Institut de Recherche pour le Développement FRANCE
French National Research Institute for Sustainable Development

Recent trends in the Peruvian Coastal Upwelling Ecosystem and implications for the anchovy habitat

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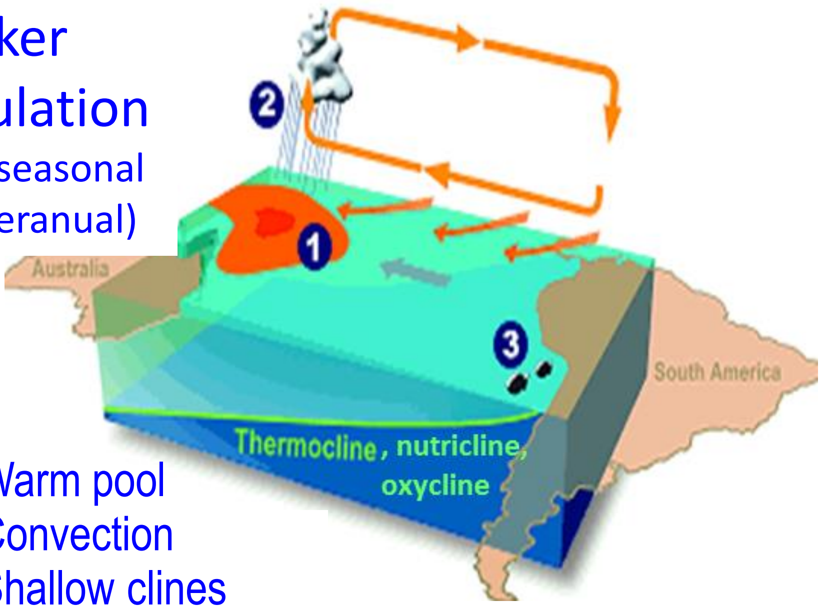
6-11 March 2017
Victoria, BC, Canada

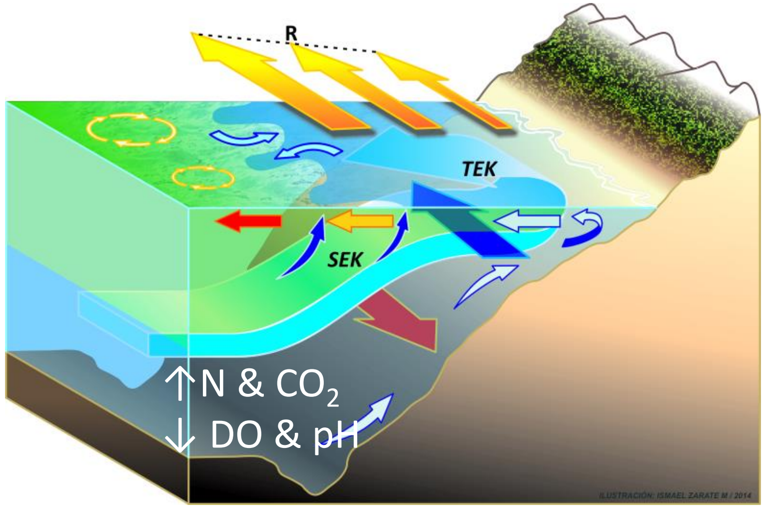
Large scale and regional forcing of the PCUE

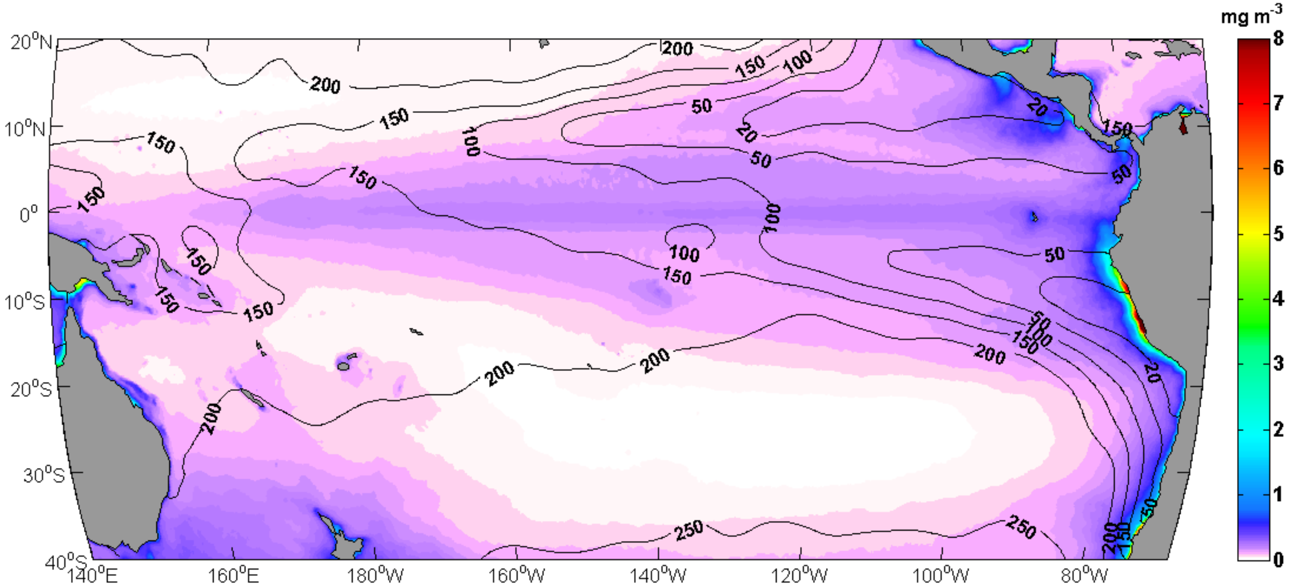
Walker circulation
(intraseasonal to interanual)



(1) Warm pool
(2) Convection
(3) Shallow clines

coastal winds and upwelling

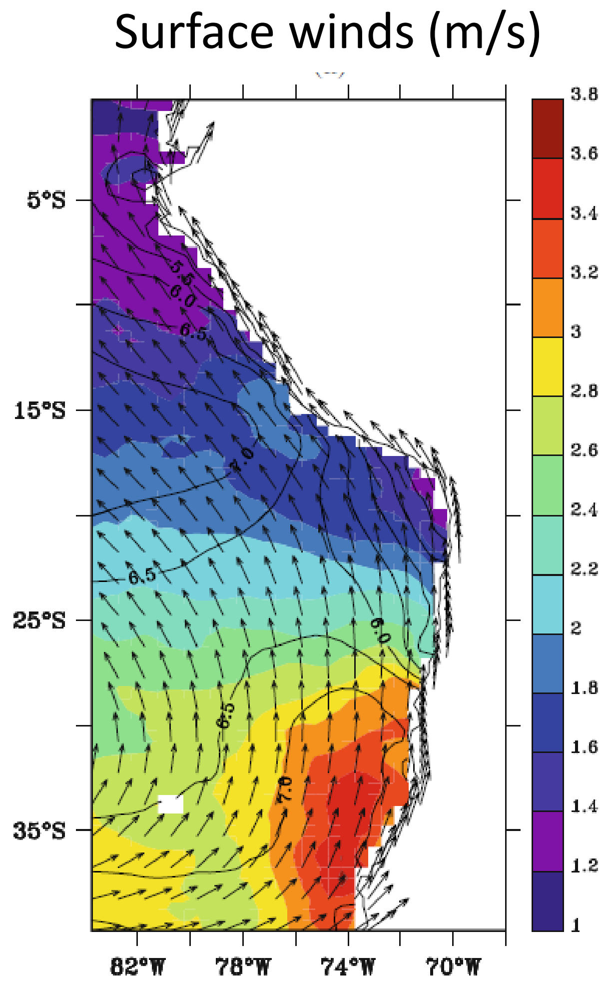




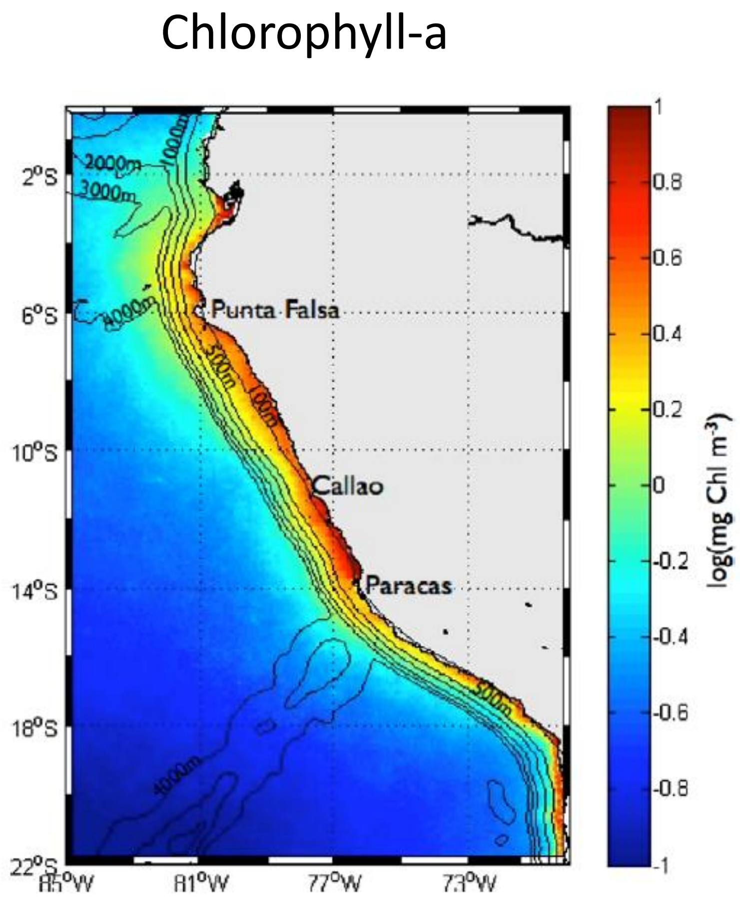
Colors:
Chlorophyll-a

Lines:
Oxygen content (micromoles per L) at 100 m depth

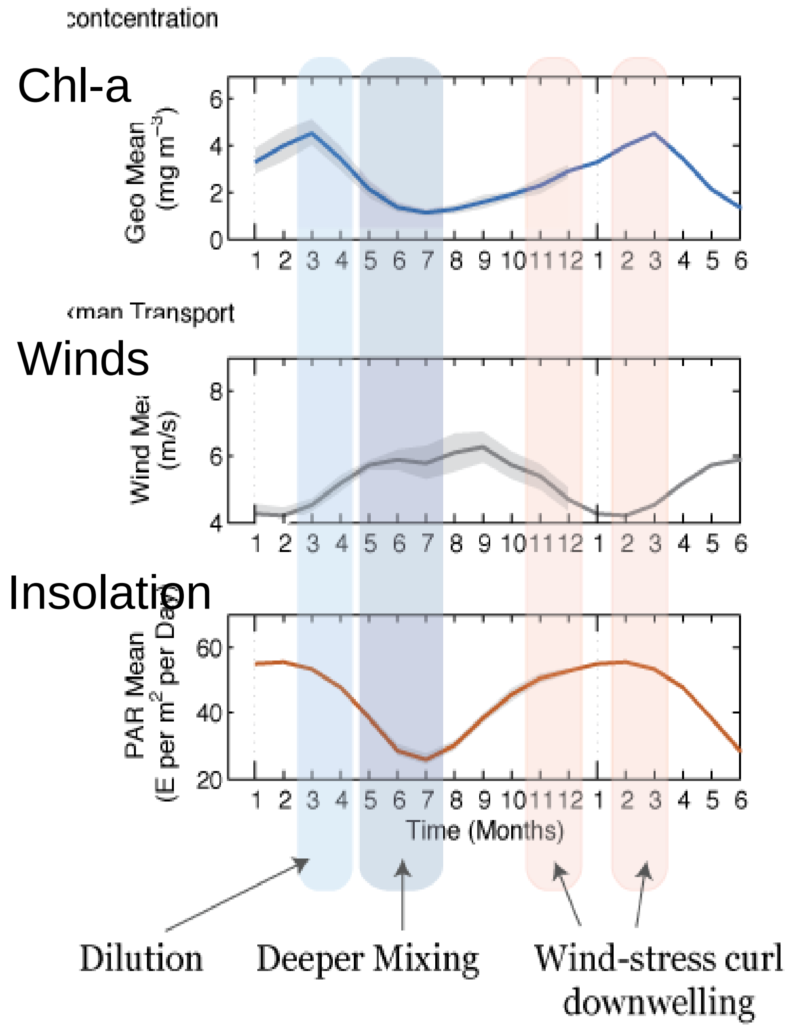
Winds, productivity and insolation in the PCUE



Goubanova et al, 2010



Brochier et al, 2008

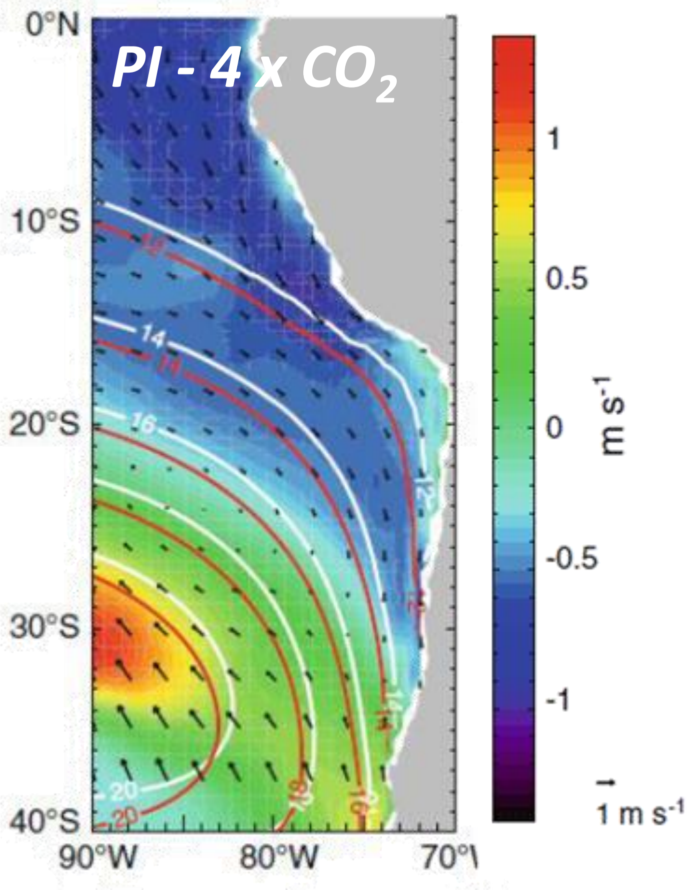


F. Chavez

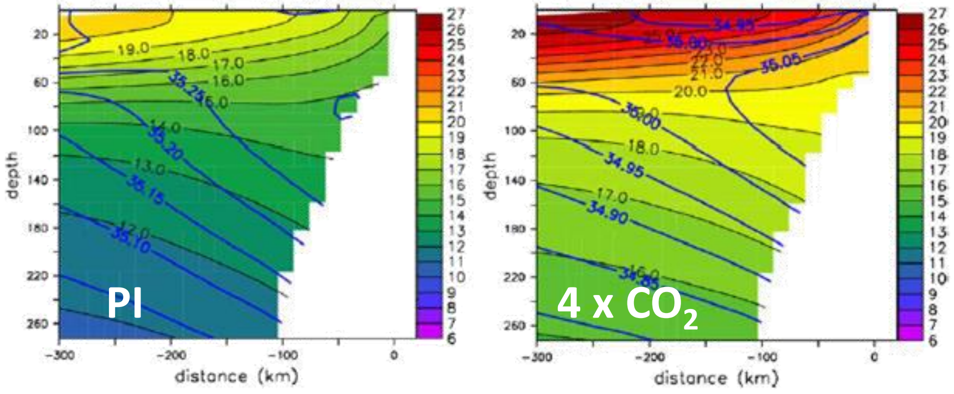
- ➢ 180° gap between anual cycles of PP and upwelling intensity. Stronger winds in winter/ spring deepen de mixing layer and enhance osffshore advection of coastal waters.

First-generation regional models predict a decrease of PP and anchovy recruitment under climate change scenarios

A

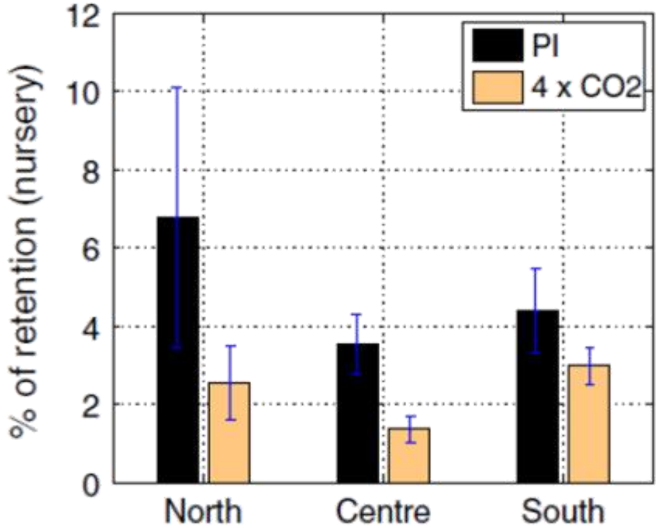


B



Models not consistent with 'Bakun's hypothesis'

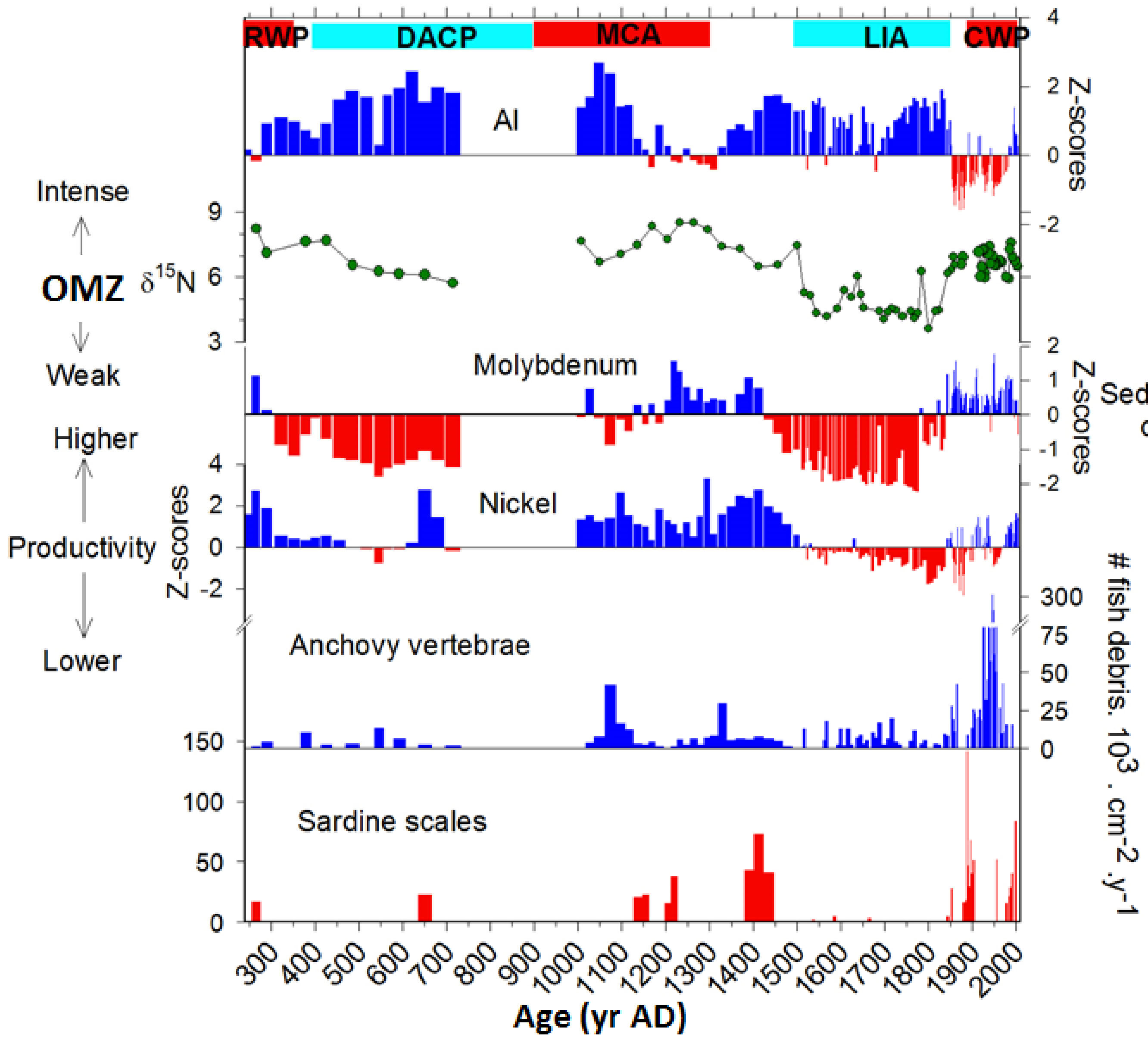
C

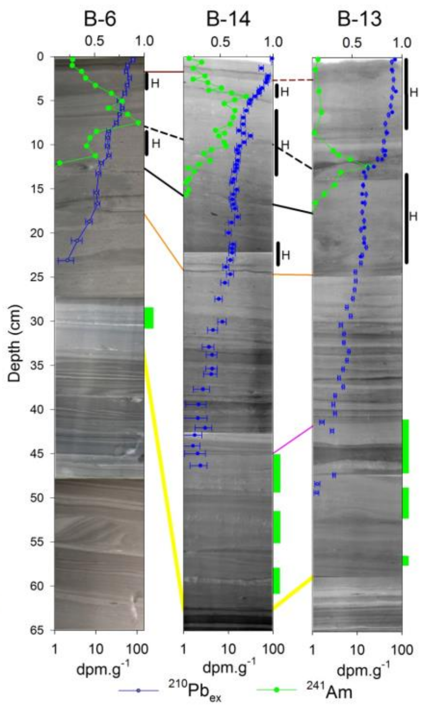


A- Differences in surface wind intensity between the 4xCO2 and PI scenarios during summer according to the global climate model LMDz (Bel Madani et al., 2013). **B-** Cross-shore vertical structure of temperature and salinity, respectively, at 10°S (Echevin et al, 2012). **C-** Anchovy larvae retention rates (% of individuals) in nursery areas, in the 'Northern' (4-16°S), 'Central' (16-24°S), and 'Southern' (24-40°S) areas (Brochier et al., 2013).

Paleo-evidence of ecosystem and anchovy flucuations

Increased export production and local biomass of anchovy during global warm periods have been inferred from Peruvian sediment records

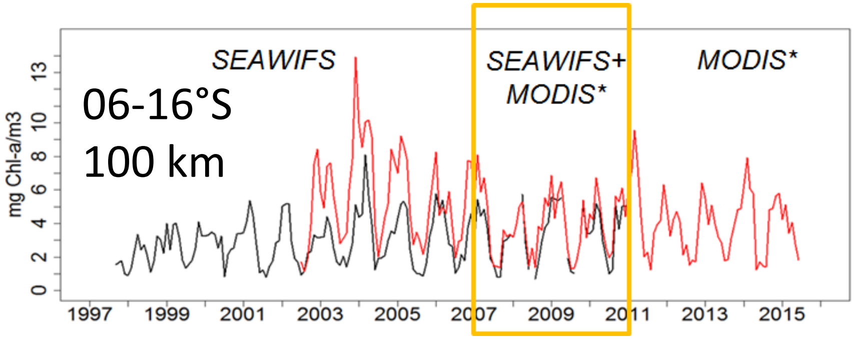


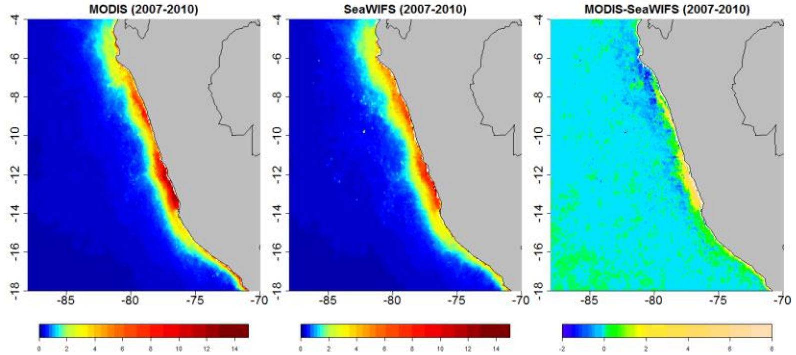


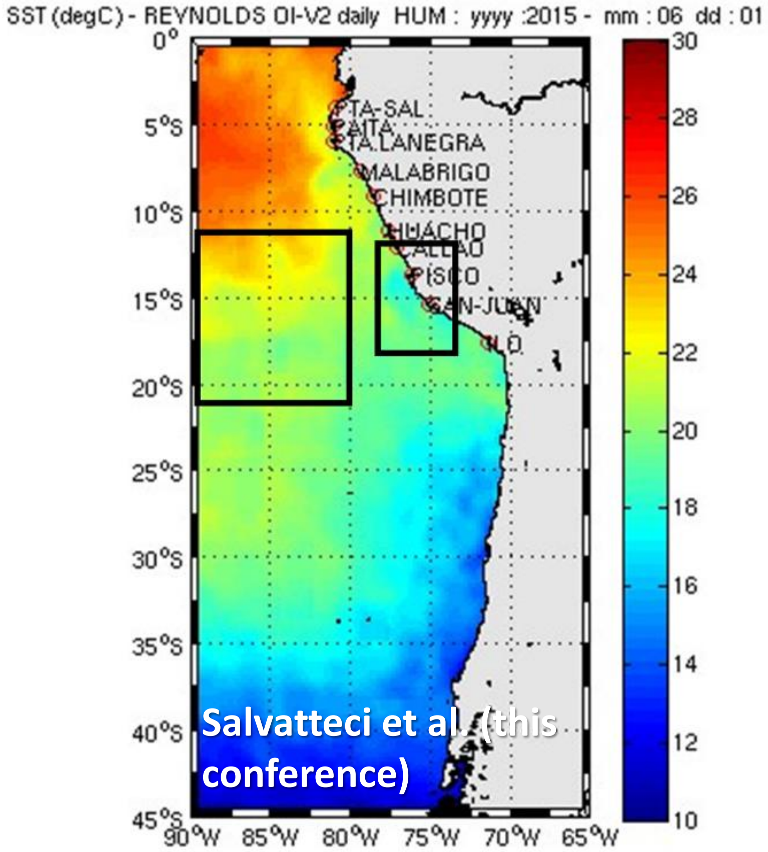
Salvatteci, 2013

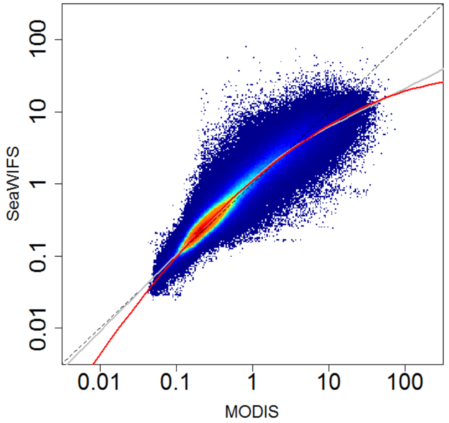
Data

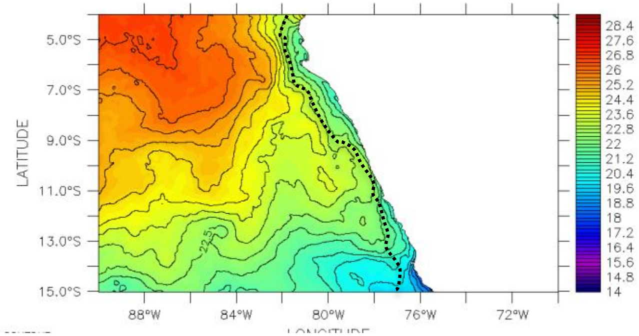
- Shipboard oceanographic parameters and piers' SST records from IMARPE and other since the 1960s.
- Reynolds SST database (1984 to 2014), 0.5° resolution.
- Multiscale UltraHigh Resolution MUR SST analysis (https://podaac.jpl.nasa.gov) (2003 to 2016), 4-km res, for developing cross-shore thermal front /gradient calculations
- SLA records (AVISO) at 95°W in the Equator and along the Peruvian coast (1994 – 2016), 0.25° res.
- SEAWIFS and MODIS surface chlorophyll-a concentrations, computed at 4-km res. A blended time-series was developed (1997 – 2014), by adjusting from the overlap period between both series
- Also, a Quickscat + Ascat blended record was developed for coastal winds



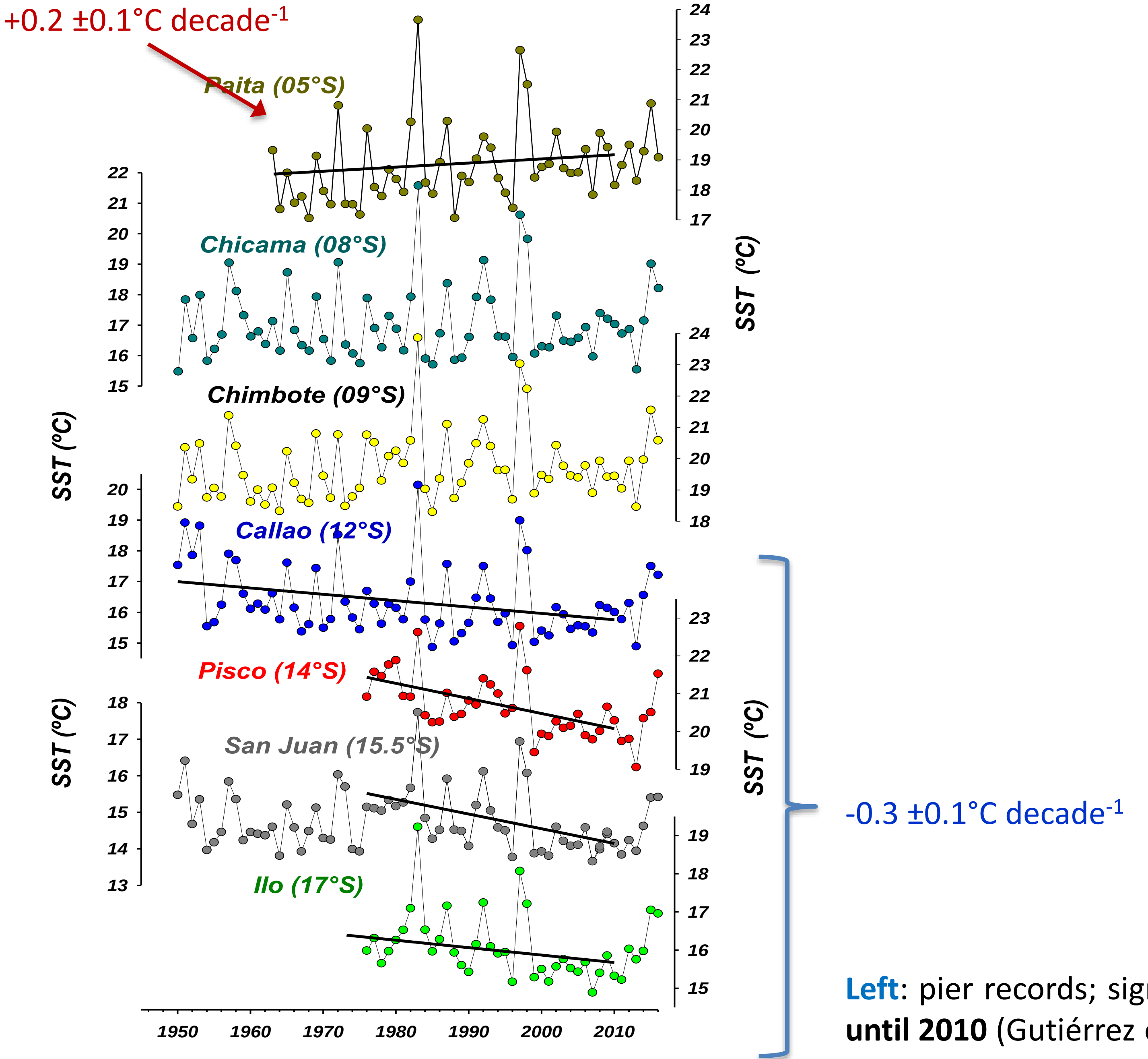




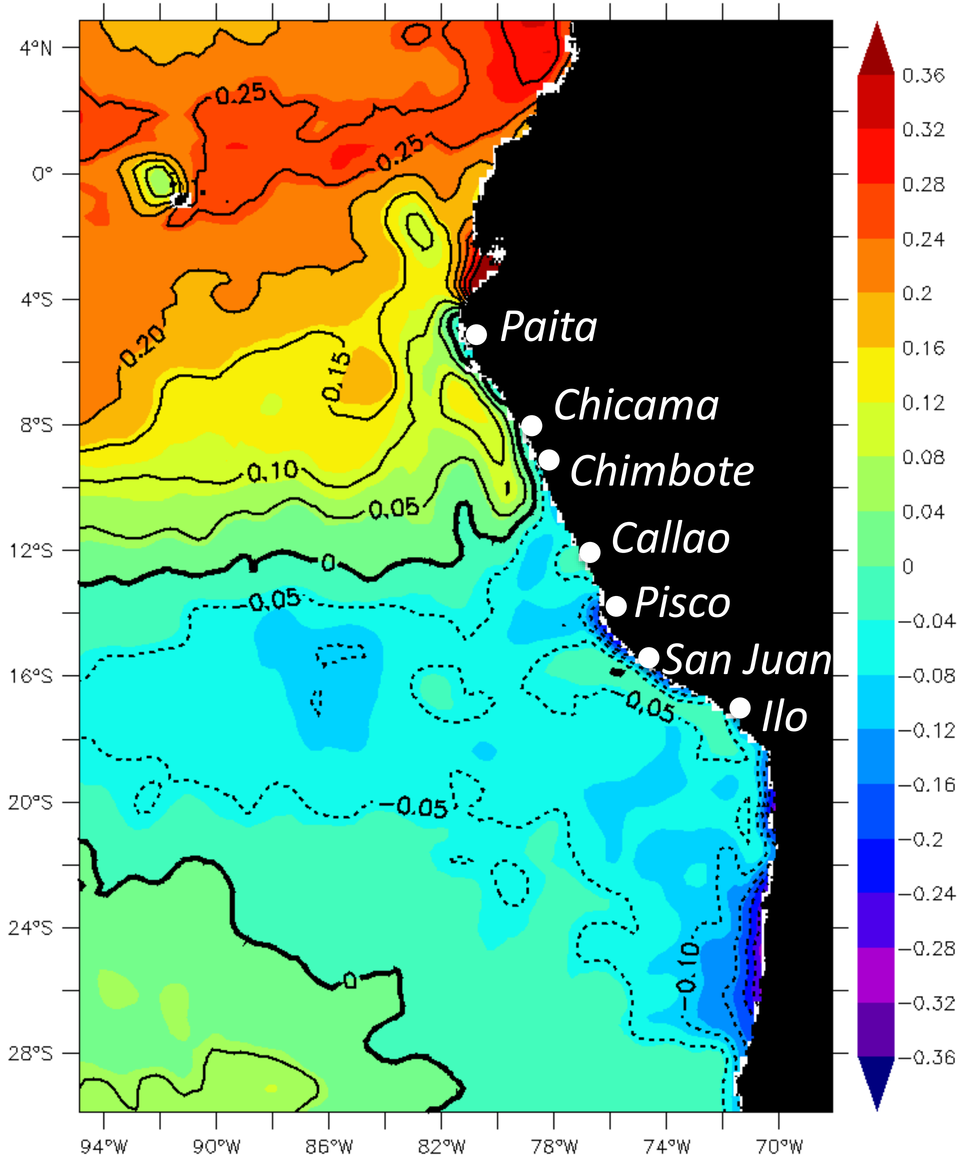




SST trends (pier records and Reynolds)



SST trends (°C decade-1) on the Reynolds database (1984 – 2016)

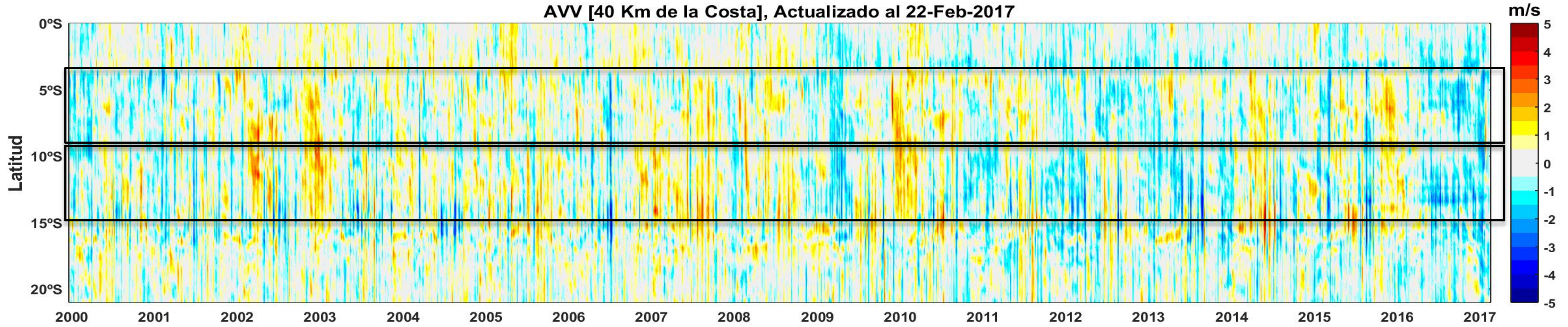


Left: pier records; significant linear fits are over-imposed on the respective periods **until 2010** (Gutiérrez et al., 2011), warming after 2010, specially in the south.

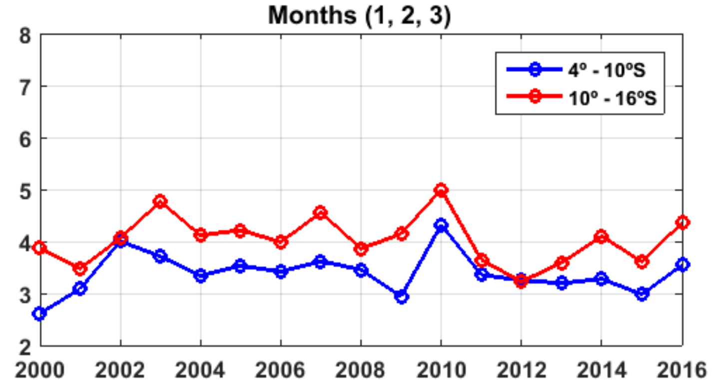
Results – Pier SST trends and p-values (2010 – 2016)

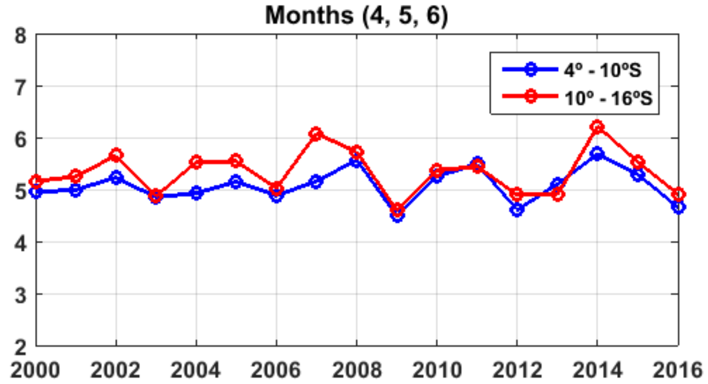
Location	All	123 (s)	456 (f)	789 (w)	10-12(sp)
Paita	ns	(-) <0.05	(-) <0.05	(+) <0.01	(+) <0.01
Chicama	(+) <0.05	ns	ns	(+) <0.05	(+) <0.01
Chimbote	(+) ns	ns	ns	(+) <0.01	(+) <0.01
Callao	(+) <0.05	ns	ns	(+) ns	(+) <0.01
Pisco	ns	(-) <0.05	ns	(+) <0.01	(+) <0.01
San Juan	(+) <0.05	ns	ns	(+) <0.01	(+) <0.01
Ilo	(+) <0.05	ns	ns	(+) <0.01	(+) <0.01

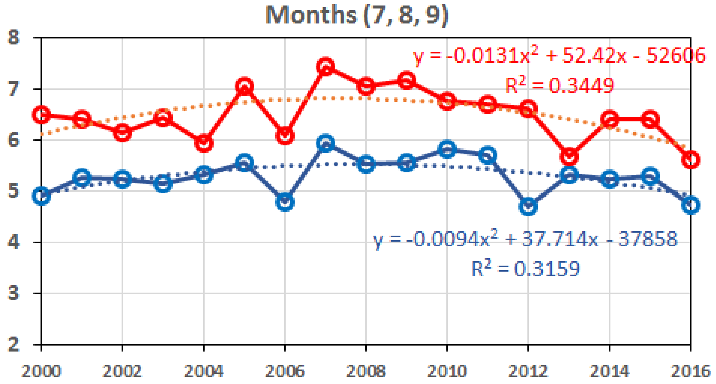
Coastal winds (0 – 40 km; Quickscat+Ascat)

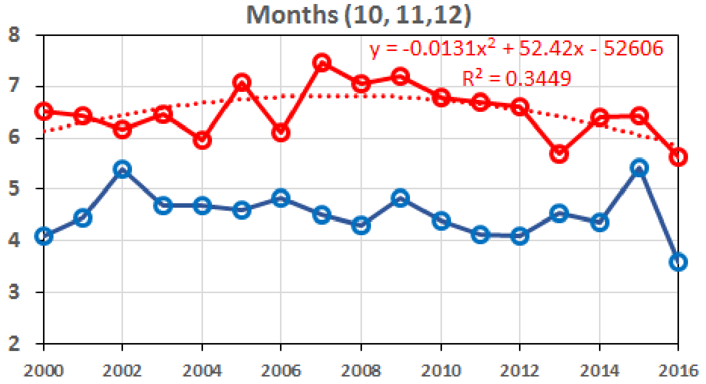


- No significant changes in **summer** or **fall** for both the Northern Region and the Central Region
- For the Central Region, a declining trend since 2007/2008 for **winter and spring**.
- For the Northern Region, a declining trend since 2007/2008 **for winter**.

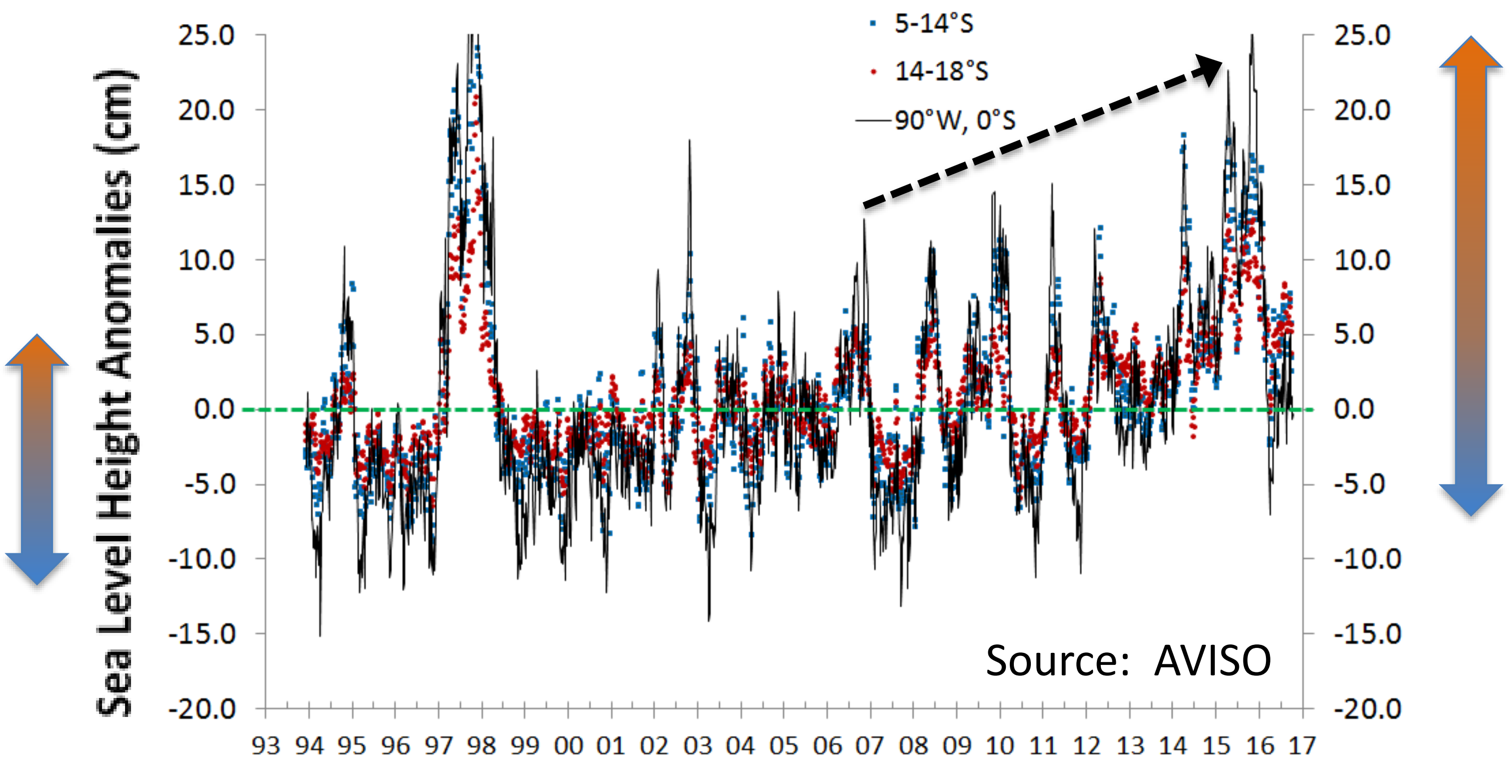




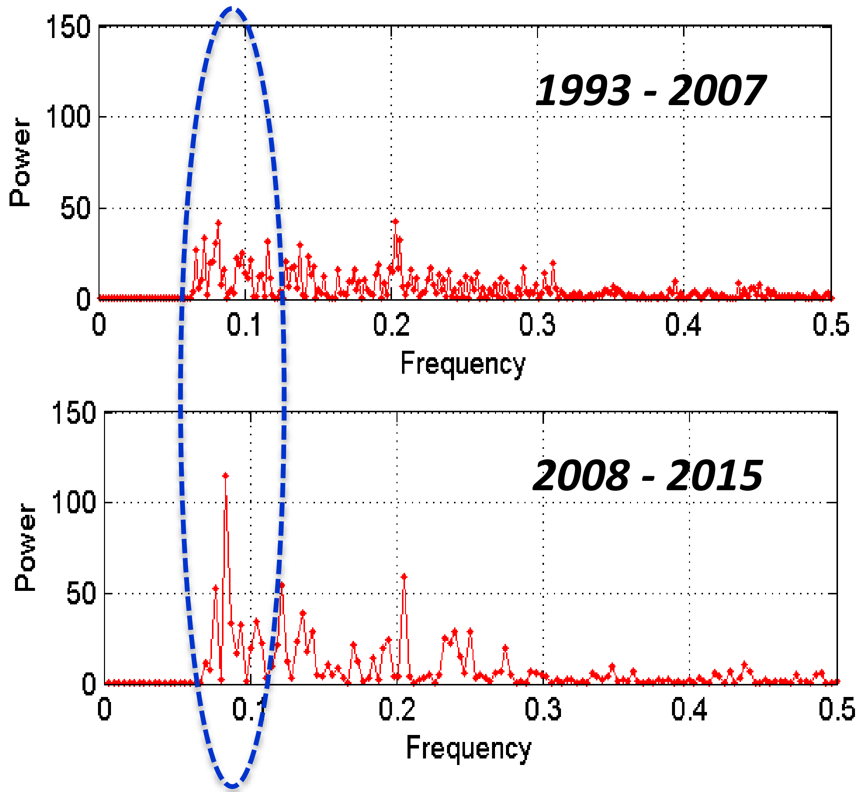




SLA records (Galapagos, NC Peru and SPeru)

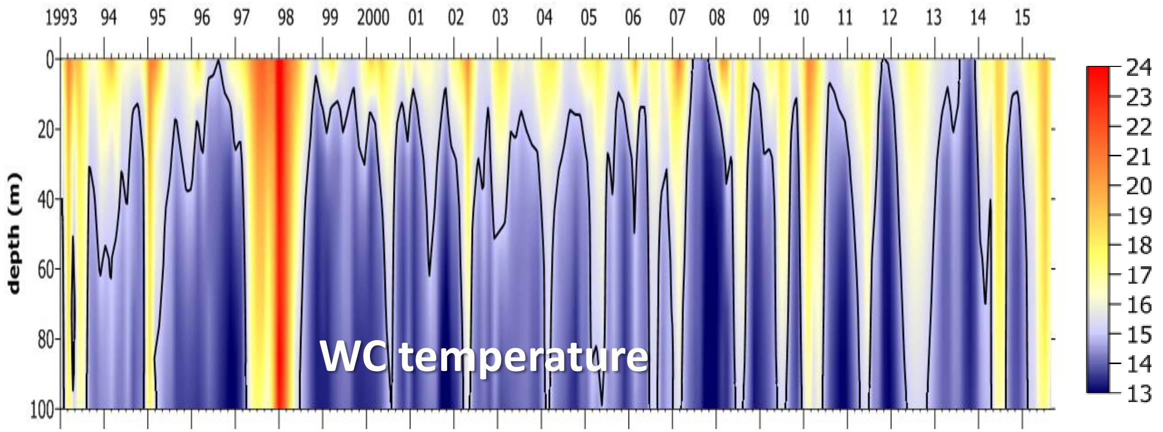


Talara (04°30'S)



Spectral power on filtered (>150 d) time series

Callao (12°S)

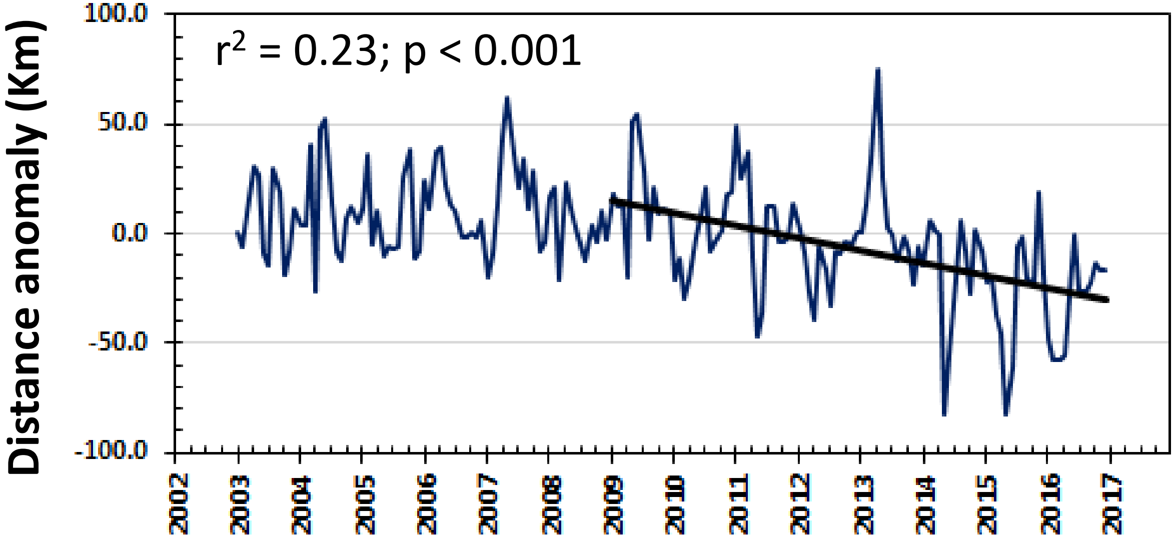


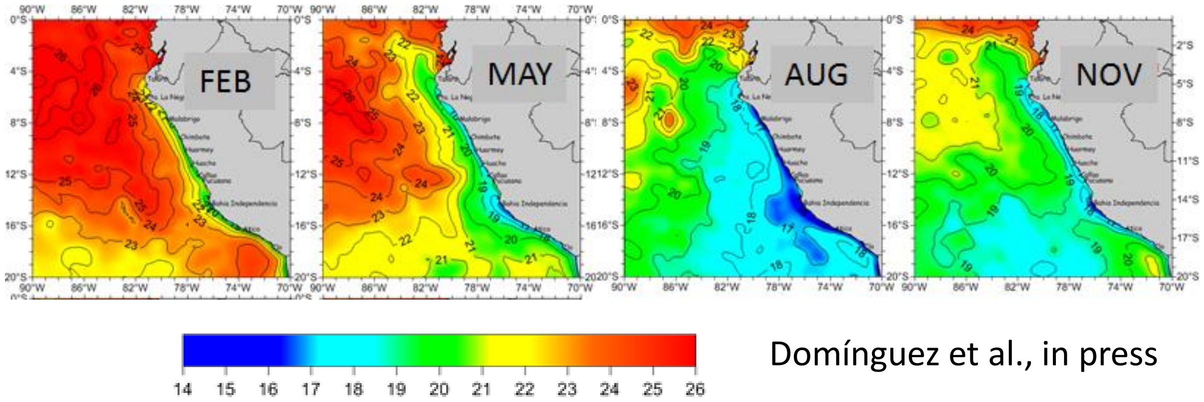
Since ca. 2008:

- positive trend of SLA in Galapagos and off Peru
- More frequent SLA peaks by fall
- stronger intra-seasonal signal at the 100 -150 d band
- stronger variability of vertical thermal structure off Peru

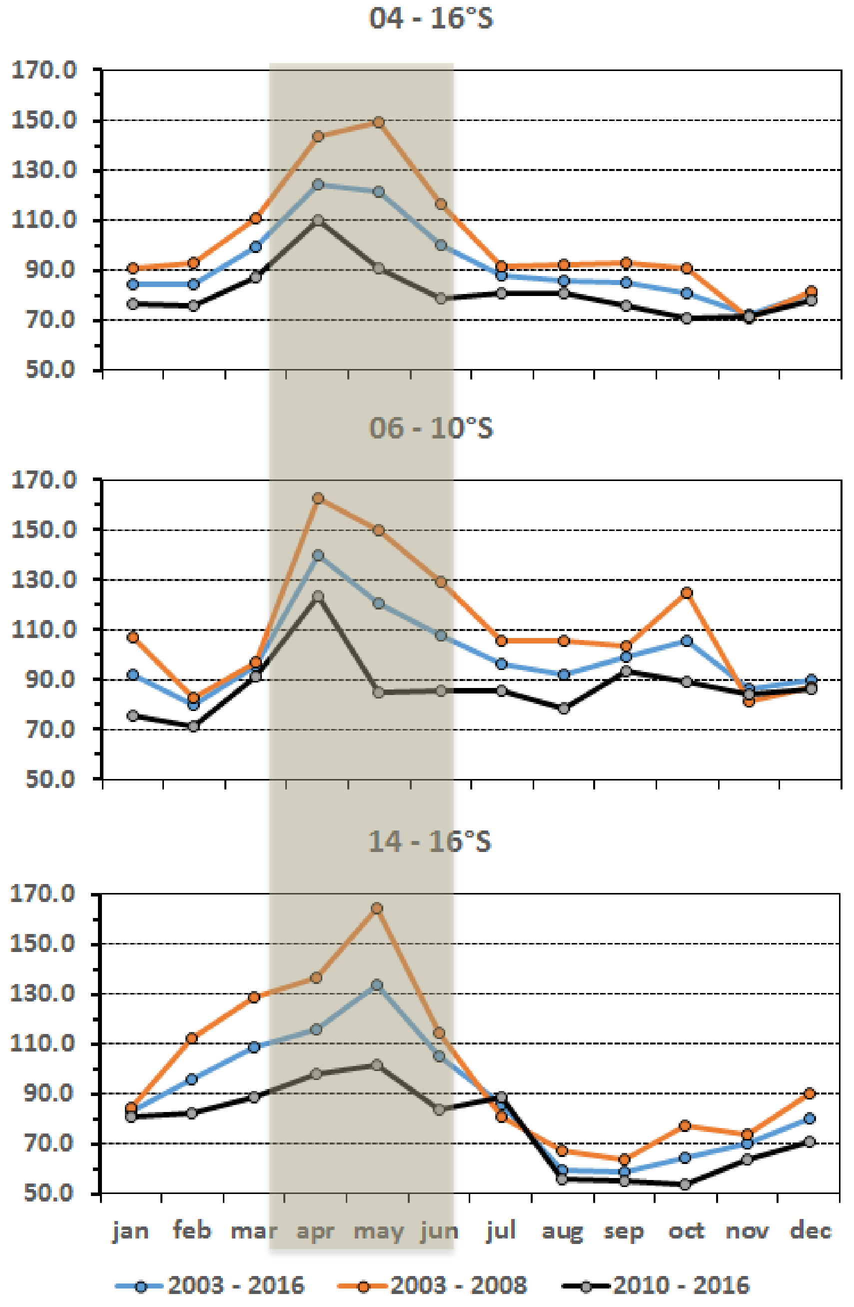
Distance of the cross-shore SST gradient

After ca.2008 there is a negative trend in the distance of the SST front (05 – 14°S). Negative trends stand for almost all regions and all seasons

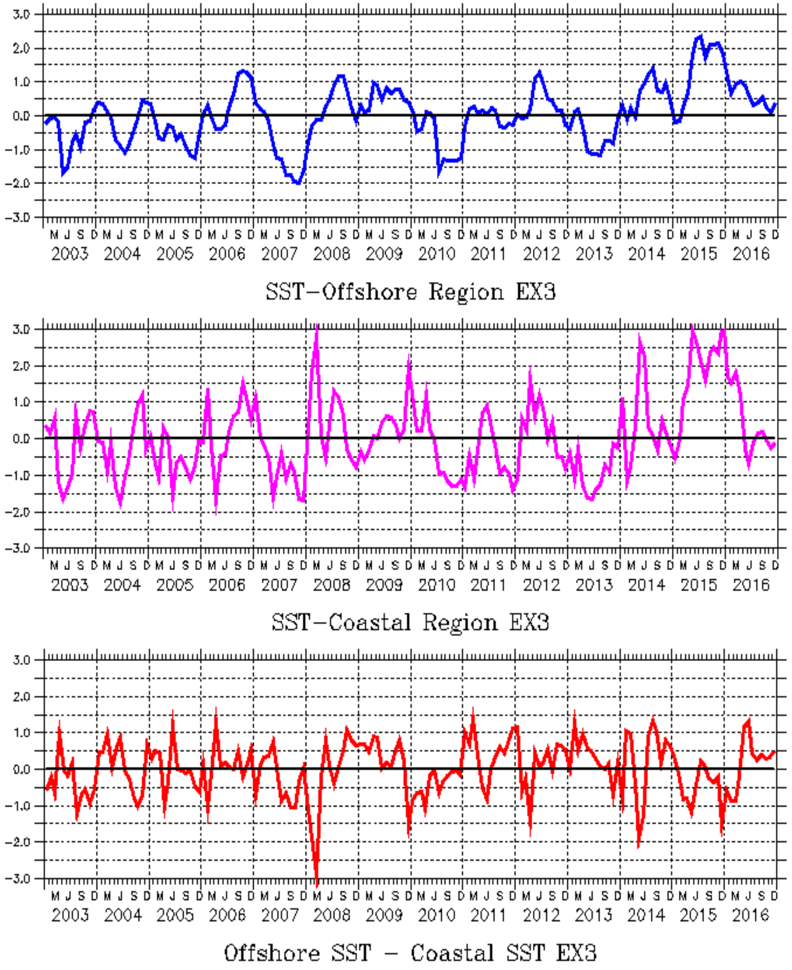


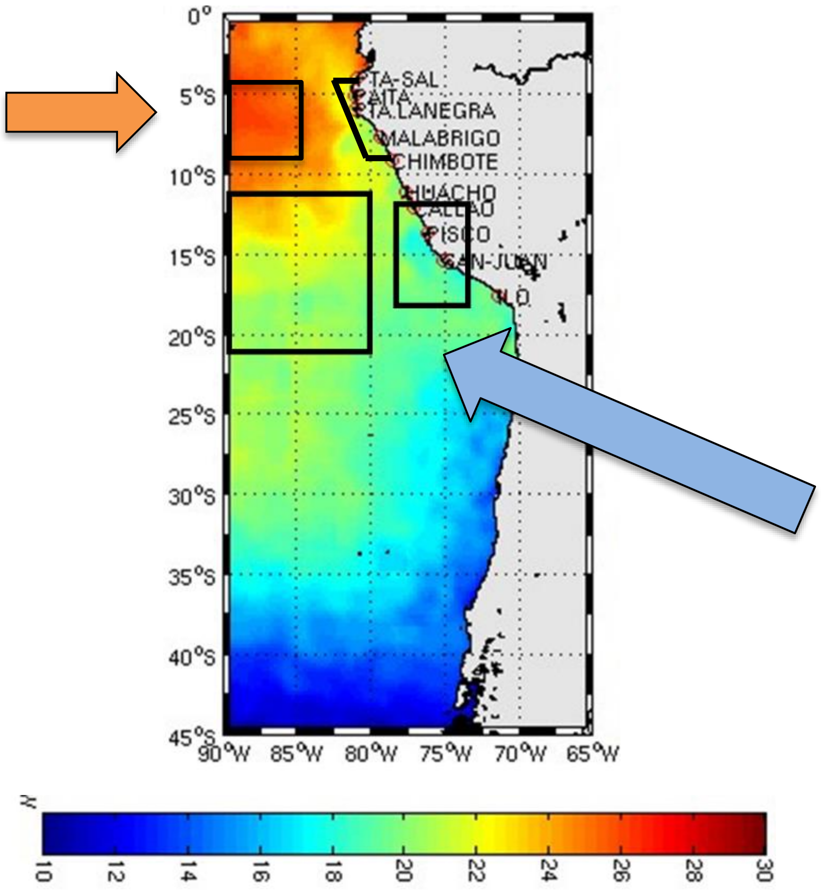


Domínguez et al., in press

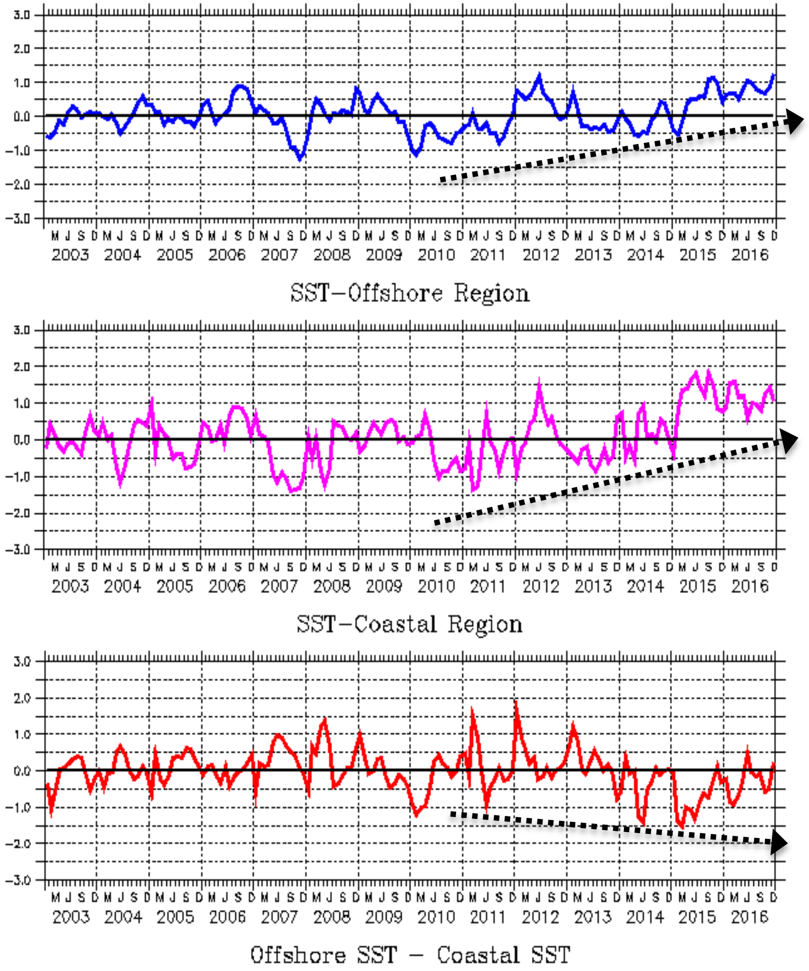


Cross-shore SST gradient intensity





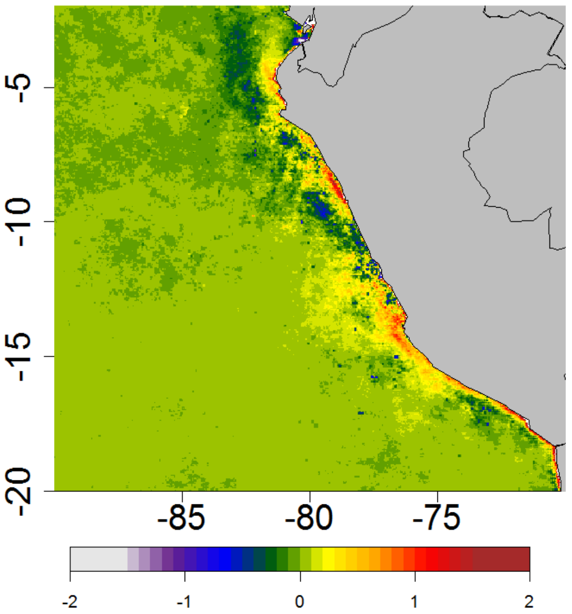
Slight decrease (mainly in autumn) of the SST gradient across CS Peru in recent years



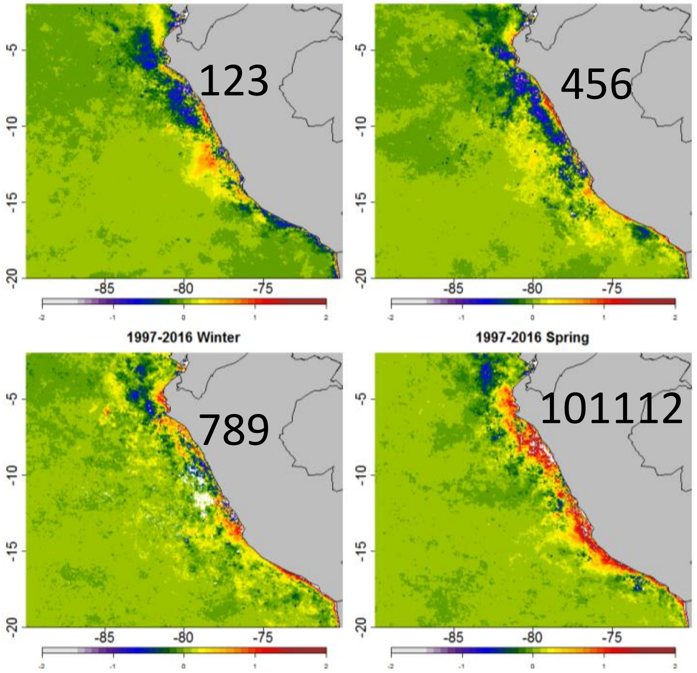
SST gradient variability is greatly affected by El Niño in the Northern region

Surface Chl-a trends (1997 – 2016, mg m^{-3} $decade^{-1}$)

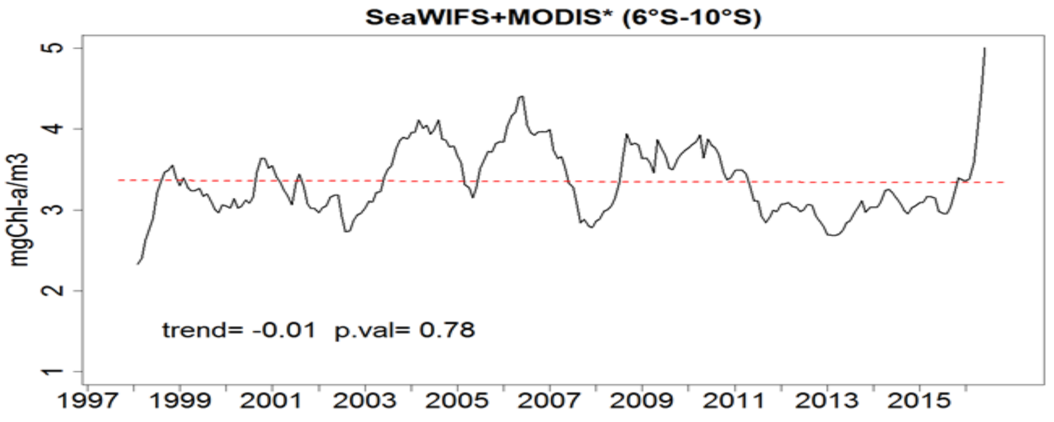
All data

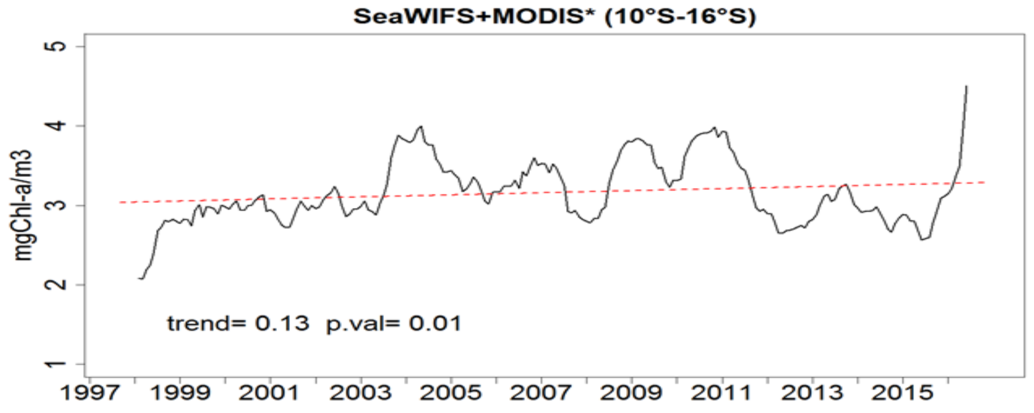


by season
(123=summer)

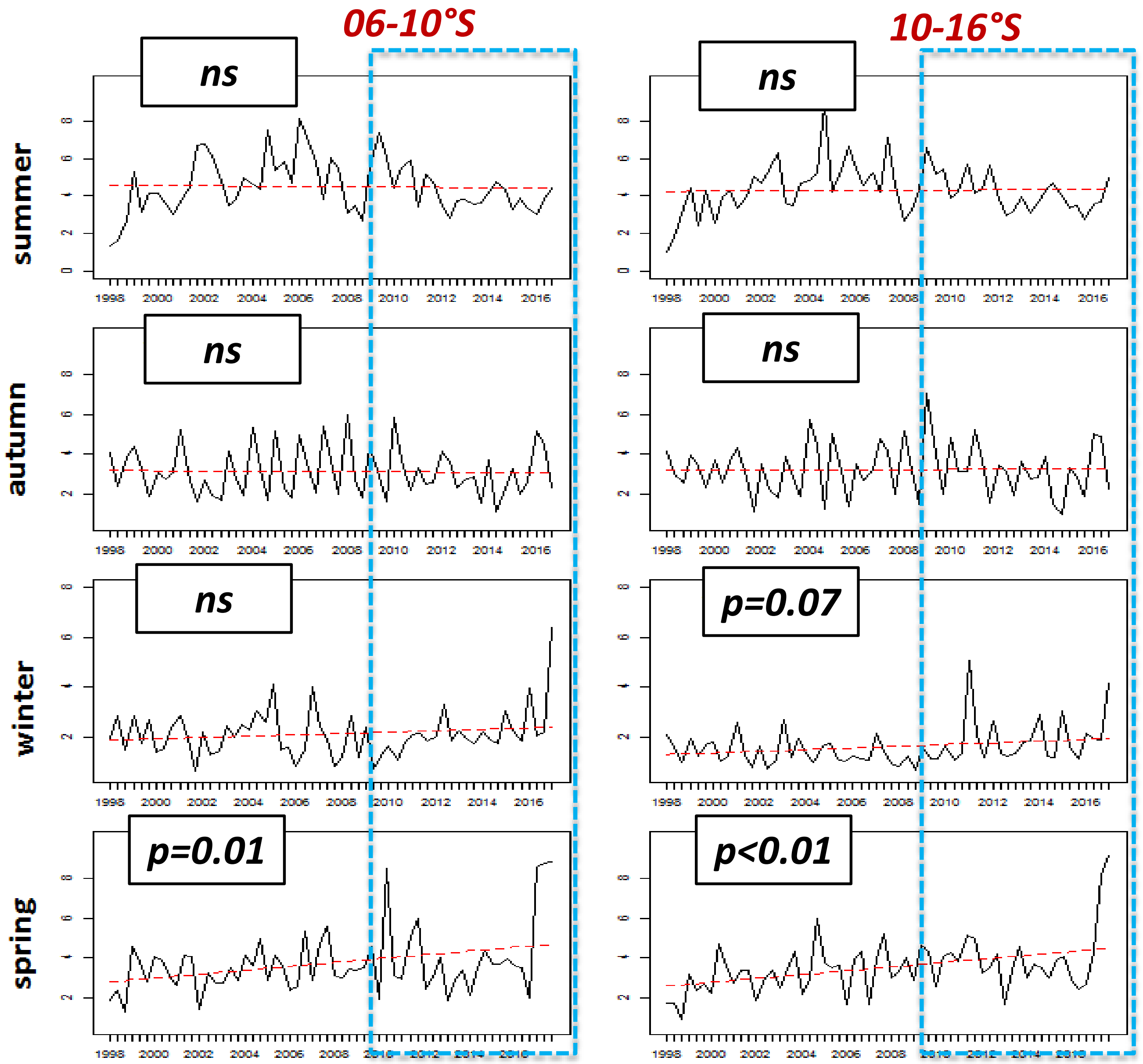


- Latitudinal and onshore-offshore gradients in characterize the surface Chl-a variability
- No significant trend for surface chl-a in the Northern area, while positive trends are evident for the Central-Southern area
- Multiannual trends vary by season (e.g fall vs spring)





Surface Chl-a trends (1997 – 2015, mg m^{-3} decade^{-1})



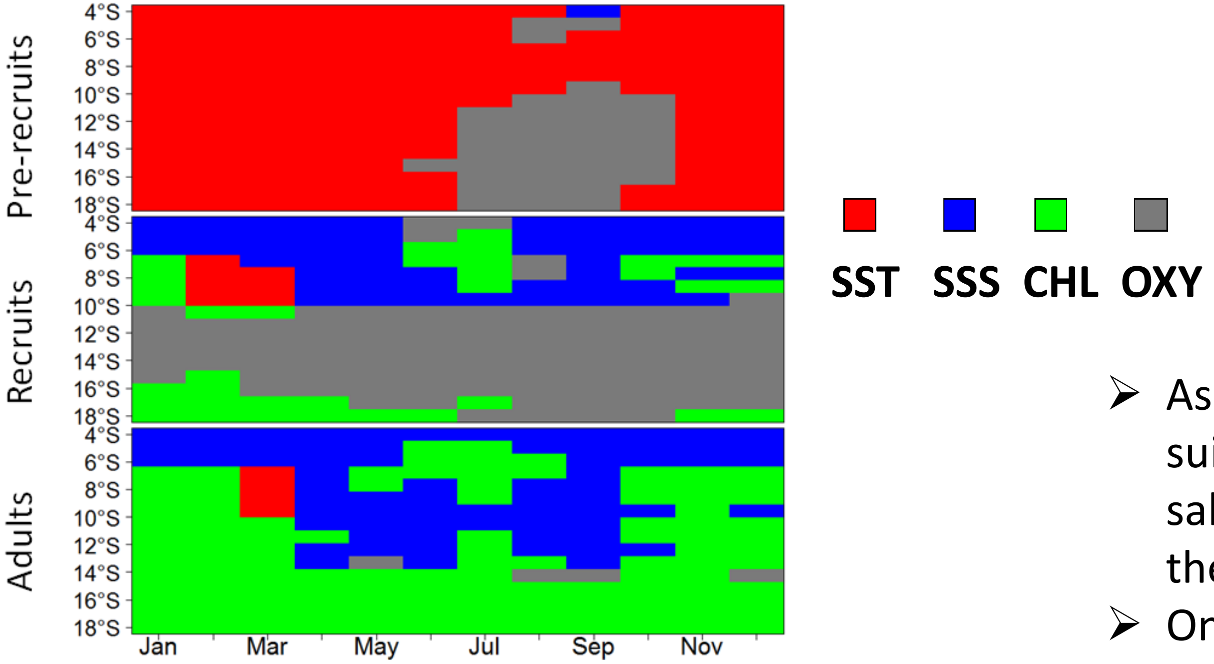
- Positive trend for Central-South is supported by spring and winter periods (weaker wind stress and turbulence?)
- Need to take into account sensor sampling for winter
- Both areas tend to exhibit a different behavior since ca. 2008.

Implications for the anchovy habitat

- Anchovy pre-recruits appear to be more sensitive to environmental conditions, with **temperature** as the main limiting factor.
- Limiting factors also vary by latitudinal region:
  - For recruits/adults, **salinity** (**related with the approach of equatorial and oceanic waters**) is an important limiting factor in the NC region, and **chl-a** is the most limiting factor for adults in the CS region

Stage	Variable	Rank
Pre-recruits	SST	11.69 °C – 18 °C
	SSS	34.80 UPS – 35.15 UPS
	CL	0.45 mg/m3 – 12.88 mg/m3
	OXY	1.20 m – 57.54 m
Recruits	SST	12.24°C – 25.34 °C
	SSS	34.65 UPS – 35.15 UPS
	CL	0.43 mg/m3 – 20.42 mg/m3
	OXY	0.85 m – 72.44 m
Adults	SST	12.19 °C – 25.70 °C
	SSS	34.50 UPS – 35.20 UPS
	CL	0.35 mg/m3 – 28.18 mg/m3
	OXY	0.98 m – 107.15 m

Anchovy Niche Ranges by Developmental Stage
(Luján & Oliveros, this conference)



Seasonal changes of the limiting factor for the anchovy potential habitat

- As the SST front gets closer to the coast in the NC region, less suitable habitat remains for pre-recruits; but also higher salinity values (associated with oceanic waters) are likely near the coast, affecting later populations stages.
- On other hand, increase of chl-a in the CS region favors the expansion of the anchovy hábitat.

Summary and concluding remarks

- Several trends emerge since about 2008/09:
  - The multidecadal cooling along the Central and Southern Peruvian coast since about mid-70's tend to weaken, with warming in the latest years, in parallel with a positive trend of SLA along the coast.
  - Coastal upwelling-favorable winds exhibit a slight decrease, particularly in winter and spring.
  - The distance to the coast of the SST front (Northern to Southern Peru) shows a negative trend, with a larger reduction in autumn, suggesting warm/oceanic waters get closer to the coast.
  - The offshore-onshore SST gradient exhibits a slight negative trend off Central Southern Peru, supporting the idea of weaker upwelling intensity in this region.

- For chlorophyll-a surface concentrations, multidecadal positive trends previously described (e.g. Gutiérrez et al., 2011) are only sustained in the Central-South area based on satellite observations particularly for the last decade.

- These observations imply changes in the potential habitat distribution for plankton and nekton species. For anchovy, observed recent variations of the aggregation patterns, towards a more coastal distribution, are consistent with these oceanographic changes.

- Given recent changes in SST/upwelling and chl-a, a posible spatial shift of the 'OEW' (from the NC to the CS region) should be further explored, affecting recruitment and other biological attributes of the species.