Variability of nutrients and its relationship with thermohaline properties and chlorophyll along the North Iberian shelf (NIS) in the last two decades

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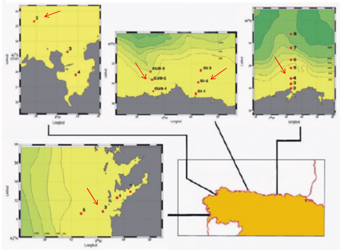
STUDY SITE: NORTH IBERIAN SHELF (NIS)
RADIALES PROJECT (http://www.seriestemporales-ieo.net)



MATERIAL AND METHODS
TIME SERIES ANALYSIS: UNIVARIATE ADDITIVE DECOMPOSITION

Climatological average; Multi-year cyclical; Remaining irregular fluctuation

$$x_t = \bar{x} + LT[x_t] + LTC[x_t] + SC[x_t] + R[x_t]$$

Long-term linear trend; Seasonal

Annual; Semi-annual

$$SC[x_t] = A_{12}\cos\left(\frac{2\pi}{12}t + \theta_{12}\right) + A_6\cos\left(\frac{2\pi}{6}t + \theta_6\right)$$

Amplitude; Phase

$$-\theta_i = \frac{2\pi}{T_i}T_m \qquad A_c = -(2/n)\log_e\left(1-\sqrt[m]{1-\alpha}\right)$$

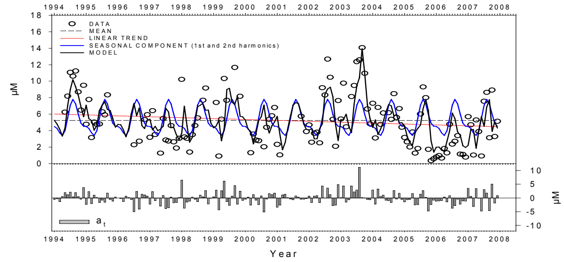
Maximum t of the cycle; Statistical significance of the cycle (Anderson criterion)

Pre-whitened residuals

$$R[x_t] = \phi_i(R[x_{t-i}]) + a_t$$

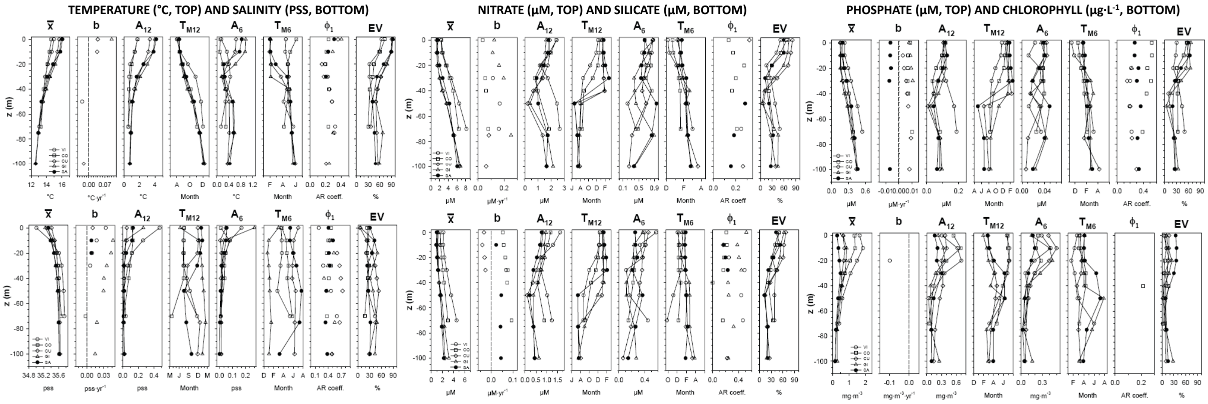
Autoregressive component

EXAMPLE OF UNIVARIATE ADDITIVE DECOMPOSITION
TIME SERIES OF SILICATE AT 35 M DEPTH IM MID-SHELF OFF VIGO

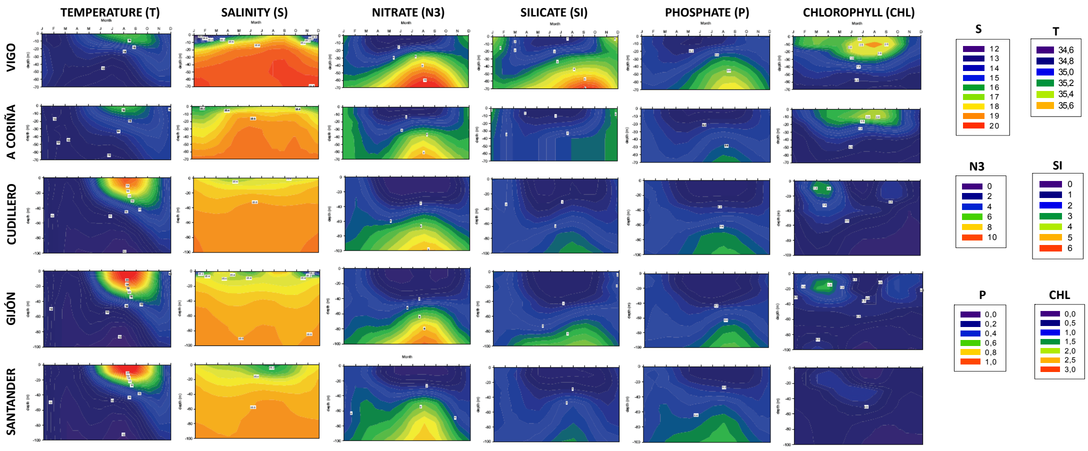


VARIATION OF THE UNIVARIATE TIME SERIES MODEL PARAMETERS WITH DEPTH (z) ALONG THE NORTH IBERIAN MID-SHELF (VIGO, A CORUÑA, CUDILLERO, GIJÓN AND SANTANDER)

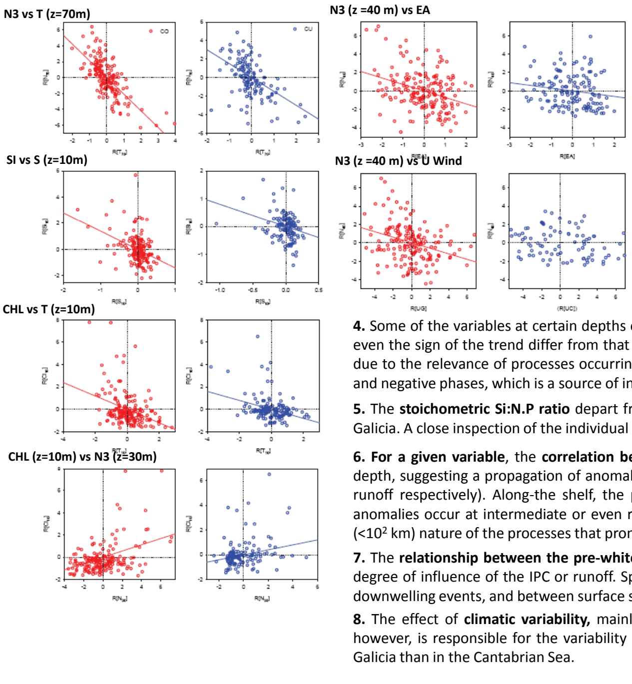
TEMPERATURE (°C, TOP) AND SALINITY (PSS, BOTTOM) — NITRATE (µM, TOP) AND SILICATE (µM, BOTTOM) — PHOSPHATE (µM, TOP) AND CHLOROPHYLL (µg·L[-1], BOTTOM)



SEASONALITY OF TEMPERATURE, SALINITY, NITRATE, SILICATE, PHOSPHATE AND CHLOROPHYLL ALONG THE NORTH IBERIAN MID-SHELF (VIGO, A CORUÑA, CUDILLERO, GIJÓN AND SANTANDER)



LINEAR RELATIONSHIPS BETWEEN PRE-WHITENED RESIDUALS. EXAMPLES FOR TIME SERIES OF A CORUÑA AND CUDILLERO



MAIN RESULTS

1. All time series components exhibit **well-defined patterns with depth and along-shelf** due to distinct influence of modulator processes such as upwelling, the Iberian poleward current (IPC), runoff and phytoplankton production.

2. The variation of the **climatic average** with depth (i.e. average profile) decrease for temperature and increase for salinity and nutrients; for chlorophyll, decrease with depth but exhibit a sub-surface maximum (DCM) at 10m in Galicia (Vigo and A Coruña) and at 30m in the Cantabrian Sea (Cudillero, Gijón and Santander). Along the shelf, the climatic average of temperature in the surface layer (z≤40m) increase northward in Galicia and eastward in the Cantabrian Sea, being similar below this depth; for salinity, nutrients and chlorophyll, the climatic average decrease northward in Galicia, and are higher in Galicia than in the Cantabrian Sea.

3. Seasonality is the most prominent temporal component (in terms of explained variance of the series). The exception is salinity, for which the most prominent modes are the inertia (i.e. auto-correlation) and the long-term trend. Seasonality is higher in the surface than in the bottom layer, with a significant drop at intermediate depths (30m in Galicia, 50m in the Cantabrian Sea) pointing out the average position of the interface (i.e. cline) between the surface and bottom layers. Seasonality is higher at any depth in the Cantabrian Sea than in Galicia due to a higher importance of processes occurring at sub-seasonal scales, like coastal upwelling, in the later of these zones. Seasonal cycles present contrasting characteristics along the shelf.

4. Some of the variables at certain depths exhibit **long-term trends**, but there is no a consistent long-term pattern along the shelf. In some cases, the annual rate of change or even the sign of the trend differ from that reported by other authors. These discrepancies illustrate the difficulty of generalizing long-term patterns over the continental shelf due to the relevance of processes occurring at intermediate and short-term scales. The inertia of the series explain the existence of positive (i.e. above the seasonal average) and negative phases, which is a source of interannual variability.

5. The **stoichometric Si:N.P ratio** depart from the 15:16:1. The potential limitation by nitrate and in some cases by silicate too is more severe in the Cantabrian Sea than in Galicia. A close inspection of the individual values show, however, situations of potential limitation by phosphate when this nutrient is close to the detection limit.

6. For a given variable, the **correlation between pre-whitened residuals** (i.e. de-seasonalized, de-trended and non auto-correlated time series) show defined patterns with depth, suggesting a propagation of anomalies trough the water column, which is independent of the upward or downward origin of the forcing factor (i.e. coastal upwelling or runoff respectively). Along-the shelf, the pre-whitened residuals of temperature and salinity correlate, indicating that the physical processes responsible for the observed anomalies occur at intermediate or even regional scales (10^2 - 10^3 km). For nutrients and chlorophyll, the lack of correlation between pre-whitened residuals stress the local (<10^2 km) nature of the processes that promote them.

7. The **relationship between the pre-whitened residuals of the hydrographic variables** point out the relevance of physical processes, such as upwelling-downwelling events, degree of influence of the IPC or runoff. Specially strong are the relationship between sub-surface temperature and nutrients all over the water column, related to upwelling-downwelling events, and between surface salinity and surface nutrients, reflecting the effect of runoff episodes.

8. The effect of **climatic variability,** mainly the North Atlantic Oscillation (**NAO**) and Eastern Atlantic pattern (**EA**) was only significant in Galicia. Meteorological variability, however, is responsible for the variability of thermohaline properties and nutrient concentration all along the North Iberian shelf, although its effect is more pronounced in Galicia than in the Cantabrian Sea.