Physical variability associated to the formation of water stratification events and emergence of anoxia in Paracas Bay (14° S) downstream the main Peruvian coastal upwelling cell

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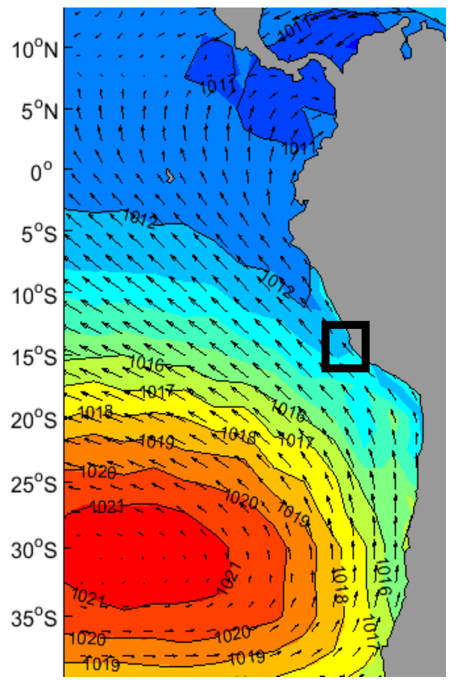
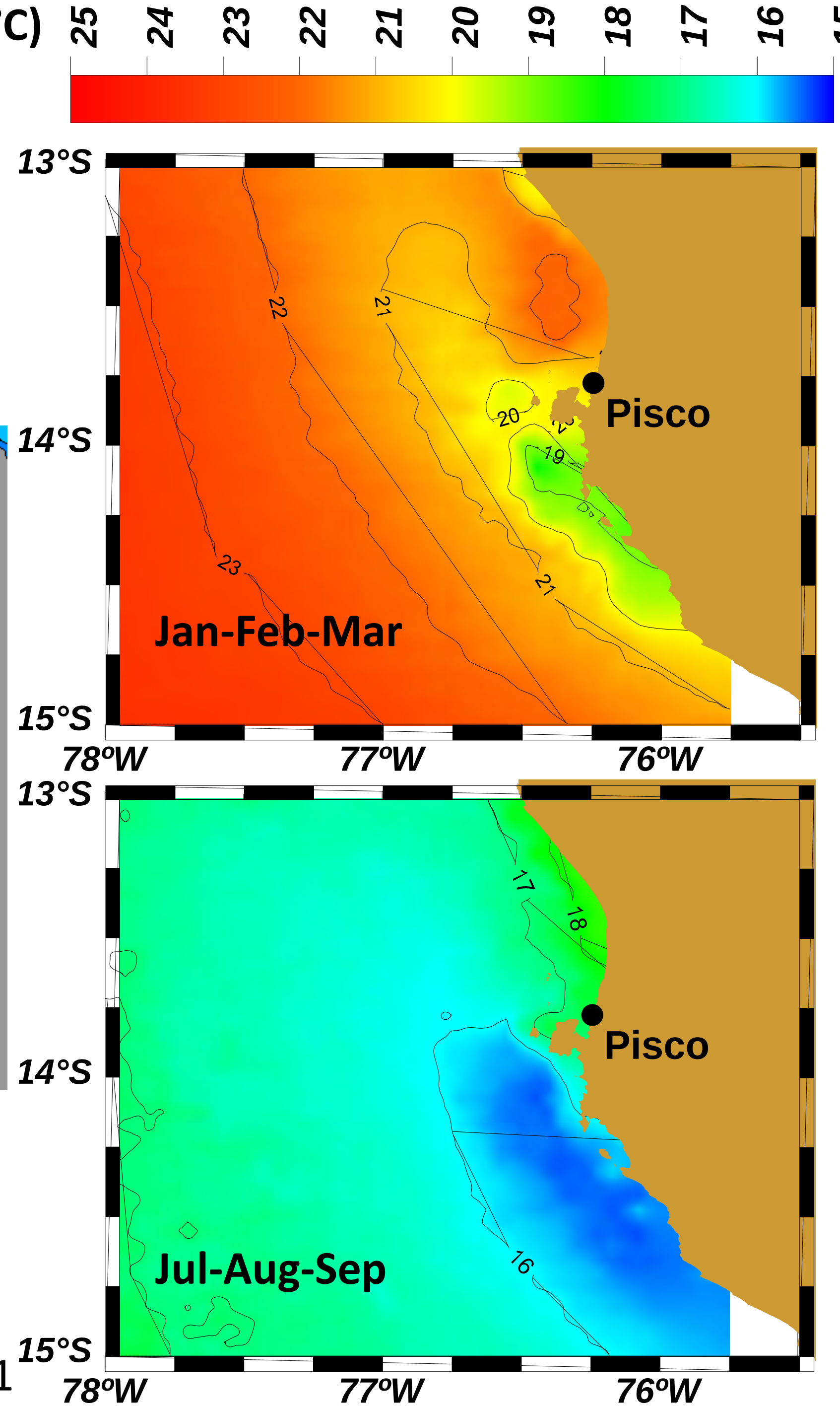
INTRODUCTION

- Most intense alongshore winds
- Main Peruvian coastal upwelling cell
- Upwelling persists throughout the year
- Paracas Bay is downstream the upwelling cell and surrounded by Paracas Peninsula

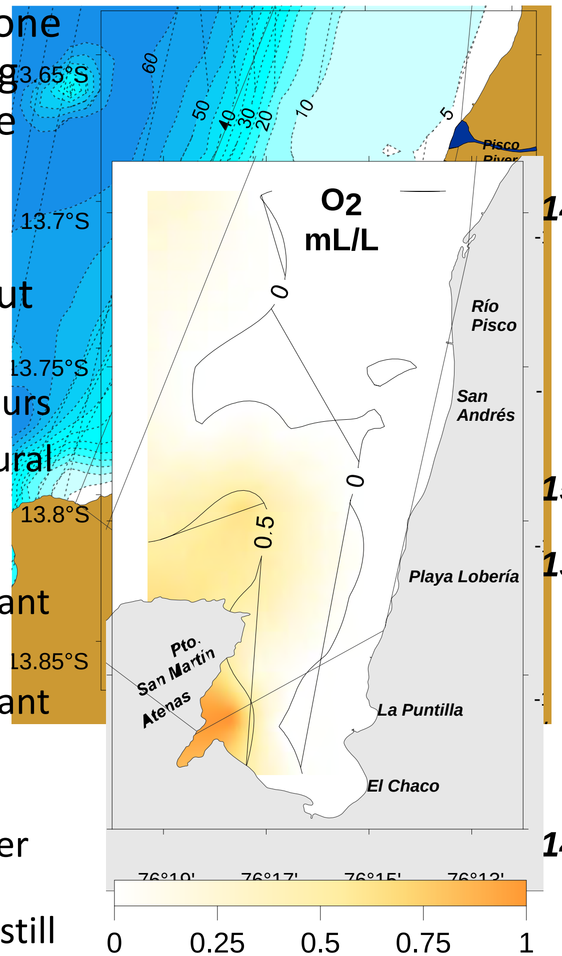


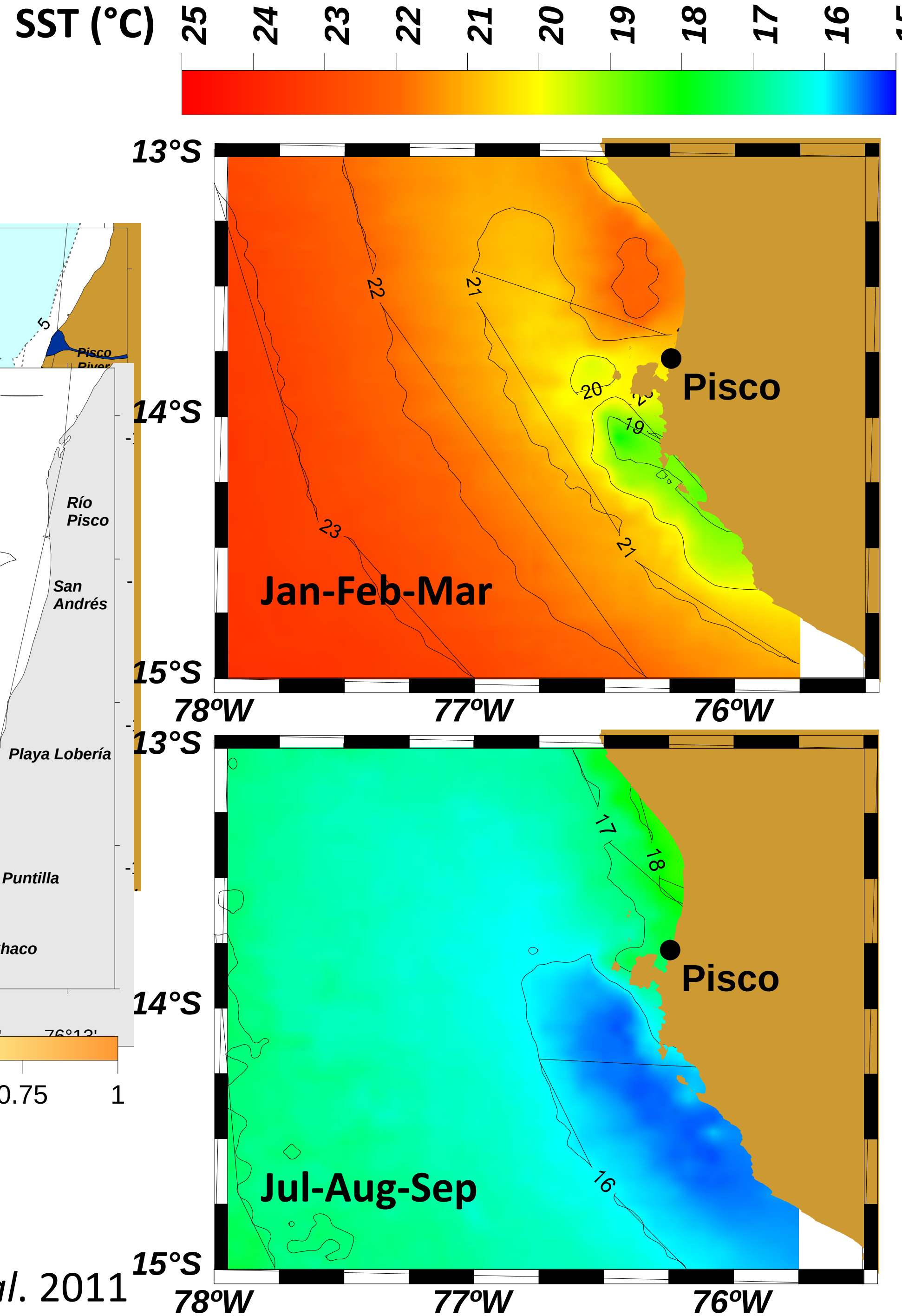


Gutiérrez *et al.* 2011

INTRODUCTION

- Paracas Bay: a transition zone between Coastal Upwelling System and inshore marine environment.
- Paracas Bay: a small dimensions embayment but very important in Peru:
  - ✓ Fishery and trade harbours
  - ✓ Platform: terminal (Natural gas by-products exportation)
  - ✓ One of the most important aquaculture zones
  - ✓ One of the most important tourism destination
  - ✓ Critical environmental phenomena (HABs, water stratified conditions, anoxia, mass mortality) still poorly understood.





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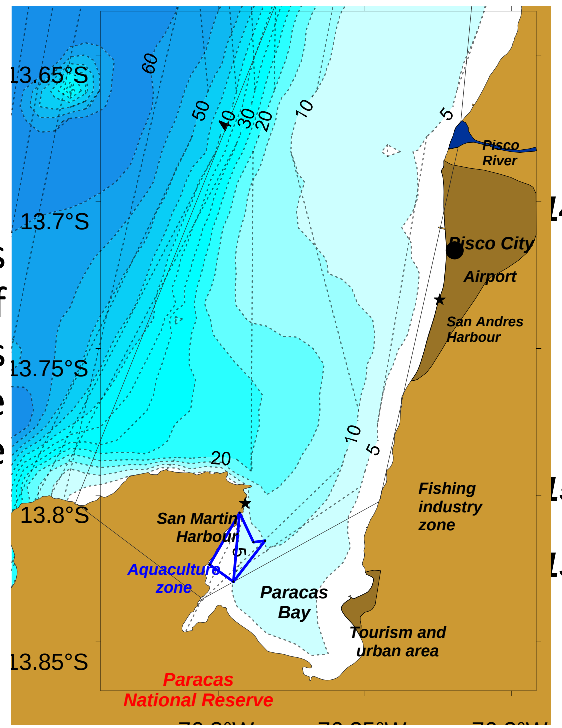
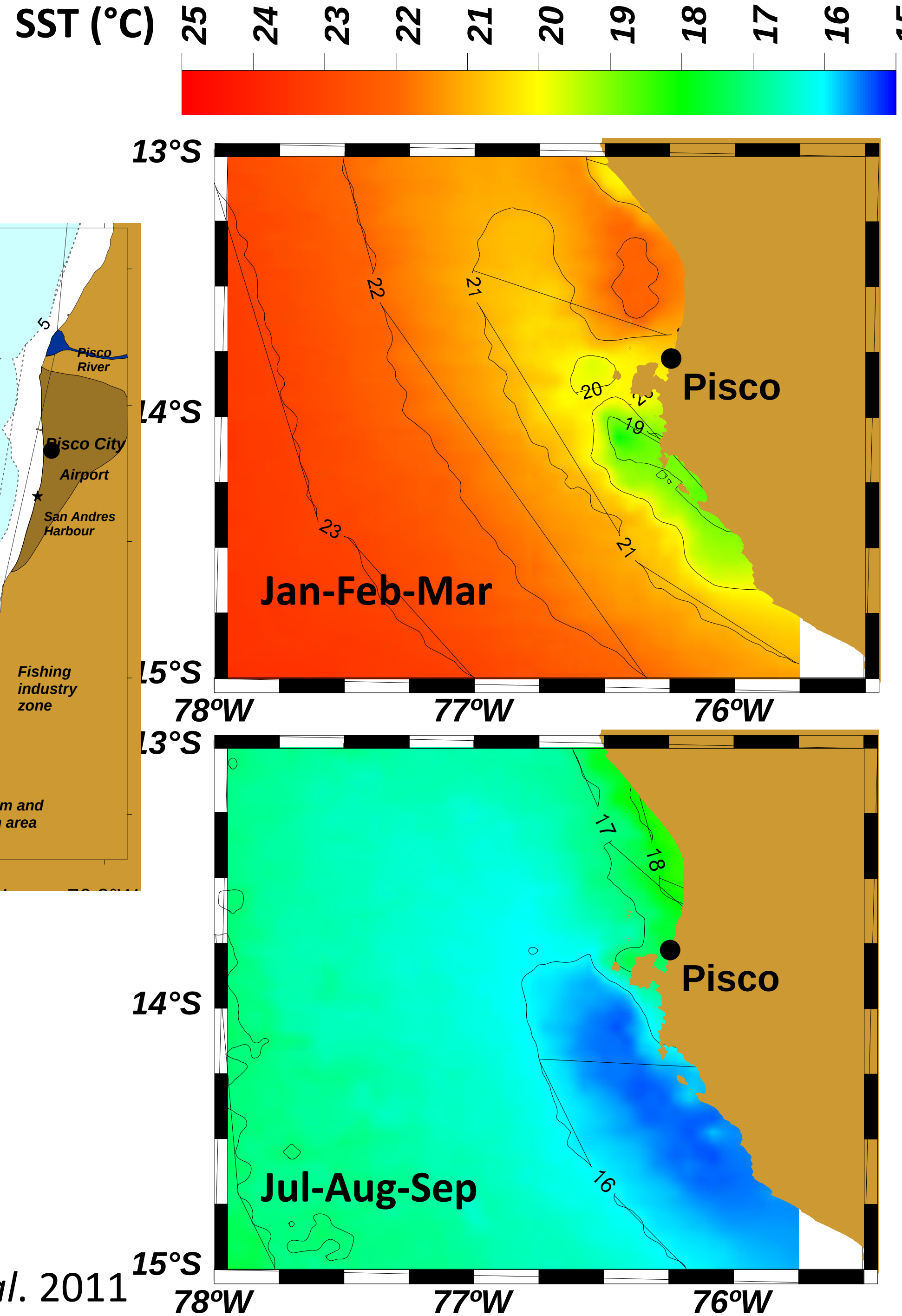
INTRODUCTION

OBJECTIVE:

Describe physical factors that lead to the formation of strong stratification events and to explain the influence of these on the emergence of anoxia in Paracas Bay.





Gutiérrez *et al*. 2011

METHODS

High frequency (daily) data from **2006-2015**:

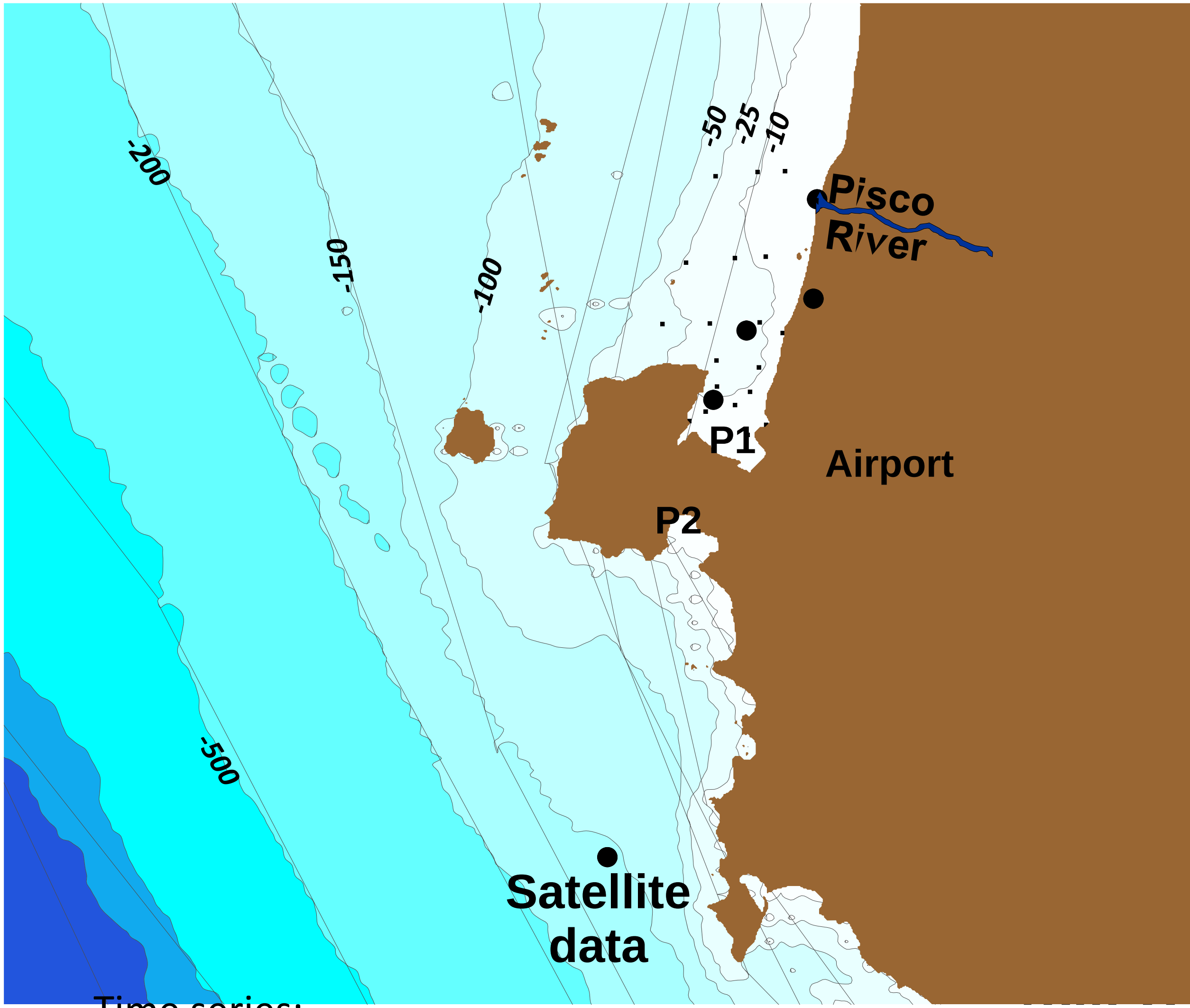
- Wind favorable to upwelling (QUICKSCAT & ASCAT)
- Local wind (Pisco Airport)
- Surface and bottom water temperature (△T)： P1
- River discharges flow (ANA)

High frequency (hourly) data from 2015 (March to December) registered by data loggers: P2

- Surface and bottom water temperature (△T) and bottom dissolved oxygen (optode sensor):

Non-periodic data (■, IMARPE *in situ* surveys)

- Surface and bottom water temperature (△T)
- Surface salinity
- Bottom dissolved oxygen

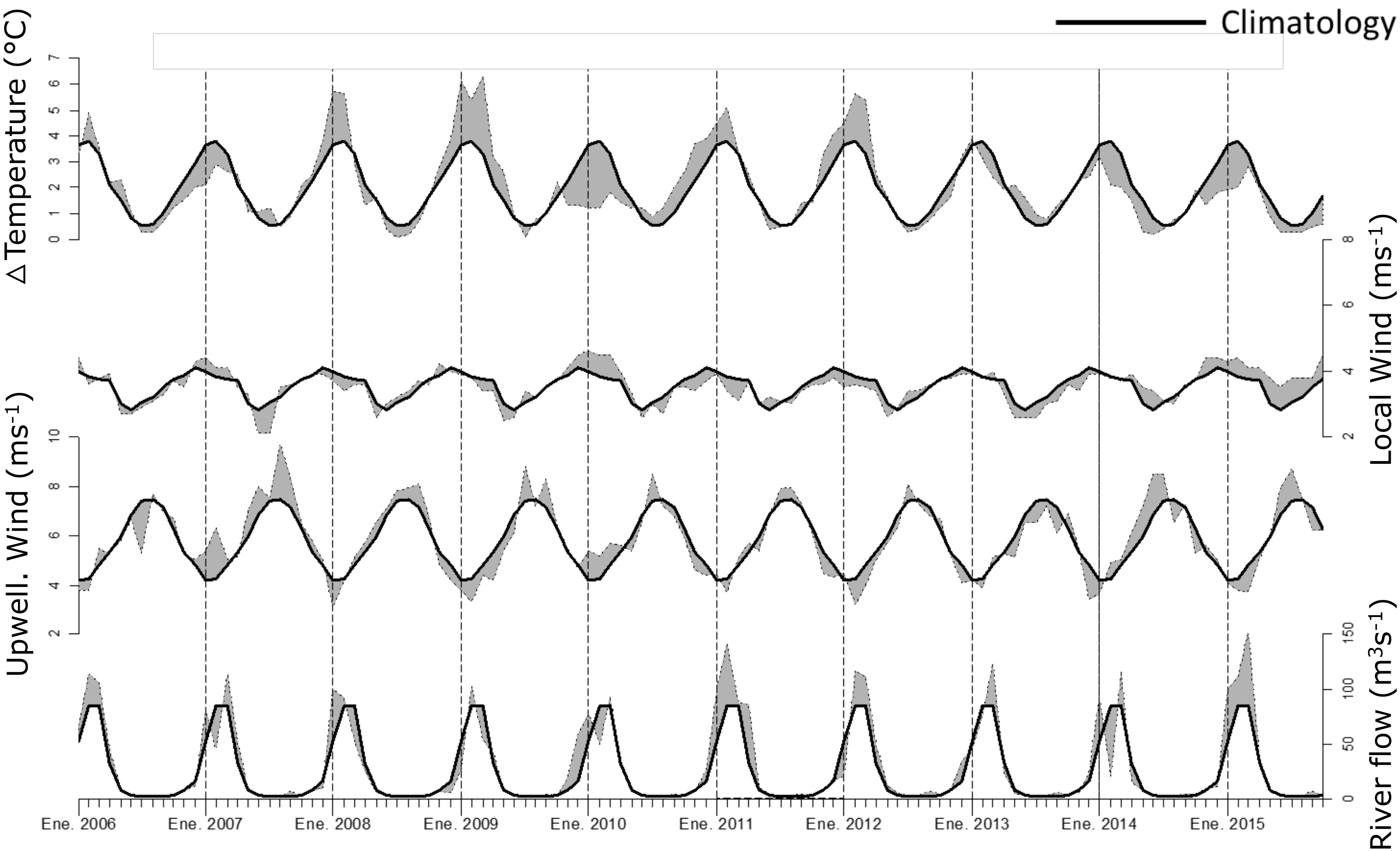


Time series:
Analysis at monthly (averages) and daily scale: Cross correlation, wavelets analysis.

Non-periodic data :
Simple correlation.

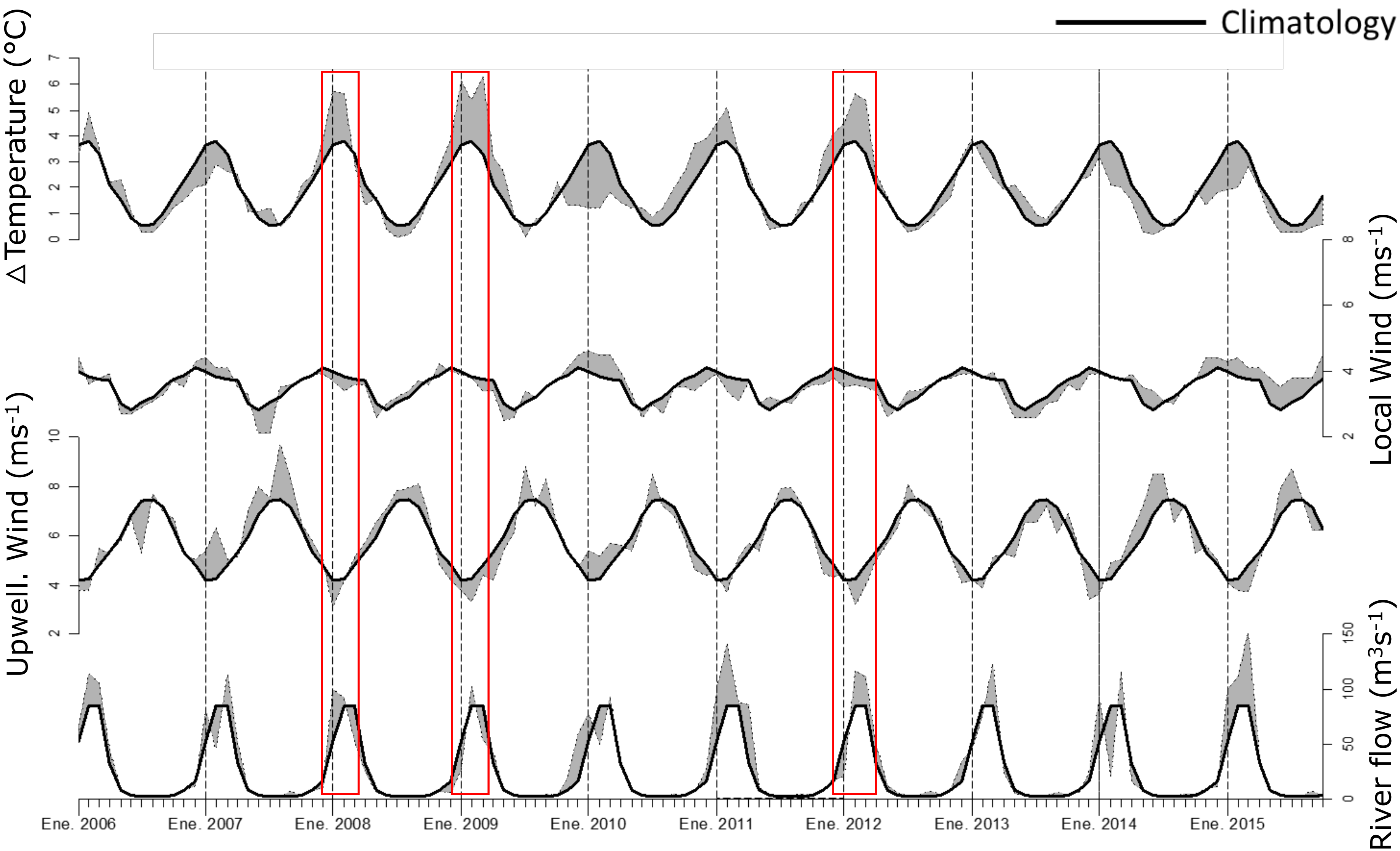
RESULTS:

Average conditions (monthly scale)



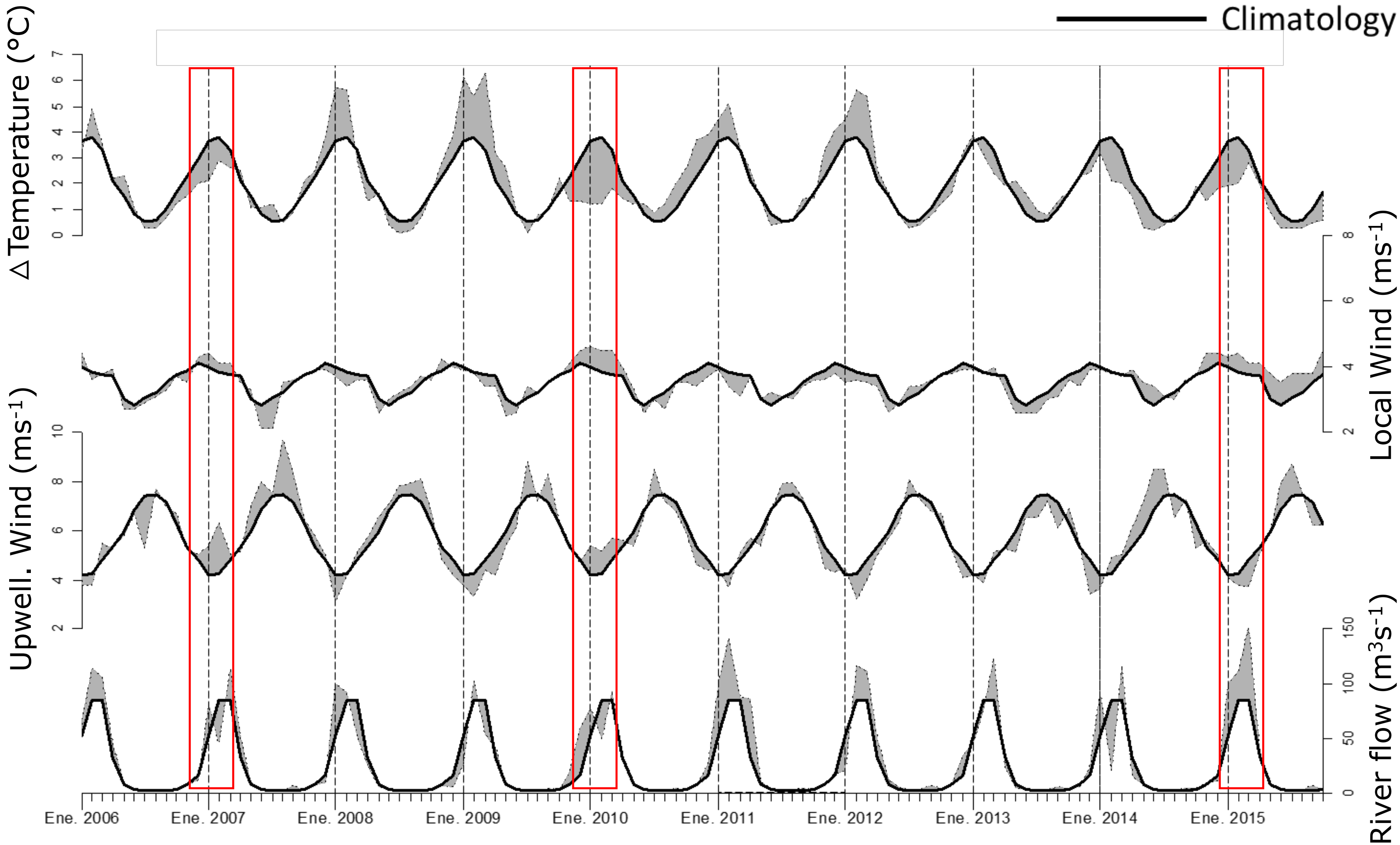
RESULTS:

Average conditions (monthly scale)



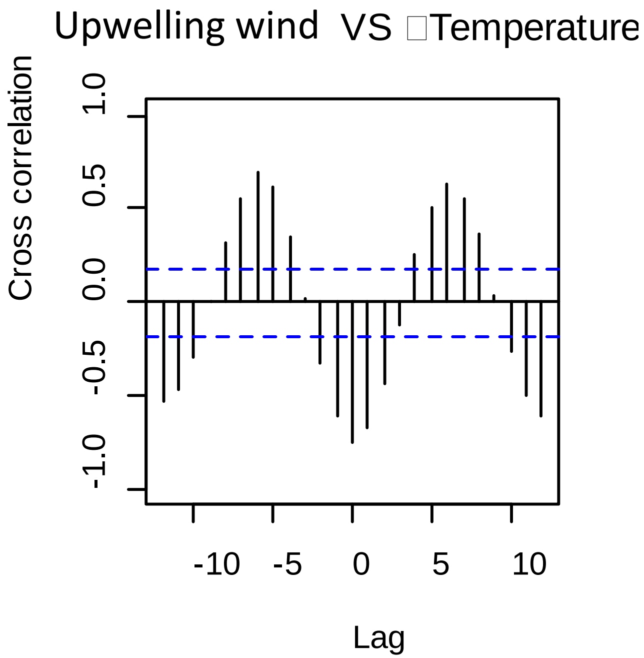
RESULTS:

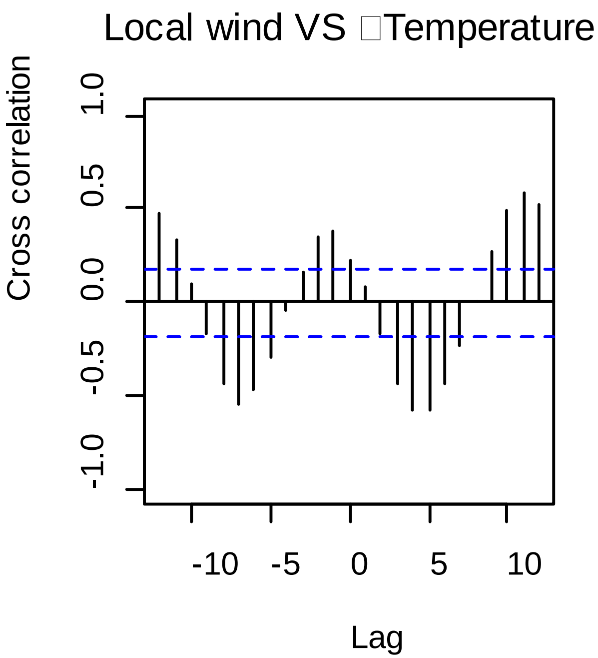
Average conditions (monthly scale)

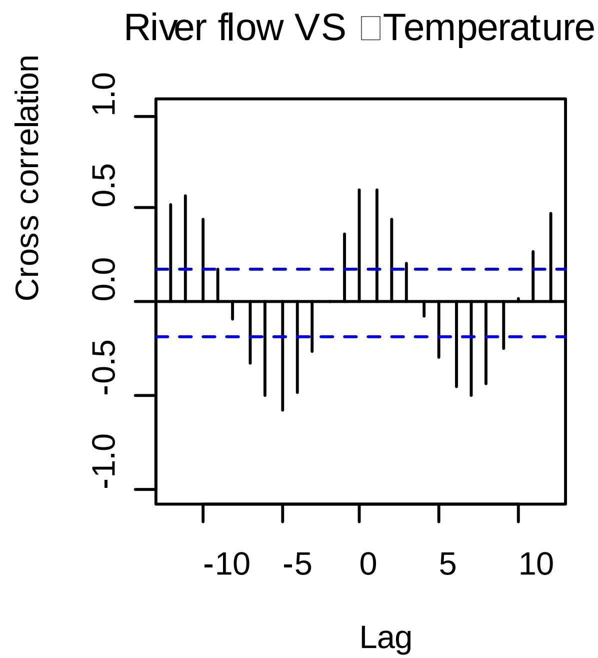


RESULTS:

Cross-correlation of ΔTemperature VS physical factors (monthly scale)



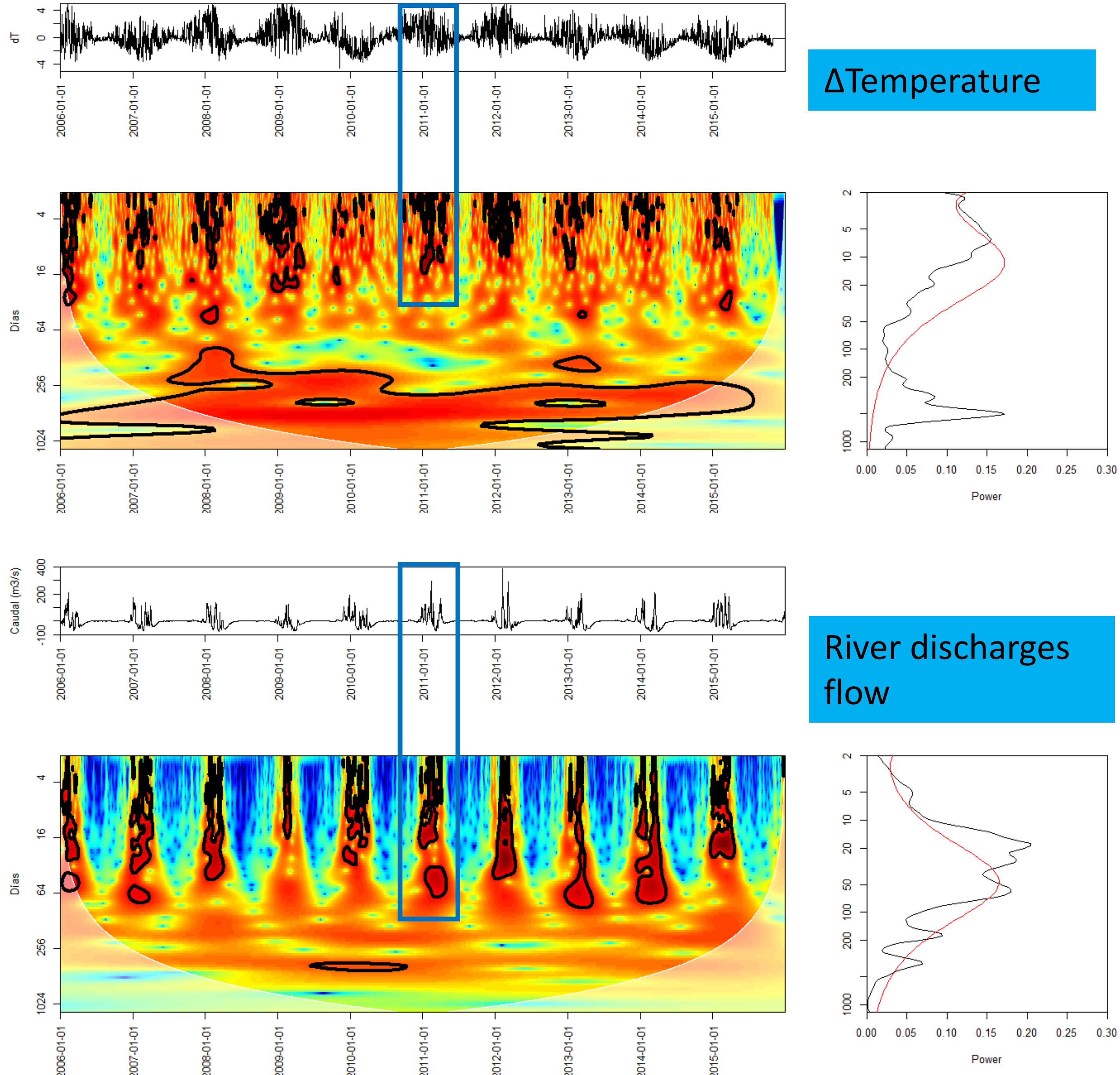




RESULTS:

High frequency (daily scale)

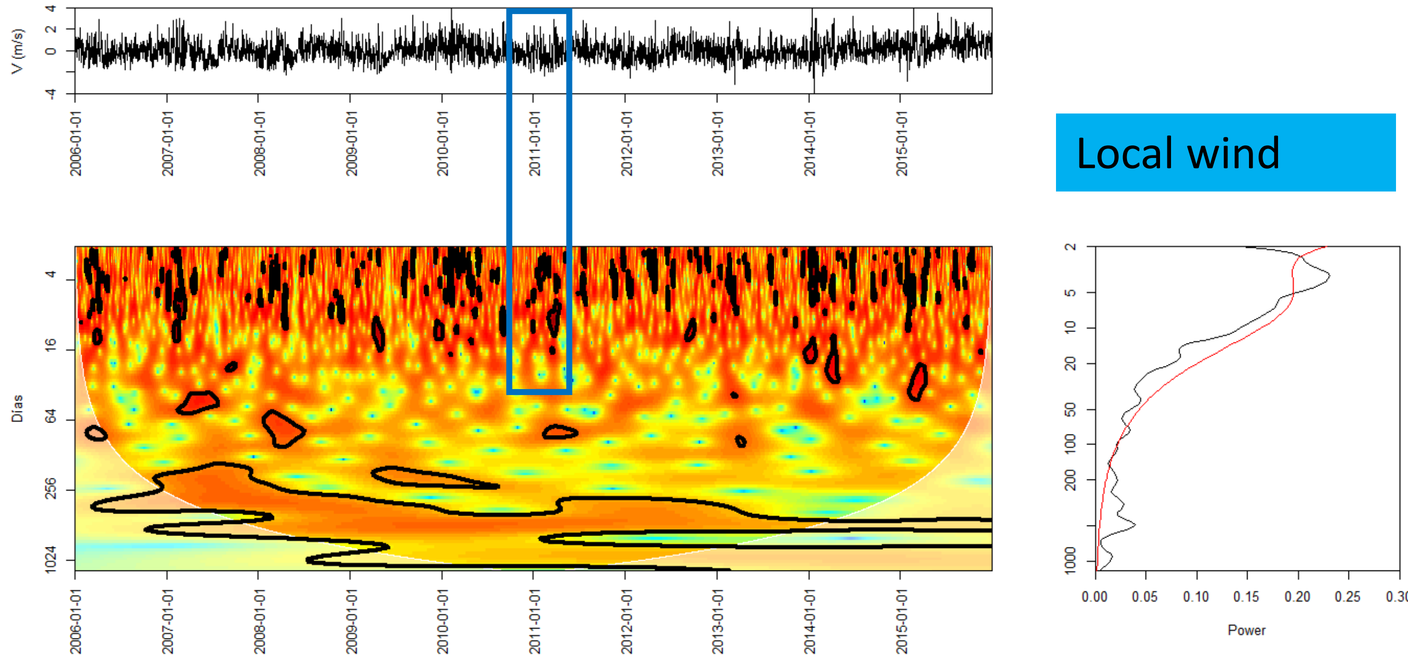
Wavelet analysis of daily anomalies



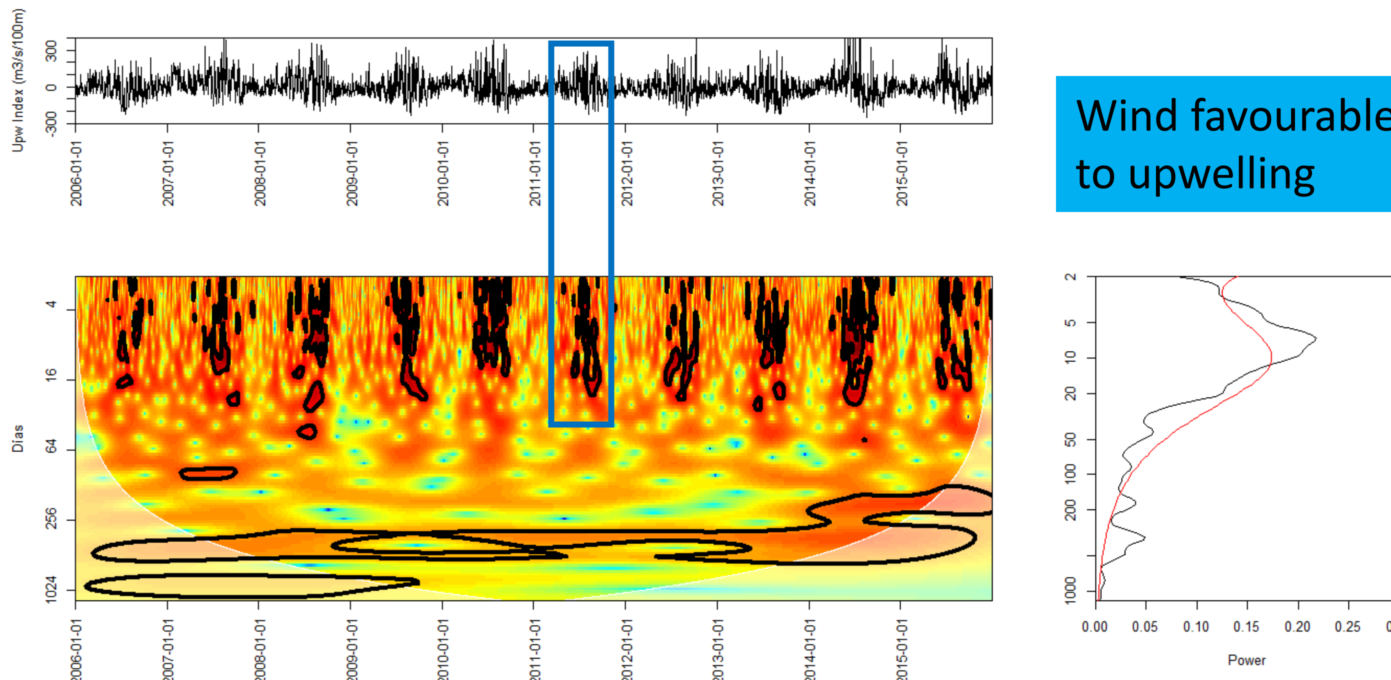
RESULTS:

Wavelet analysis of daily anomalies

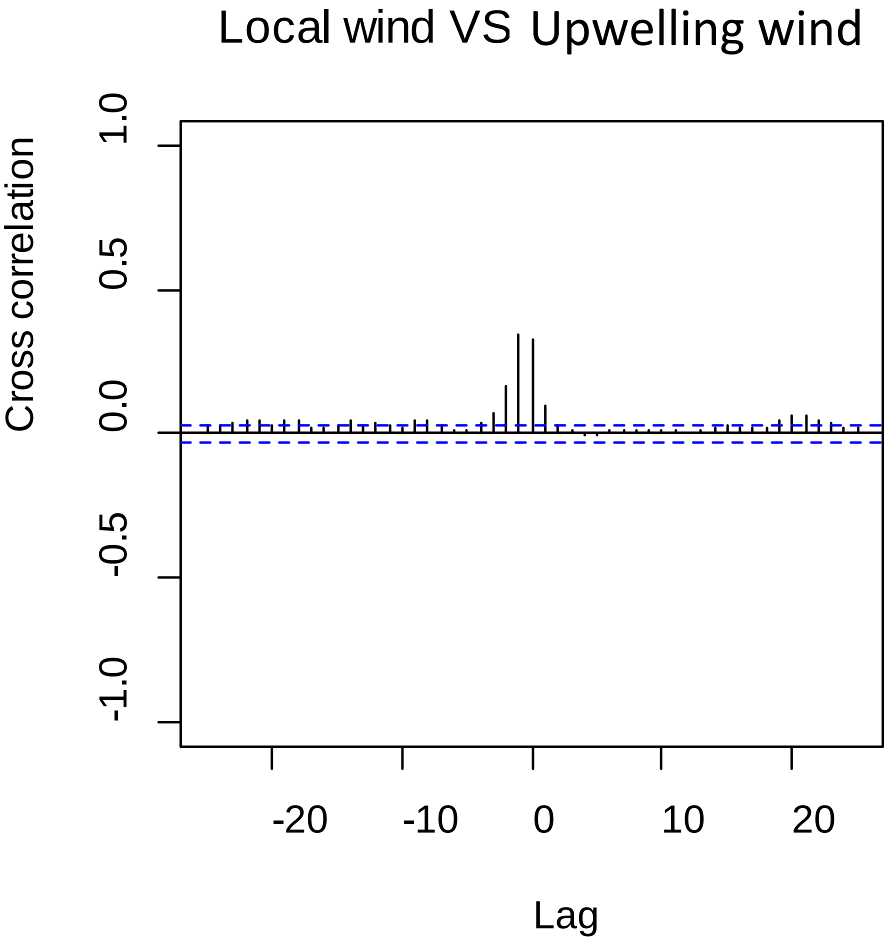
Local wind



Wind favourable to upwelling

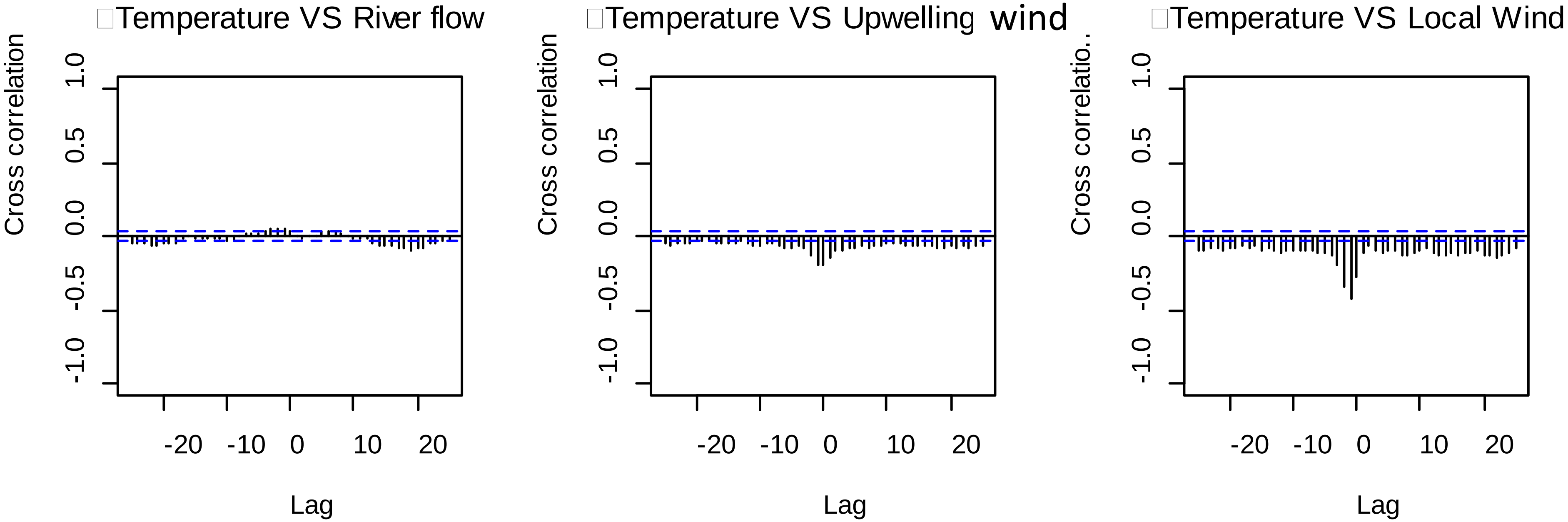


RESULTS:
Cross-correlation of upwelling and local winds anomalies



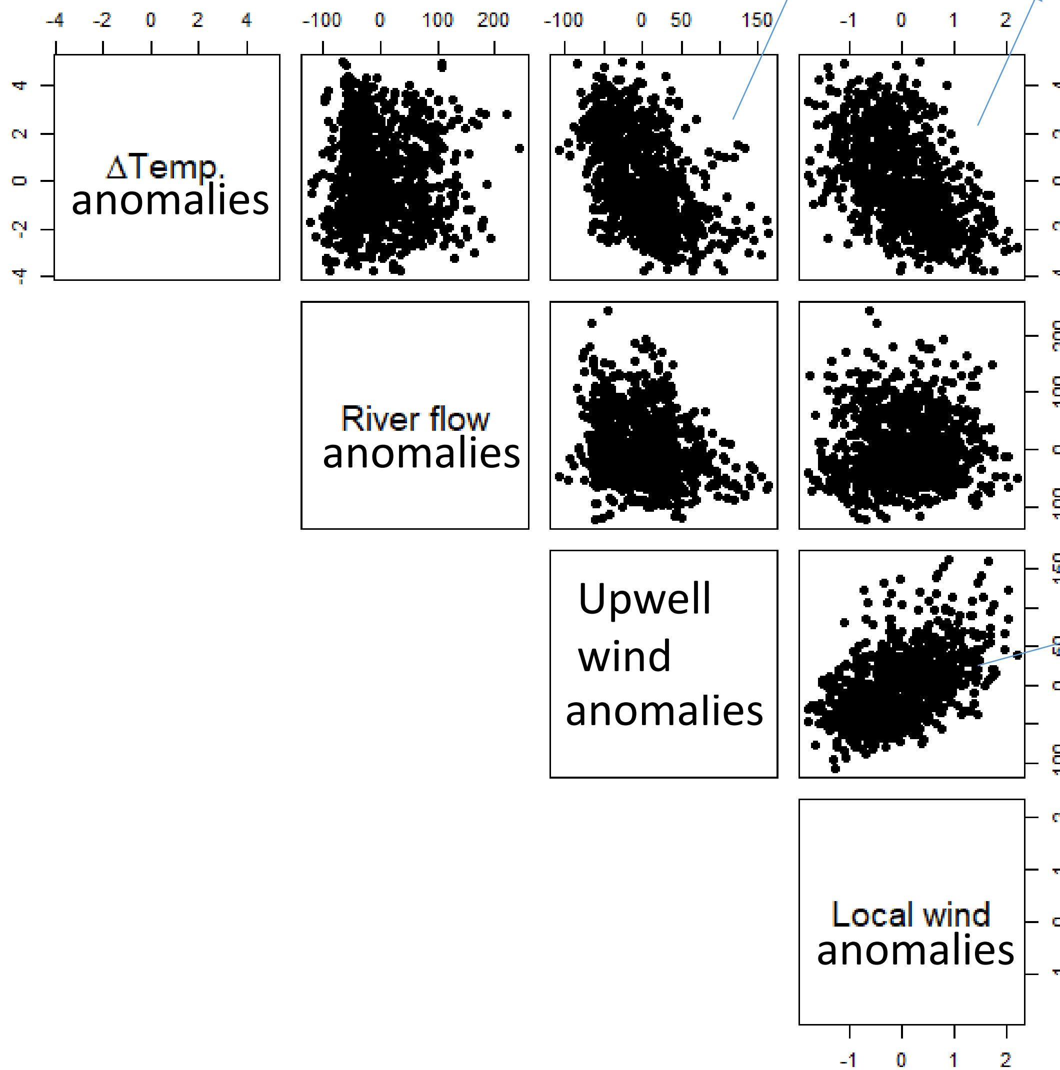
RESULTS:

Cross-correlation between Δtemperature anomalies and physical factors anomalies



Correlation between anomalies of stratification (ΔTemperature) and physical factors considering summer months data only

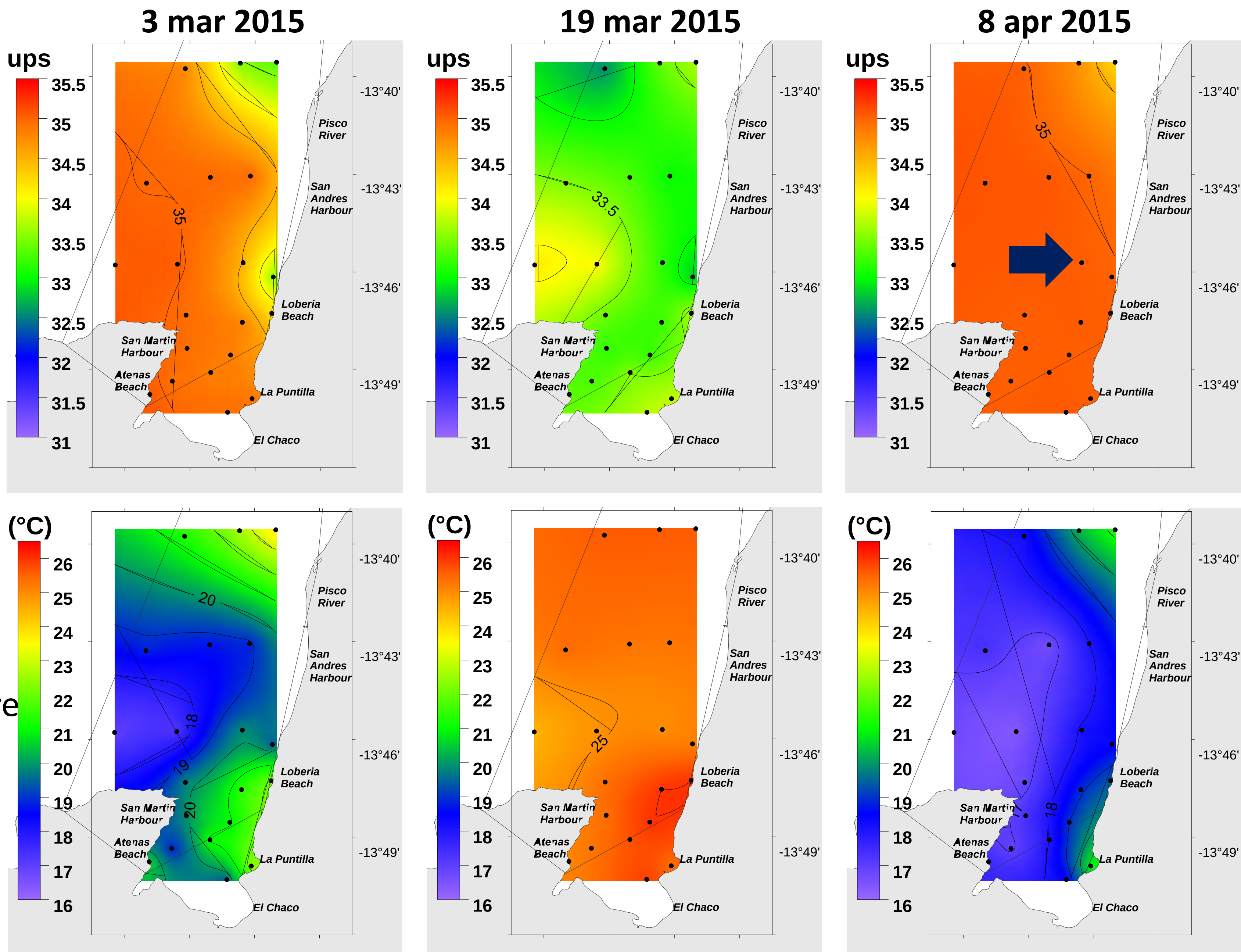
Even in summer months only there is no correlation between river discharges flow and ΔTemperature



Non periodic data (case: March-April 2015)

Surface salinity

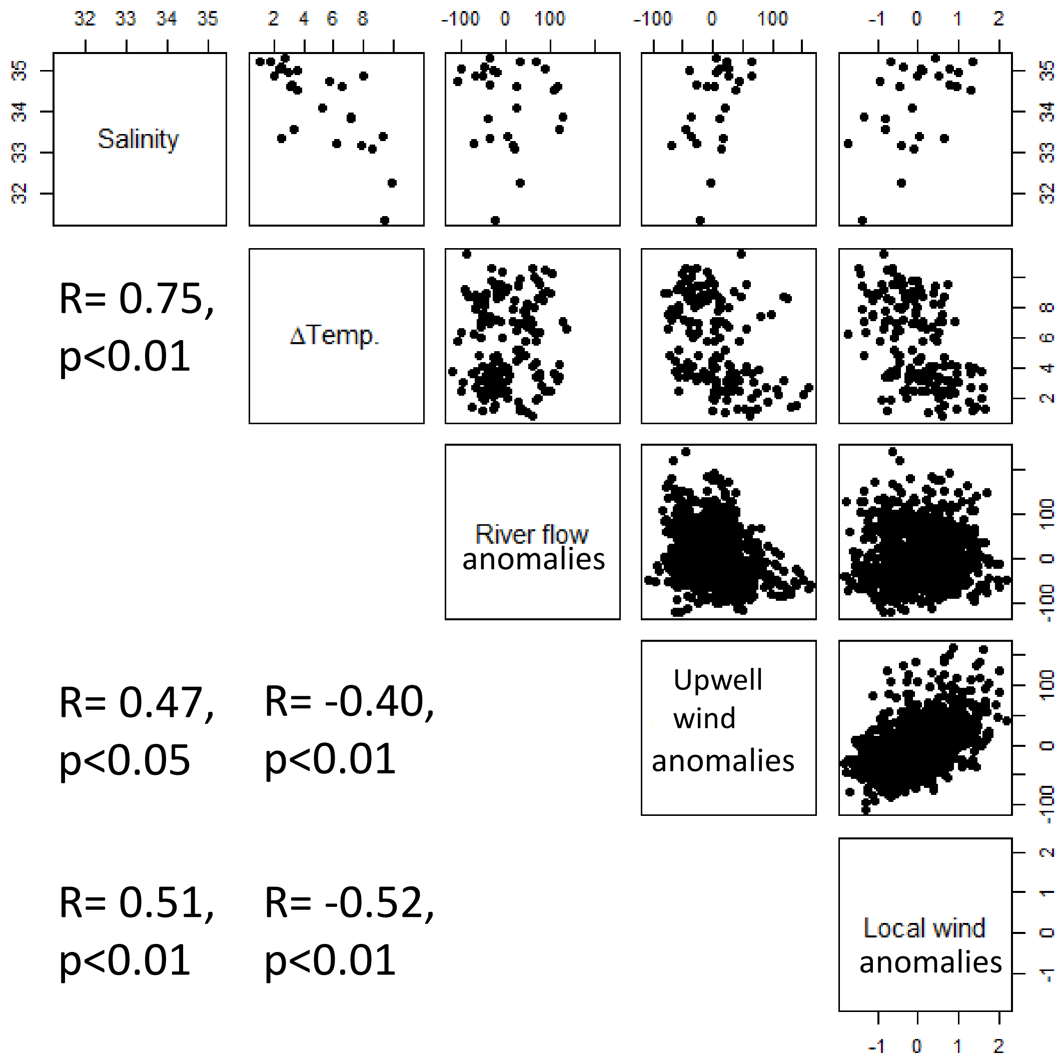
Surface temperature



RESULTS:

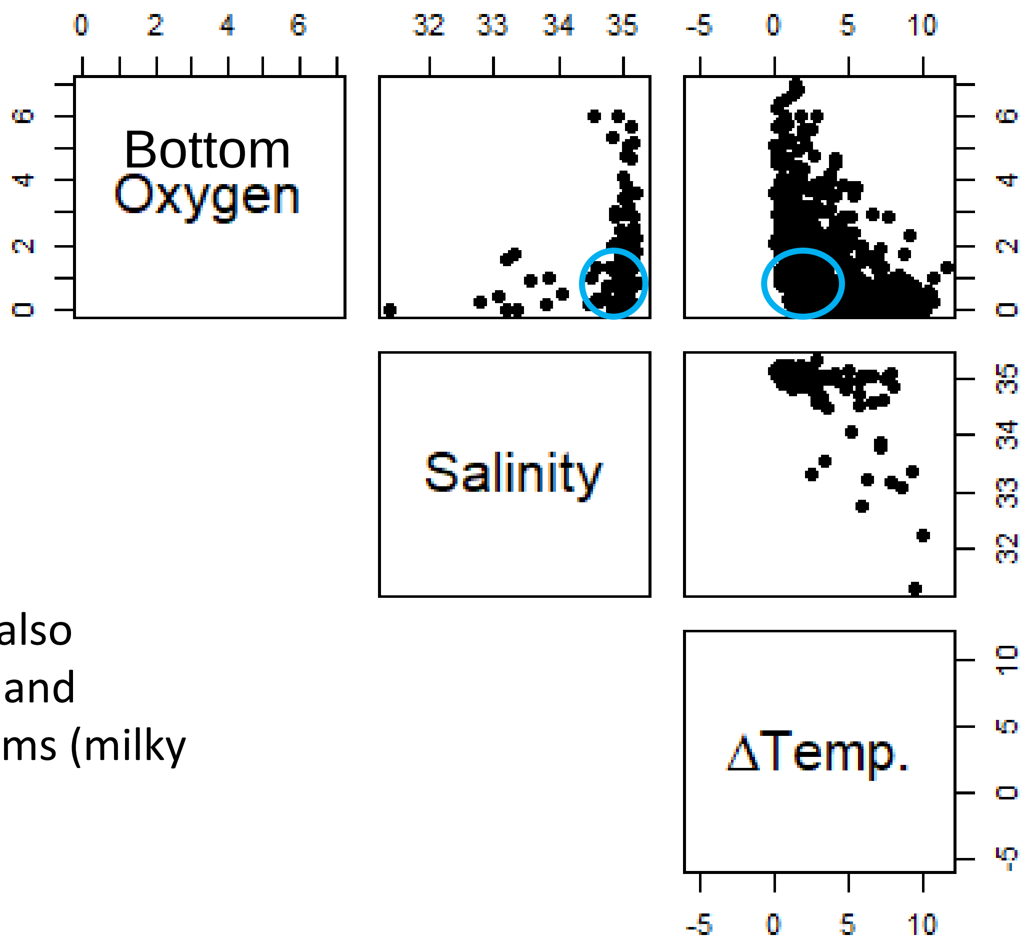
Correlation between non periodic data (summer months only) and physical factors anomalies

Non periodic data



RESULTS:
Non periodic data
Correlation between non periodic data (all seasons)

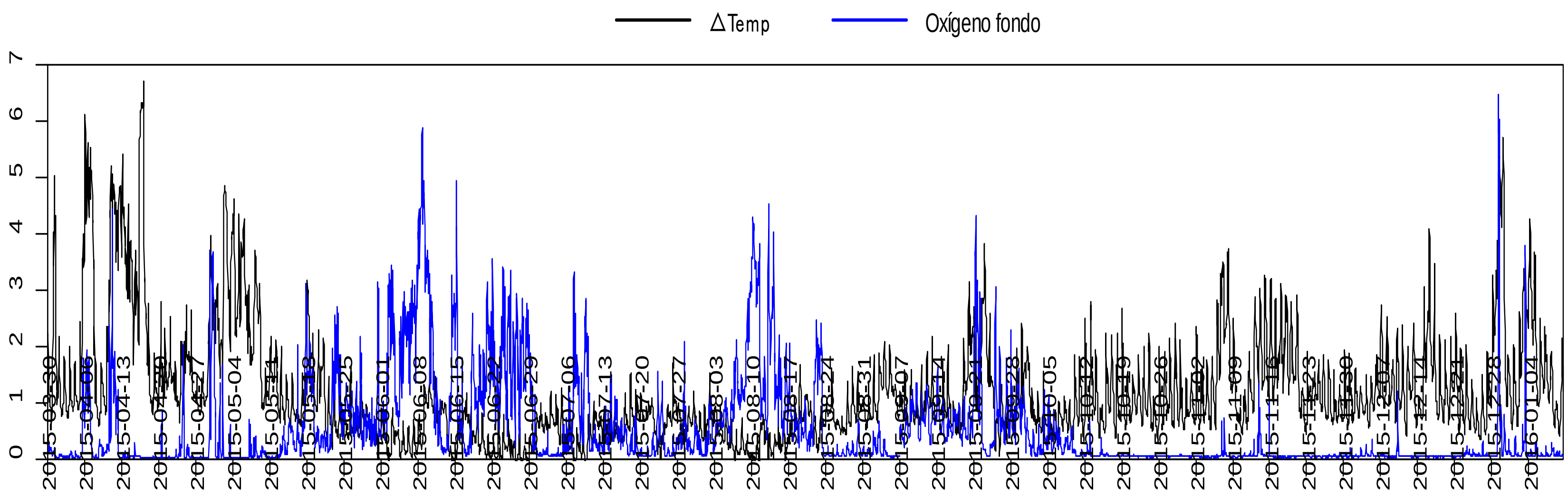
ΔTemperature exhibits the highest levels at lowest levels of surface salinity, and at the same time dissolved bottom oxygen is in hypoxic levels (<2mL/L) or there is anoxia.



Some hypoxia and anoxia events also occur at normal values of salinity and Δtemperature: another mechanisms (milky cold waters)

RESULTS:

High frequency data inside Paracas Bay (P2) based on surface and bottom temperature sensors and bottom optode oxygen sensor



CONCLUSIONS:

- Weaker coastal wind intensity and strong river discharges condition the development of water stratification in Paracas Bay particularly in summer.

- The formation of strong stratification events is due to increases in the surface temperature as a result of upwelling wind and local wind calms that allow the arriving of low surface salinity waters to the bay.

- Bottom oxygen is near or in hypoxic levels most of the time in Paracas Bay due to the low oxygen content of the incoming upwelling waters, but strong summer stratification events contribute to the emergence and spread of anoxia.