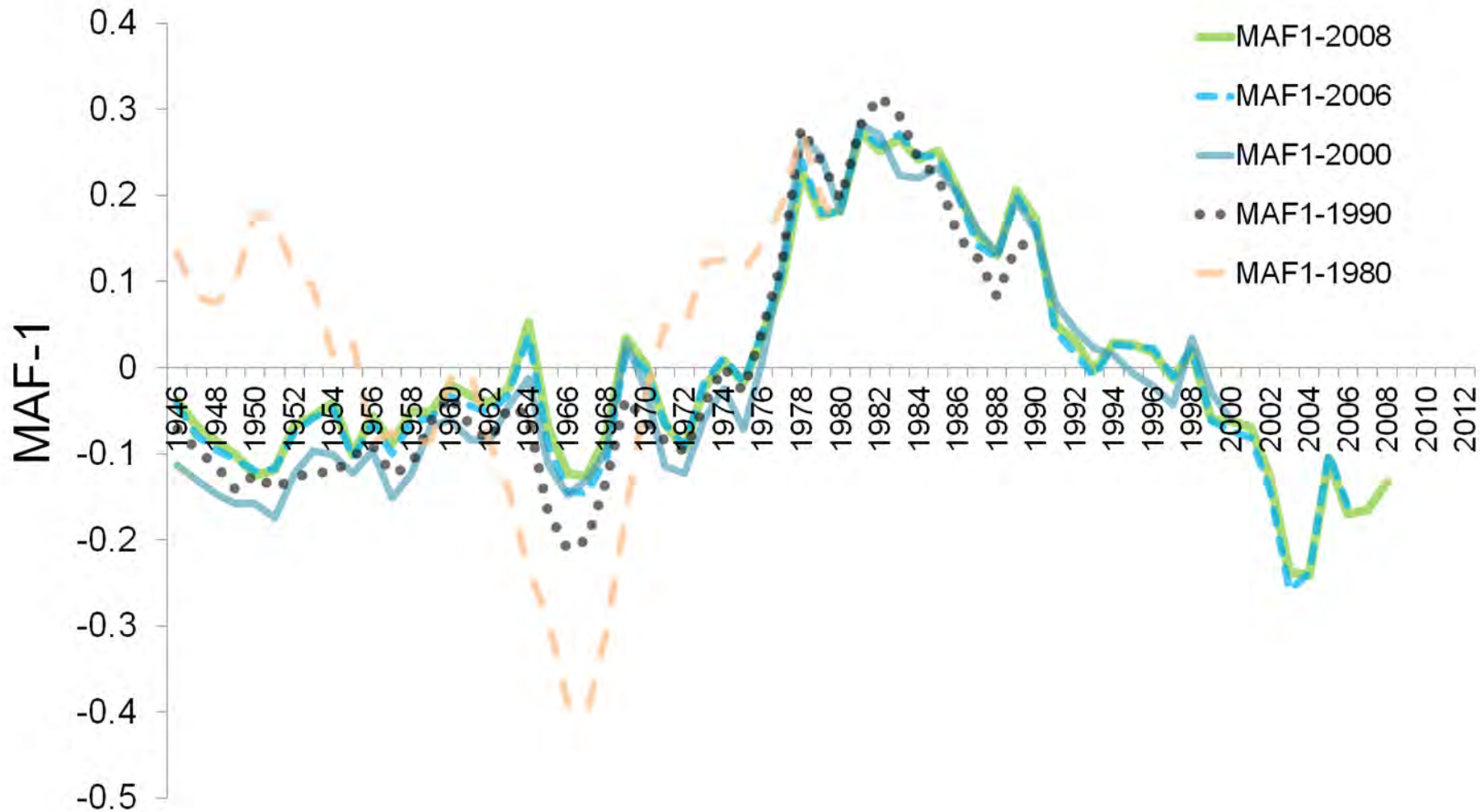


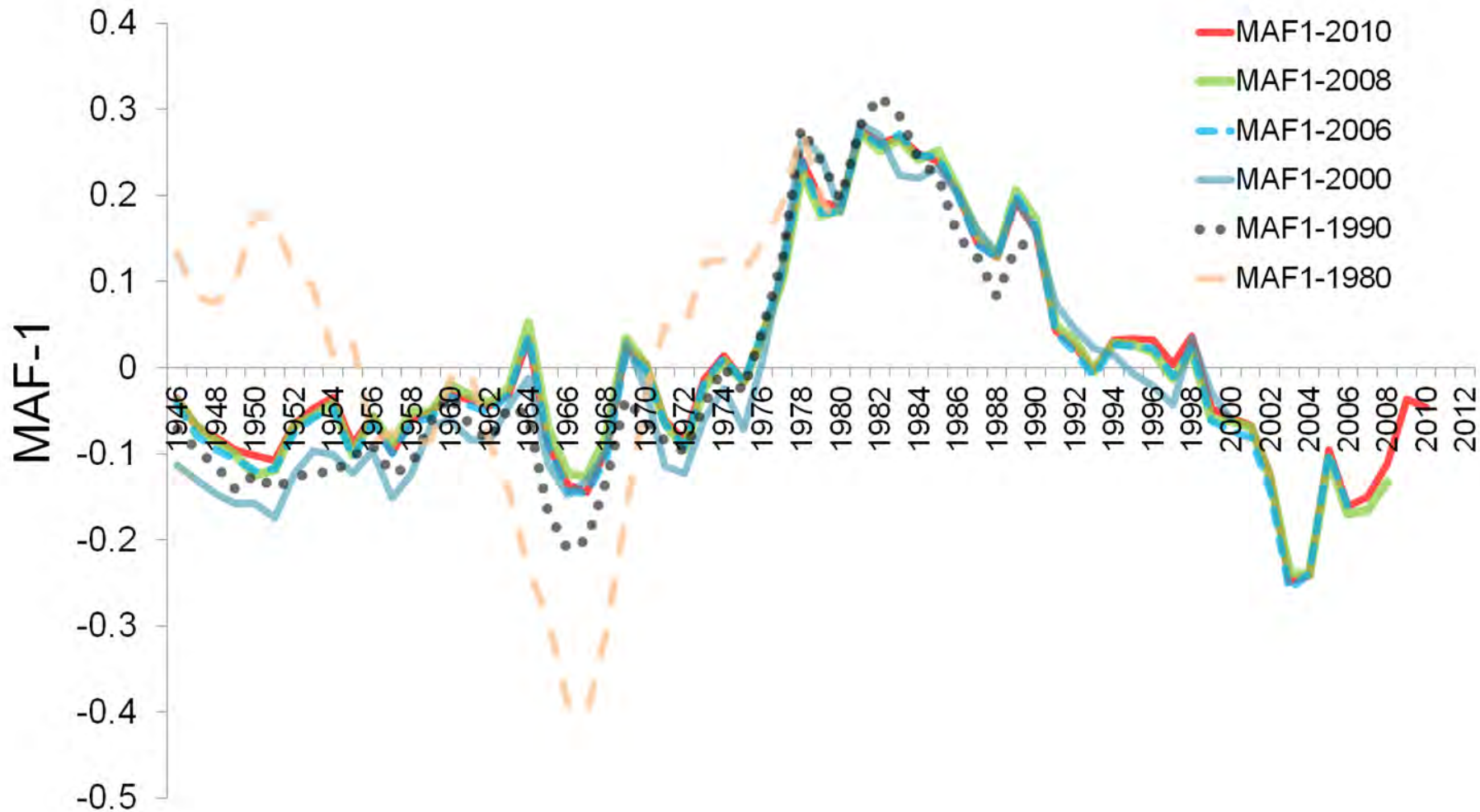










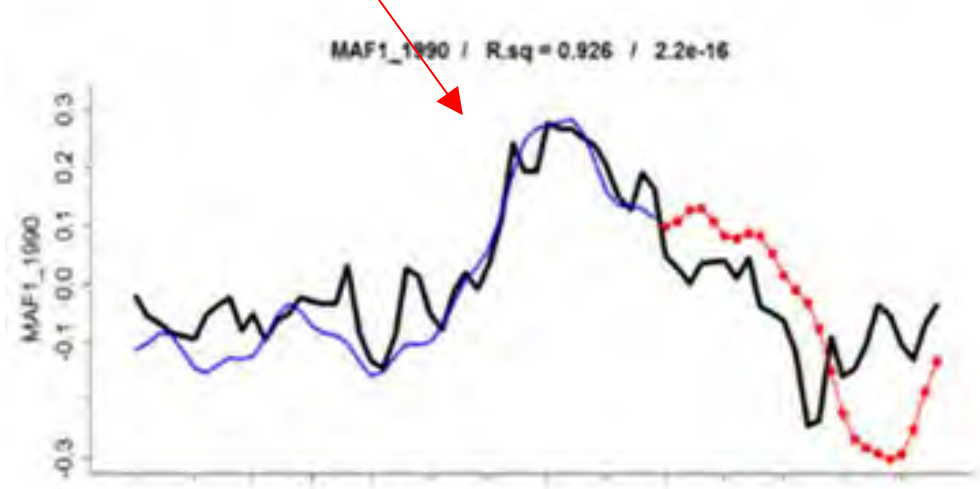
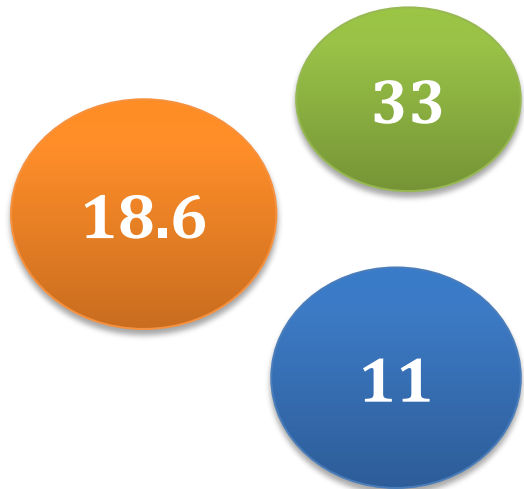
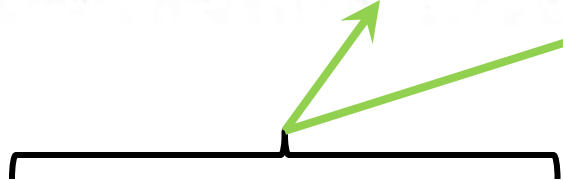


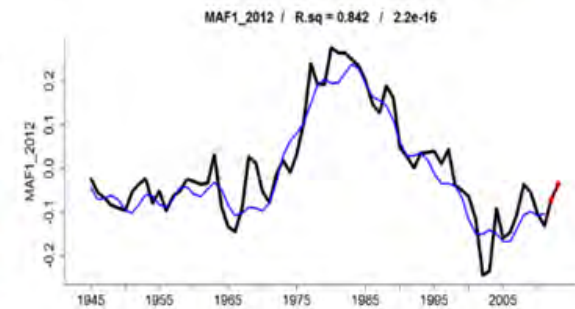
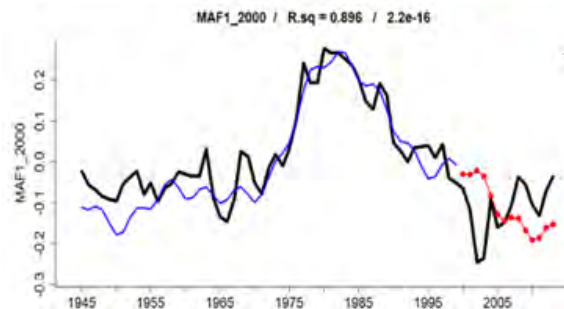
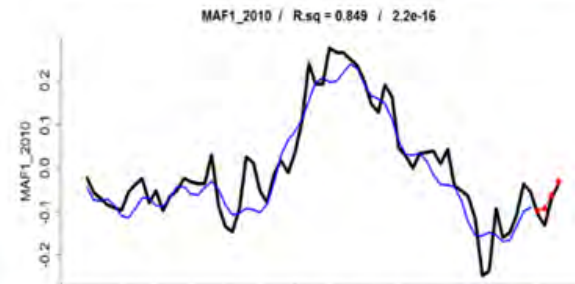
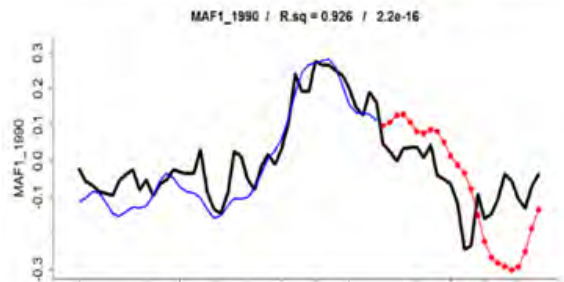
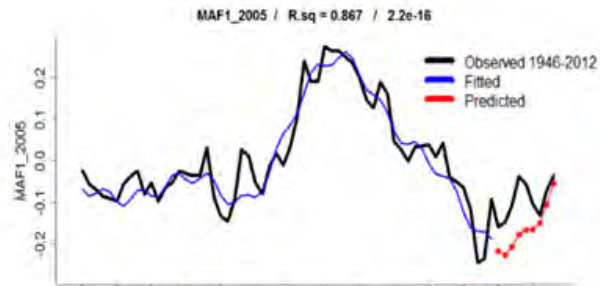
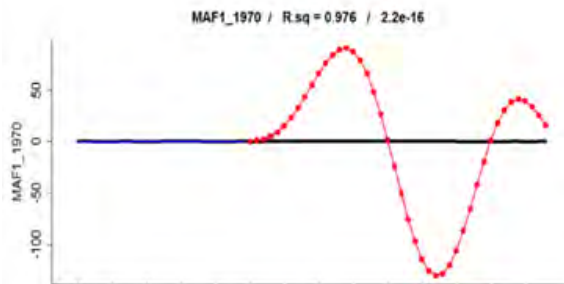
**Selected
periodicities**

Vs

**False (random)
signals**

$$Y_t = a_0 + a_1 \cdot \cos(\omega t) + b_1 \cdot \sin(\omega t)$$



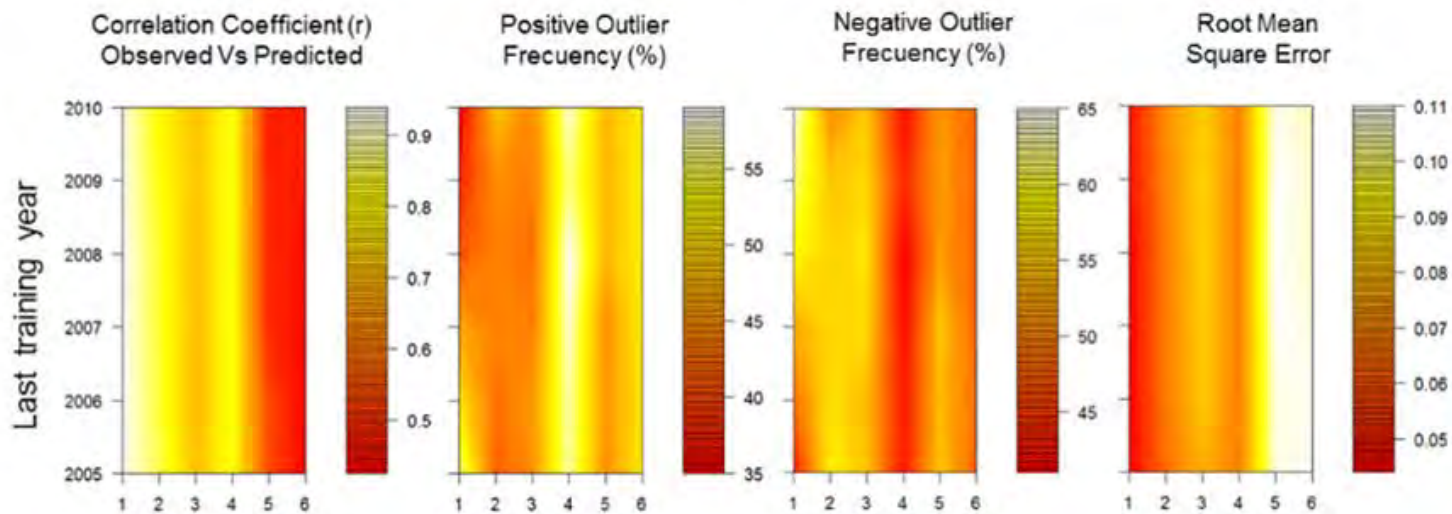


SKILL STATISTIC	EXPLANATION
R	Correlation coefficient: Observed vs. predicted
Positive Outlier Frequency (%)	Fraction (percentage) of errors greater than \bar{X}
Negative Outlier Frequency (%)	Fraction (percentage) of errors less than \bar{X} .
Root Mean Square Error	$RMSE = \sqrt{\frac{1}{N} \sum_{t=1}^N e_i^2}$

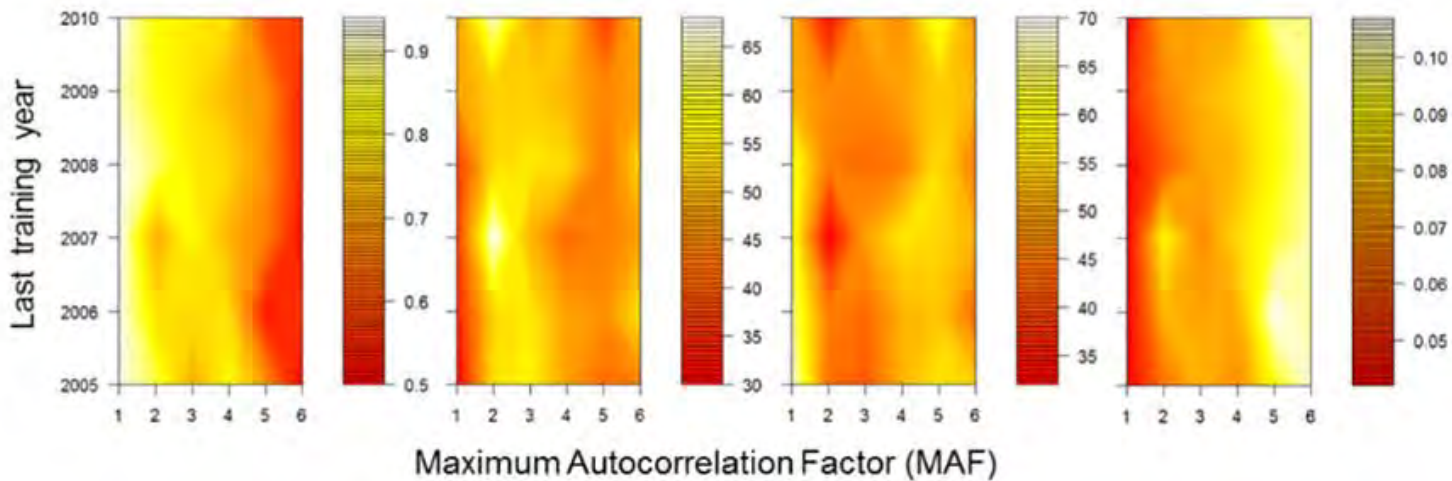
**Selected
periodicities**
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**False (random)
signals**

Zhang A, Hess KW, Wei E, Myers E.
 Implementation of **model skill assessment**
 software for water level and current in tidal
 regions. US Department of Commerce, NOAA
 Technical Report NOS CS 24. 2006.

Selected Low-frequency signals



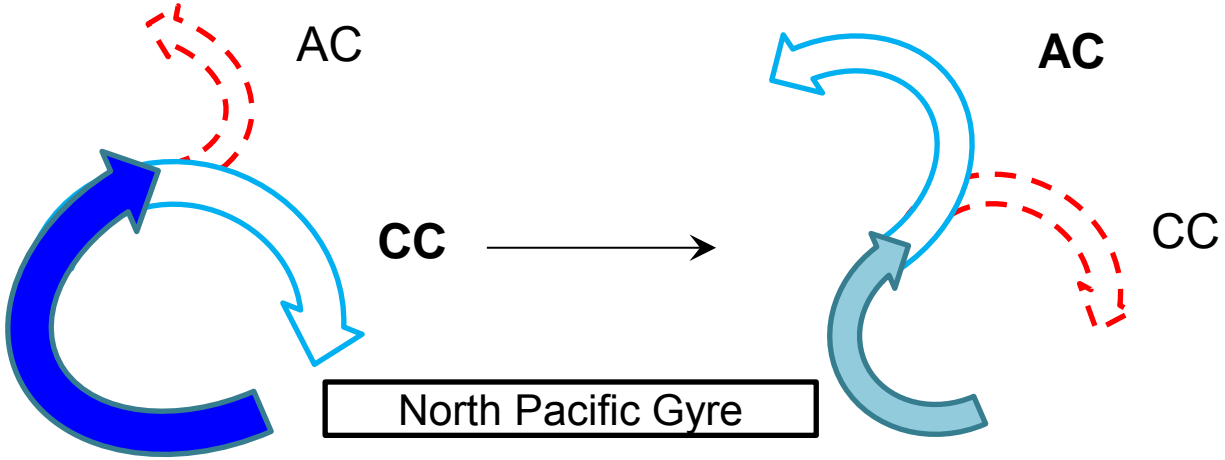
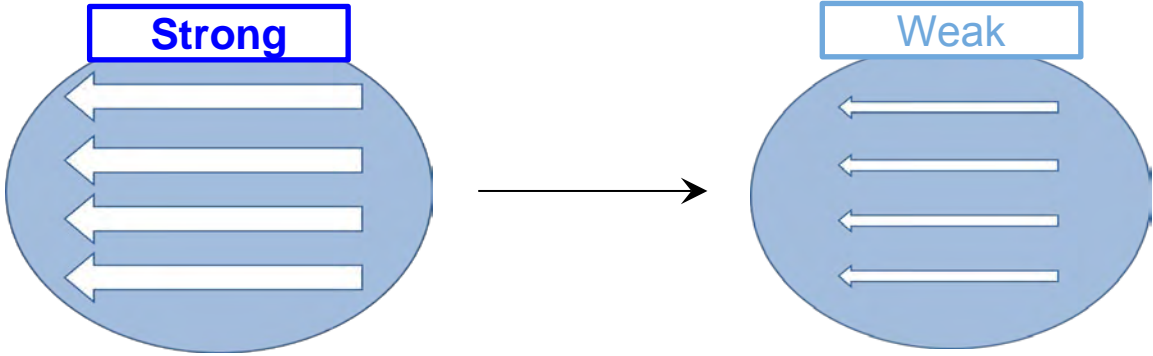
Random (false) signals



How can we explain the presence
of this cycles?

30
years

Atmospheric Circulation



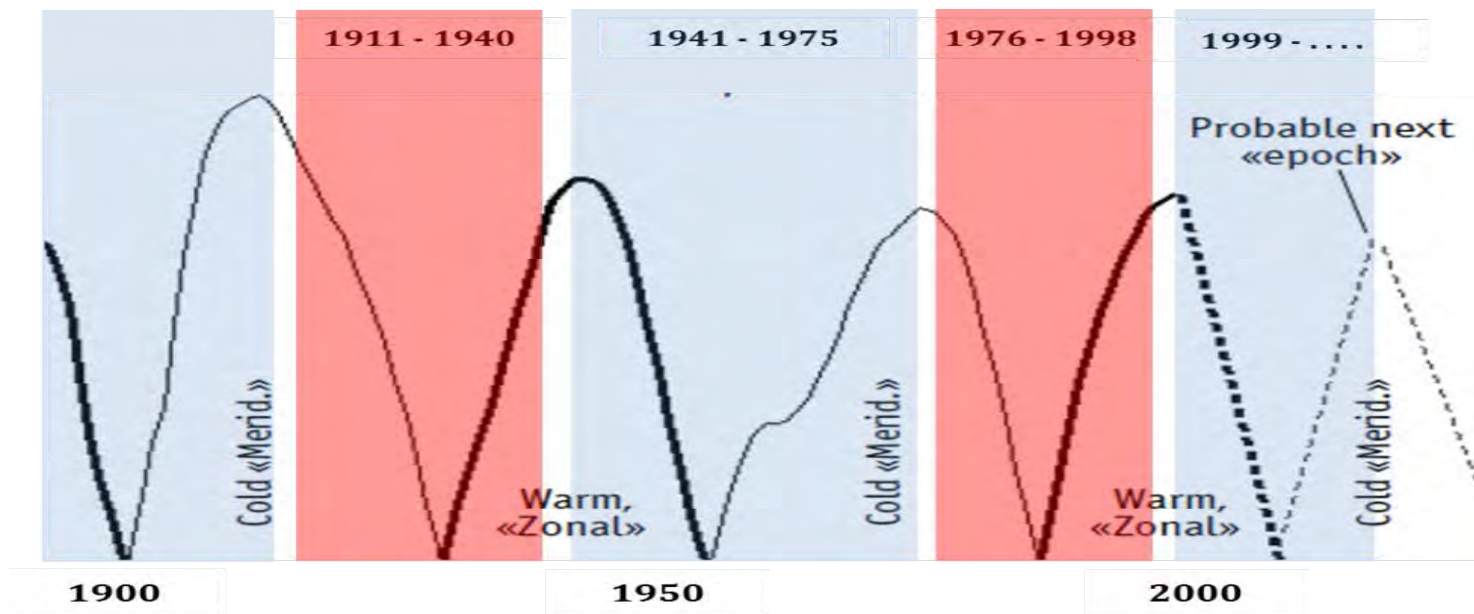
Di Lorenzo *et al.*, 2008; Cummings and Freeland, 2007; Beamish *et al.*, 1999; King *et al.*, 1998; Ware 1995;

30

years

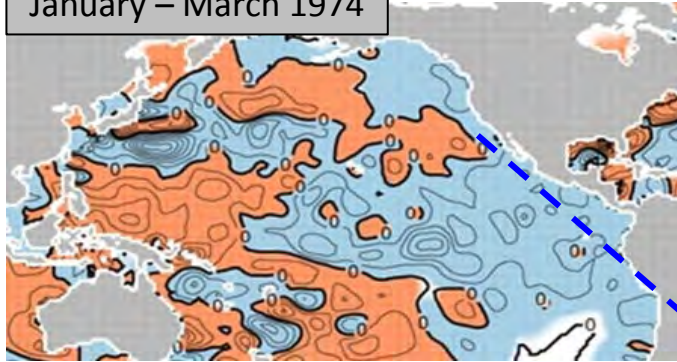
High atmosphere → Wind surface

- Transitions of Meridional to Zonal winds dominance



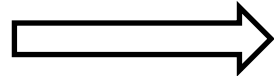
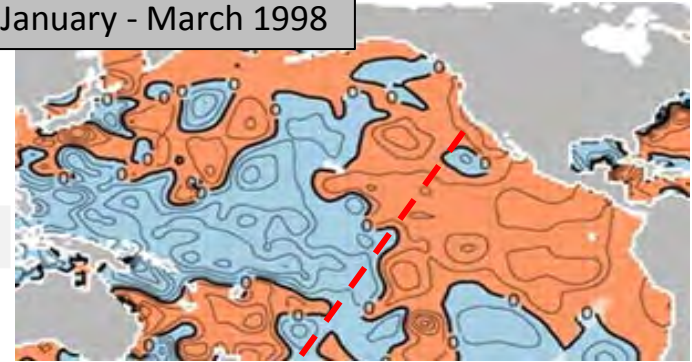
Meridional dominance

January – March 1974

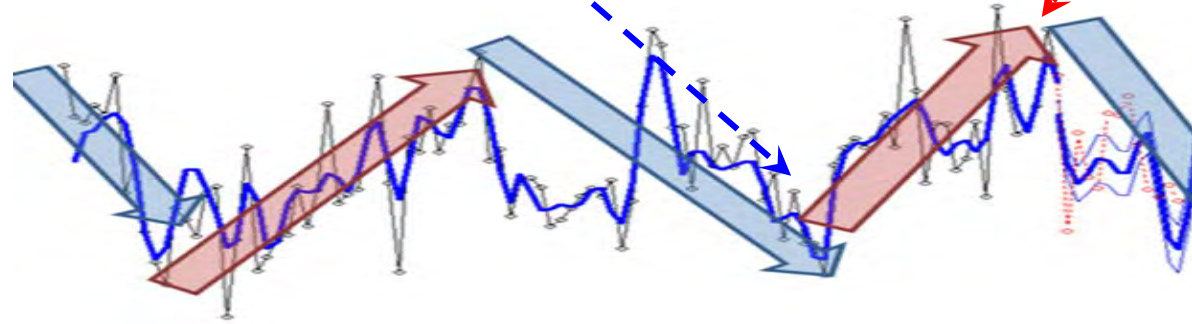


Zonal dominance

January - March 1998



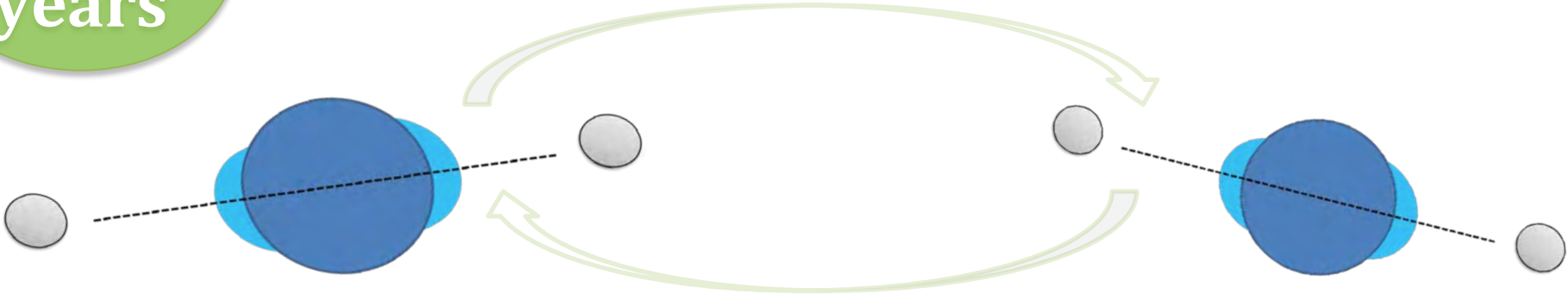
Heat content (0-2000m)



California Current Sea Surface Temperature

18.6
years

Moon Nodal Cycle



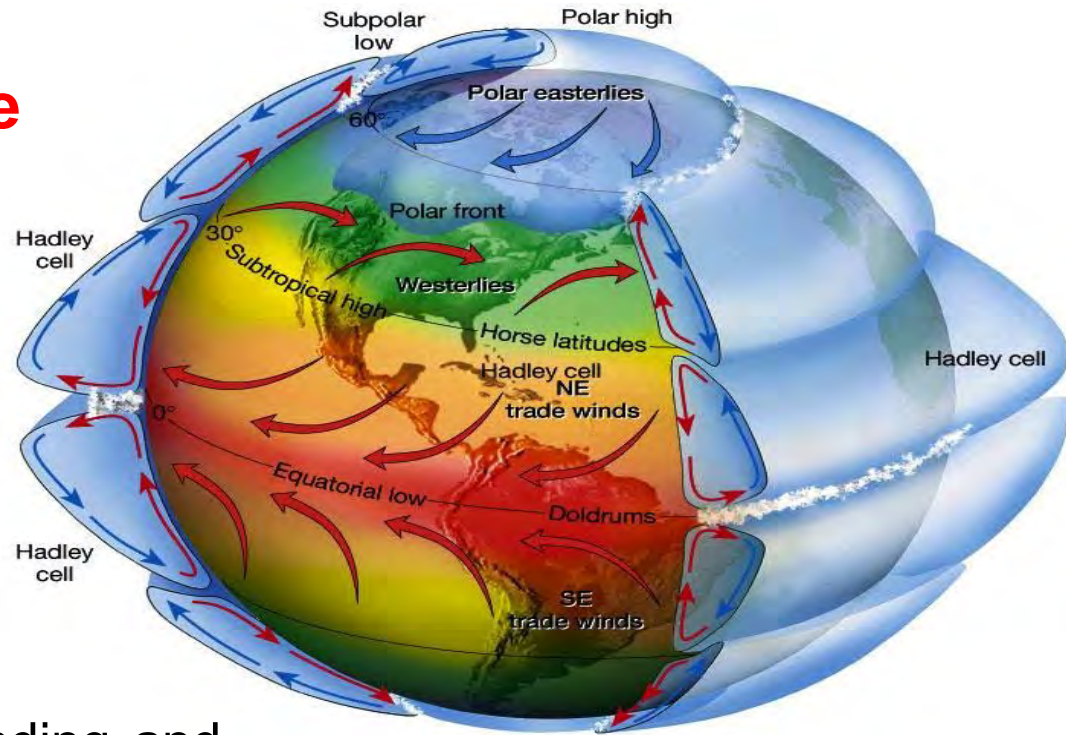
- Displace atmospheric pressure centers
- Increase / reduce atmospheric pressure gradients
- Regional attraction of air and water masses.

Munk y Bills, 2007; Pugh, 1987; Baar *et al.*, 2012; Trenary y Han, 2012.

11
years

Solar Irradiance

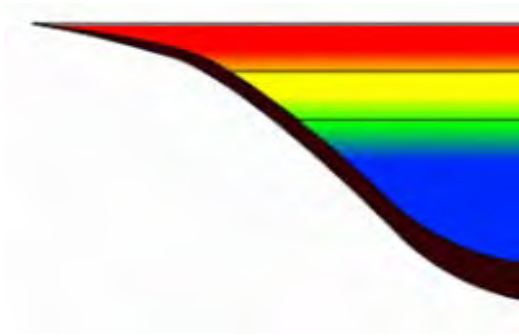
- Pressure centers strengthening / weakening.
- Increase / reduce ascending and descending air fluxes at atmospheric cell boundaries.



11
years



Under an scenario of weak atmospheric circulation (zonal winds dominance)



Water column stratification

Less nutrients availability

Primary Producers (big cells)



PP (small cells)

CONCLUSIONS

1) MAFs (low-frequency signals) are composed by **similar periodic signals**.

CONCLUSIONS

2) The relative importance of each detected MAF was variable, according to the geographic location, **reflecting interactions of (underlying-common) large-scale to local climate conditions.**

CONCLUSIONS

3) The Ekman transport studied through the Upwelling index for the geographical domain 21 – 60°N, contains low-frequency signals that vary in proximity to changes in **long-term dominant winds, the lunar nodal cycle and solar irradiance.**

. . . These natural phenomena are known to **influence upwelling/downwelling at shorter time scales**, for example: the predominance and intensity of zonal/meridional winds in the scale of days to weeks, and the lunar phase cycle that modulates water and air masses distribution in a daily and weekly basis (tides).

... what is coming?

What are the upwelling-downwelling MAFs relationships with physics of coastal and pelagic habitats ???

e.g. vertical velocities, eddies, eddy kinetic energy, offshore advection ...

Macro-scale patterns in upwelling/downwelling activity at North American west coast

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¡Thank you!

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