



Monitoring spatial patterns for ecosystem assessment, the Bay of Biscay pelagic zone as example.

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- Operational monitoring system
 - Observe with attention to warn of an abnormal situation as fast as possible.
 - Based on indicators
 - ...that assume to reflect the state of the monitored system, or at least one of its components.
- Environment of the pelagic ecosystem

- Hydro-dynamical model coupled to a bio-geochemical model (ECO-MARS 3D) :
 - Hindcast simulation over the period 1971-2007

Raw outputs → **Environmental indices with potential interest to pelagic fish populations**

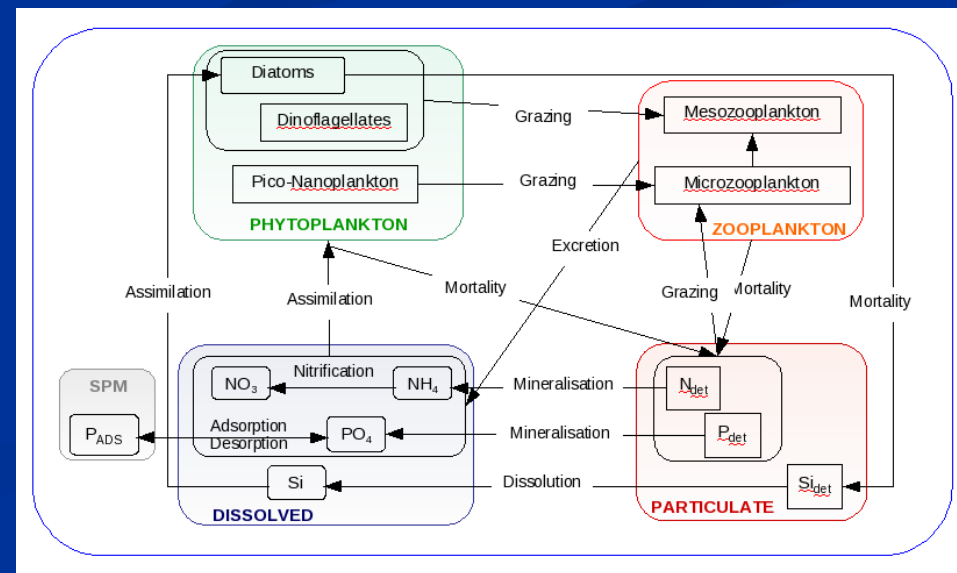
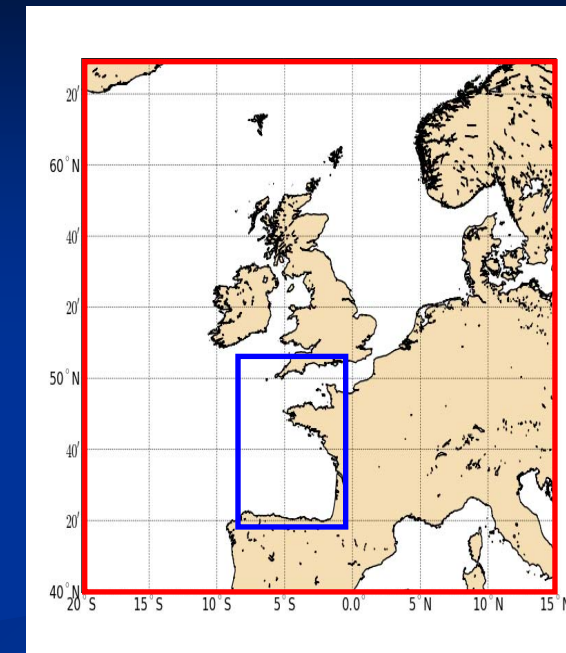


- ECO-MARS-3D (GDGE) Configuration
 - 43.2°N – 50.8°N / 8°W – 0.4°W
 - Horizontal resolution : 4 km
 - Vertical resolution : 30 sigma layers

- Surface elevation (tides) from a larger 2D Model is provide to the 3D model boundaries.

- T, S, chlorophyll and nutrients climatology for the boundaries conditions.

- Forcing :
 - Daily river discharges and nutrient loads :
 - Loire, Gironde, Adour, Vilaine
 - Atmospheric model :
 - ERA : 1.25° (1971-2001)
 - ARPEGE : 0.5° (1996-2007)
 - Studied period : 1972 à 2007

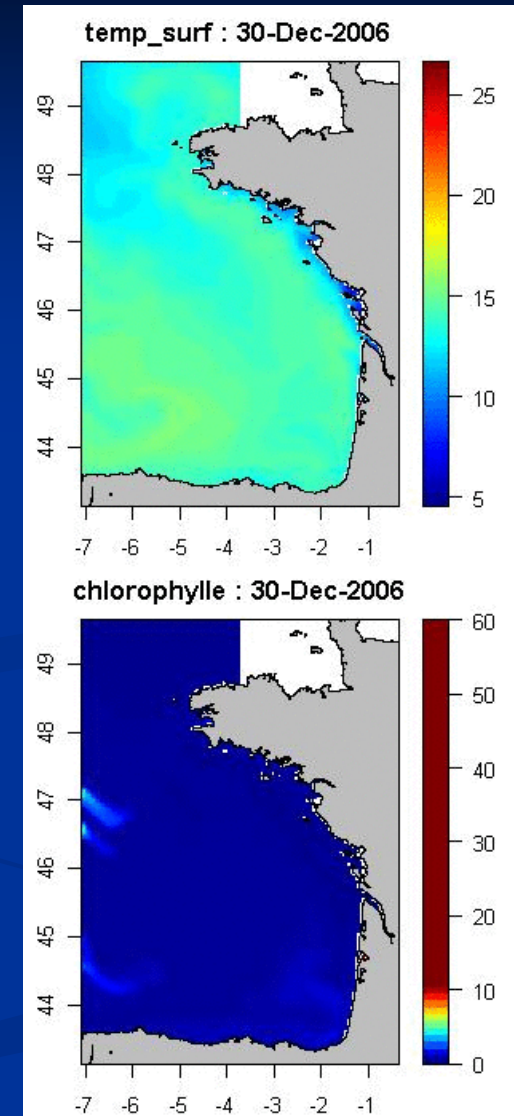




- Sea surface temperature
- Sea bottom temperature
- Sea surface salinity
- Equivalent fresh water height
- Chlorophyll-a concentration
- primary production over 3 days
- Depth of pycnocline
- Deficit of potential energy (in density)
- Density frontal index (from potential energy)
- Horizontal component (U,V) of the surface current (10m)



Map time series of indices (averaged each 3 days, that is to say 122 time lag for 1 year, and 4392 time lag for 36 years).





- EOF (Empirical orthogonal functions)

- Multivariate analysis of dominant patterns of variability in a map time series

$$X(t, s) = Z(t, s) - \bar{Z}(\cdot, s) = \sum_m \sqrt{\lambda_m} u_m(t) e_m^T(s)$$

Scaling factor

- Principal components: projection of X on the eigen vectors

$$u_m(t) = \sum_{s=1}^K X(t, s) e_m(s)$$

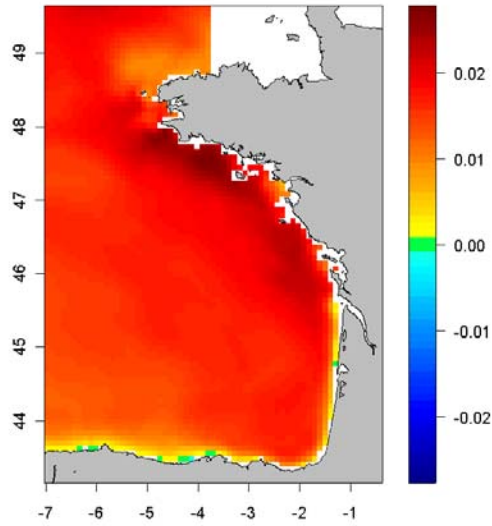
- Additional observations: projection of X_+
 - Local variance in space:

$$VL(s)_m = \left[\text{var}(\sqrt{\lambda_m} u_m(t) e_m^T(s)) / \text{var}(X(t, s)) \right] \times 100$$

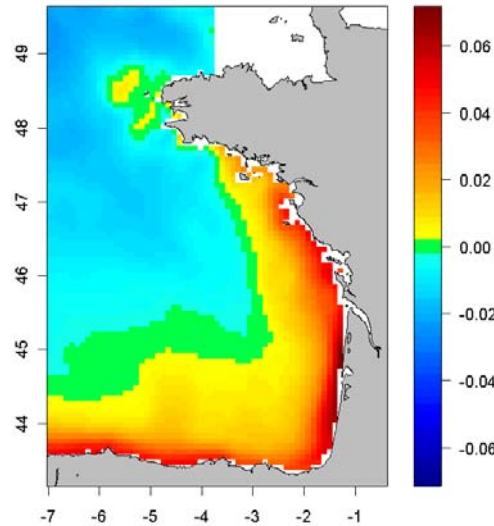


EOFs of the sea surface temperature

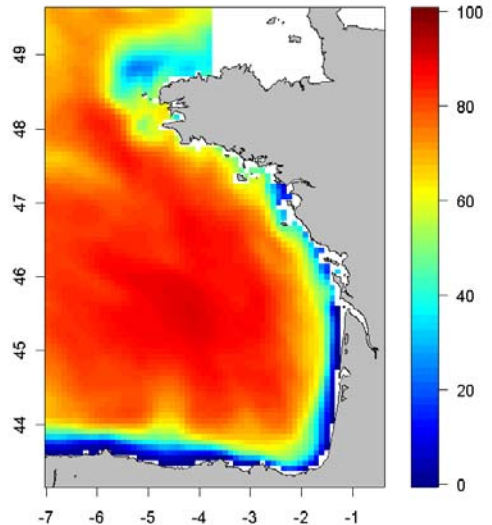
EOF 1 (67 %)



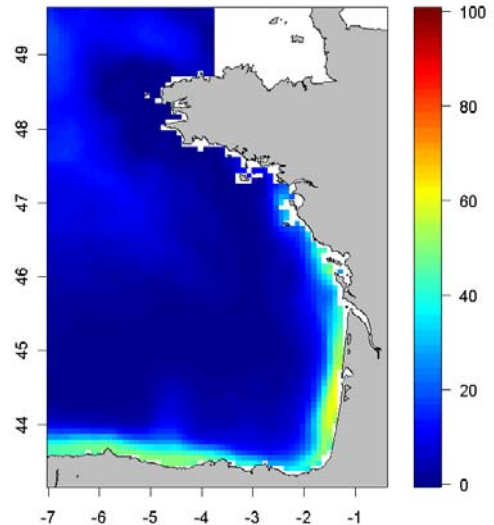
EOF 2 (10 %)



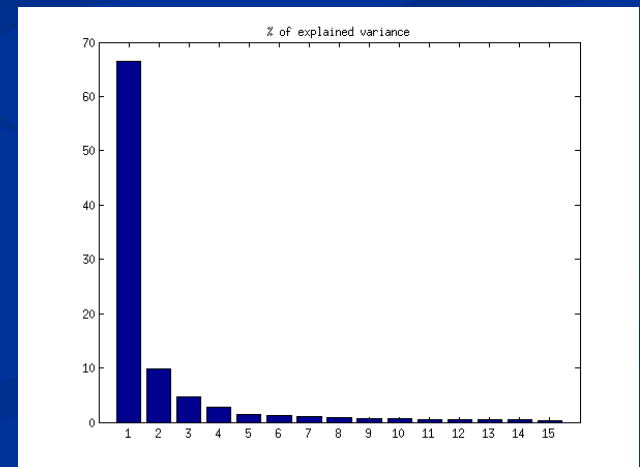
Local variance ref 1

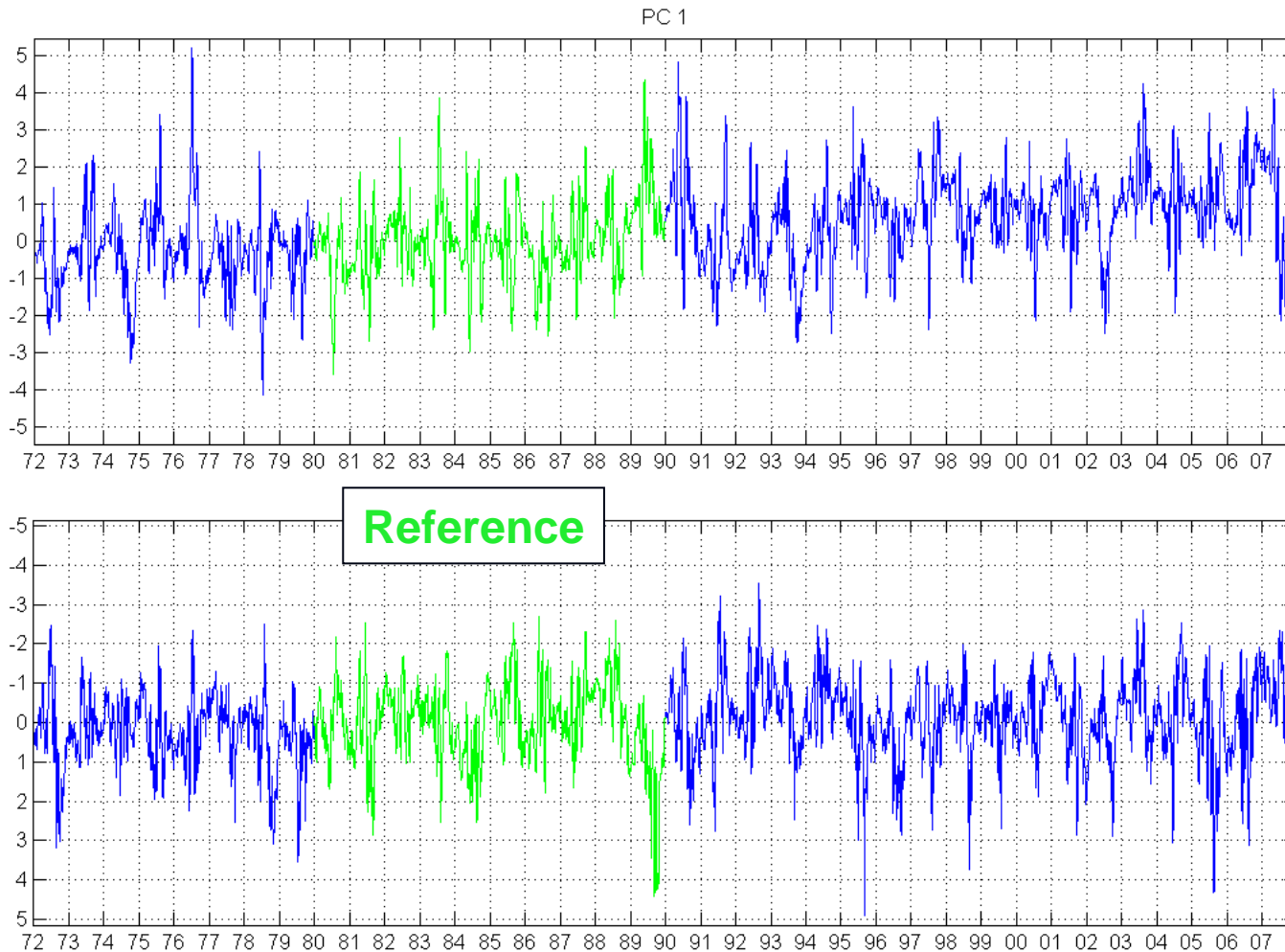


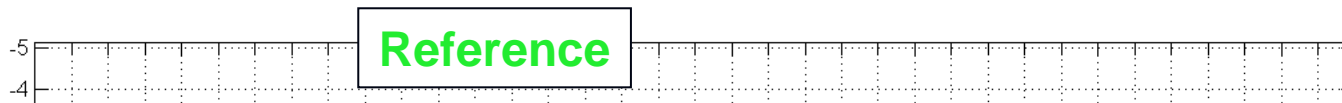
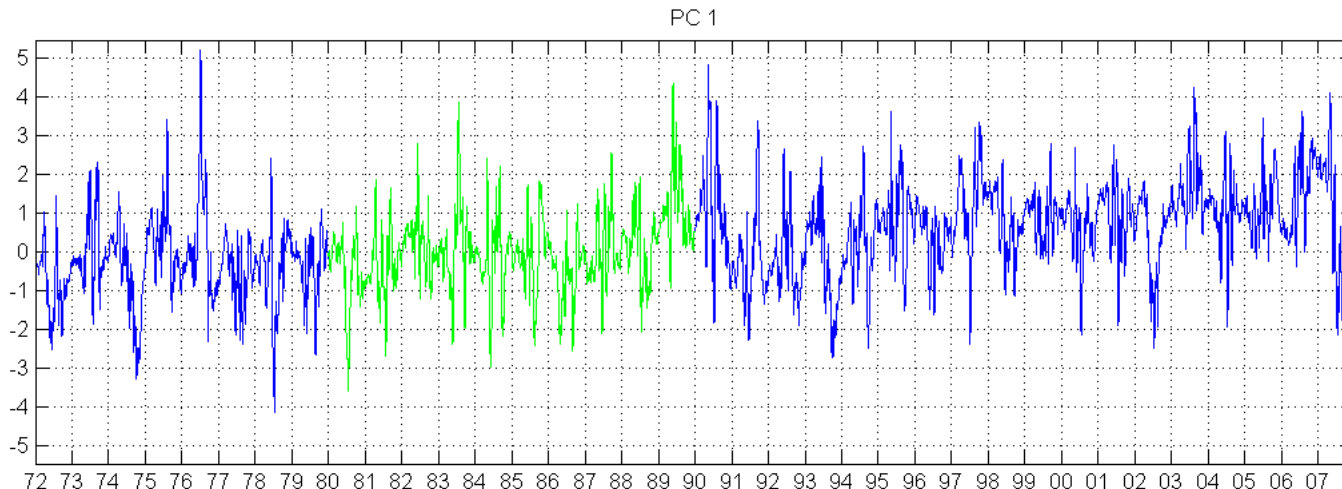
Local variance ref 2



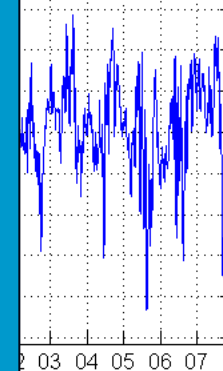
- 77% of explained variance for the two first EOFs.
- EOF1: The Bay of Biscay except the coastal and Ouessant zone.
- EOF2: the coastal zone.







- Years outside the reference period = supplementary observations
- Seasonal signal suppress
 - Seasonal reference mean subtracted to the original series (1972-2007)
- Reference period fixed to the years 1980-1989
 - Stable meteorological regime (East Atlantic pattern slightly > 0)





Combined FIR Dicusum-Shewhart

→ to detect changes in the mean

■ FIR Dicusum :

- Define the reference mean and standard deviation (μ & σ)
- Standardise the data $z = (x - \mu) / \sigma$; choose the allowance k

$$S_0^+ = +h/2 \quad S_0^- = -h/2$$

$$S_i^+ = \max(0, S_{i-1}^+ + z_i - k)$$

$$S_i^- = \min(0, S_{i-1}^- + z_i + k)$$

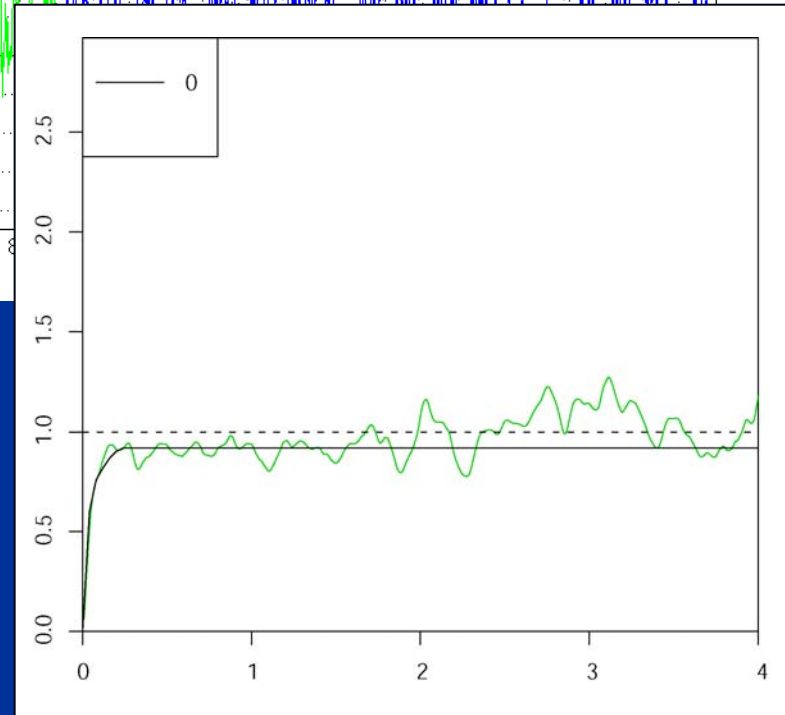
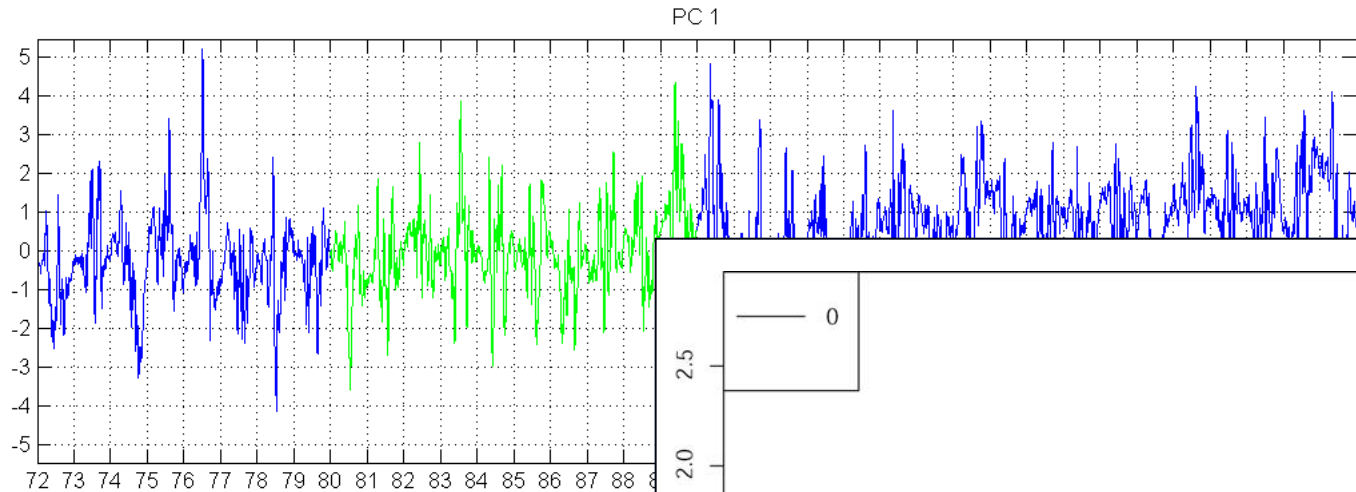
- Raise signal if $S_+ > h$ or $S_- < -h$

■ Shewhart :

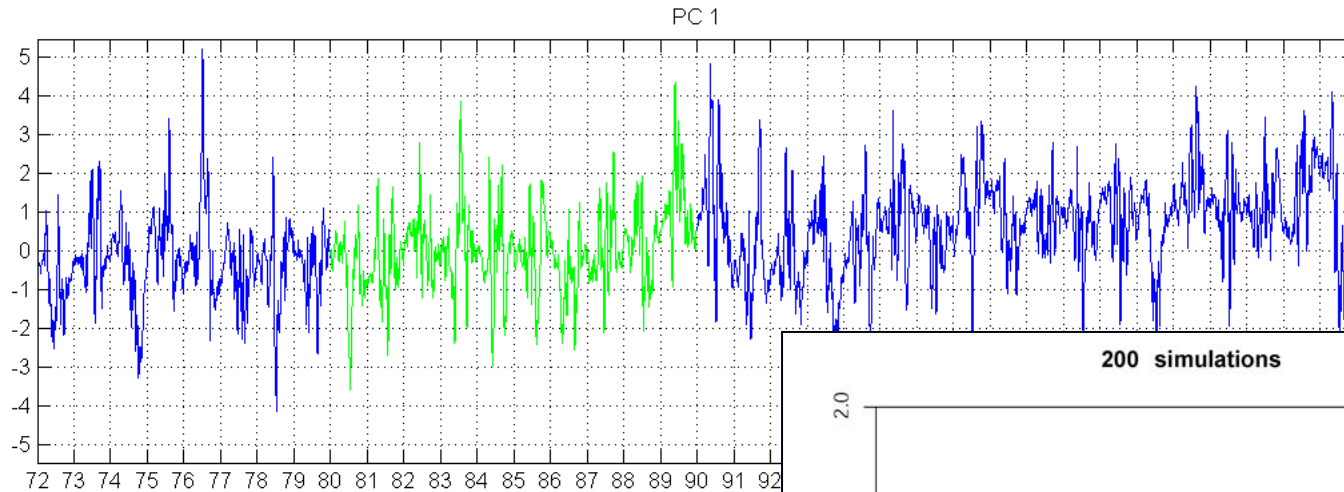
- Values of z above $\pm 3\sigma$ are out of control

■ Evaluation of the statistical performances

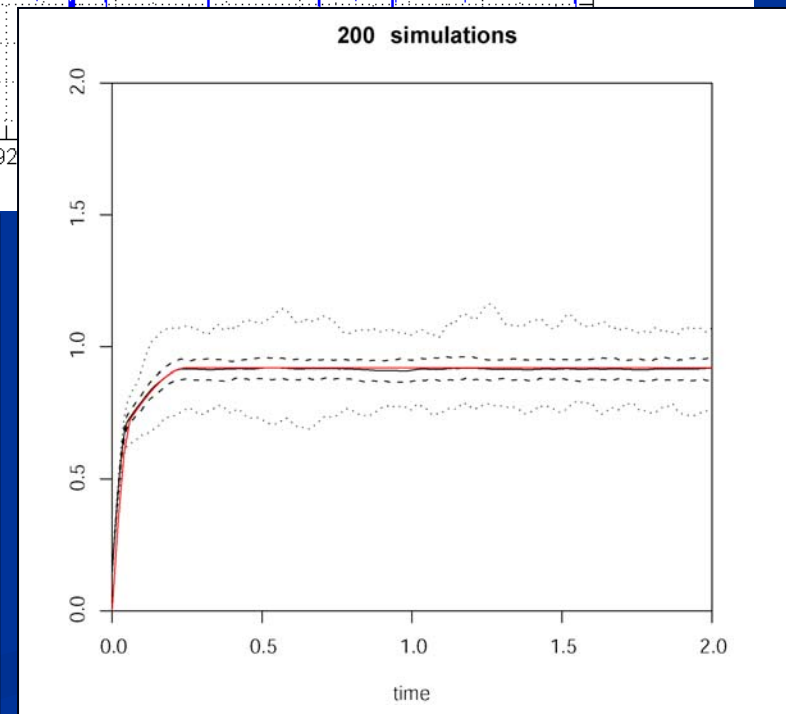
- ARL(0) and ARL(d) function of parameters k et h .



- Modelling the variogram computed over the reference period.



- Non-conditional geostatistical simulation :
 - 200 realisations
- ARLs computation for different k and h :
 - The allowance k is set to the half deviation (in sd unit), that we want to detect.
 - h is chosen so as that $ARL(0)$ is high and $ARL(d)$ small enough.





ARLs computation by simulation (3)

dev	k	h_10	h_20	h_30	h_40	h_50	h_60	h_70	h_80	h_90	h_100
0	0,0625	14	32	56	87	129	183	249	307	366	483
0	0,1250	17	38	73	128	197	279	403	581	778	1001
0	0,2500	21	62	131	253	433	721	1175	1718	2315	2691
0	0,5000	49	178	452	1112	2161	3136	3752	4045	4179	4228
0	0,7500	116	509	1678	3109	3974	4204	4244	4259	4300	4300
0	1,0000	271	1572	3354	4127	4267	4295	4300	4300	4300	4300
0	1,5000	1476	4001	4295	4300	4300	4300	4300	4300	4300	4300

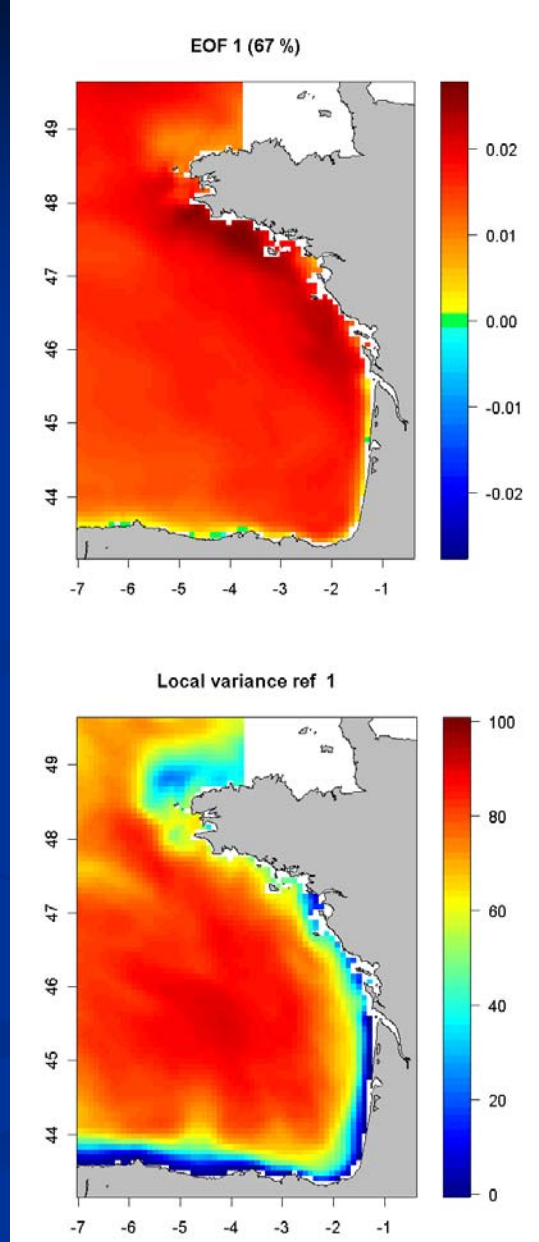
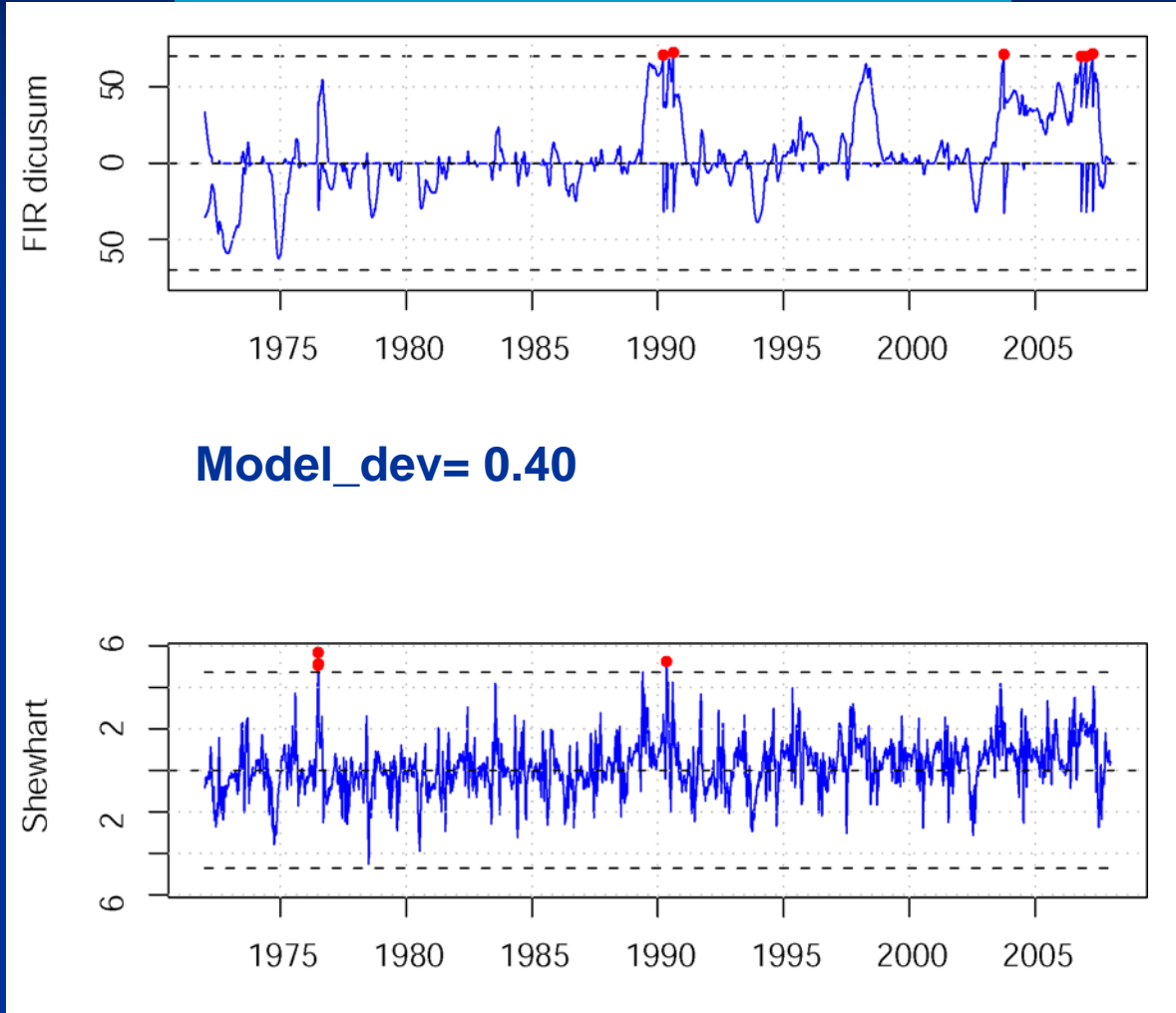
dev	k	h_10	h_20	h_30	h_40	h_50	h_60	h_70	h_80	h_90	h_100
0,1250	0,0625	14	31	53	86	137	193	242	291	353	397
0,2500	0,1250	17	36	61	98	148	194	235	280	314	357
0,5000	0,2500	18	38	57	78	101	122	144	164	185	210
1,0000	0,5000	14	24	34	43	52	62	70	80	89	100
1,5000	0,7500	10	16	22	27	34	39	45	51	58	64
2,0000	1,0000	7	11	16	20	24	29	32	36	40	44
3,0000	1,5000	4	7	9	12	14	16	17	19	20	21

- $ARL(0)=3974, ARL(d)=34.$



Combined FIR Dicusum-Shewhart (1)

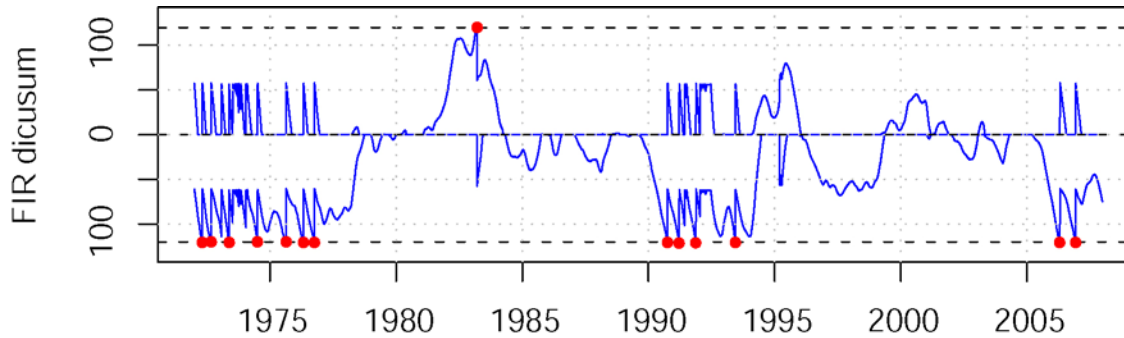
■ PC1 (surf temp): $k=0.75$; $h=50$



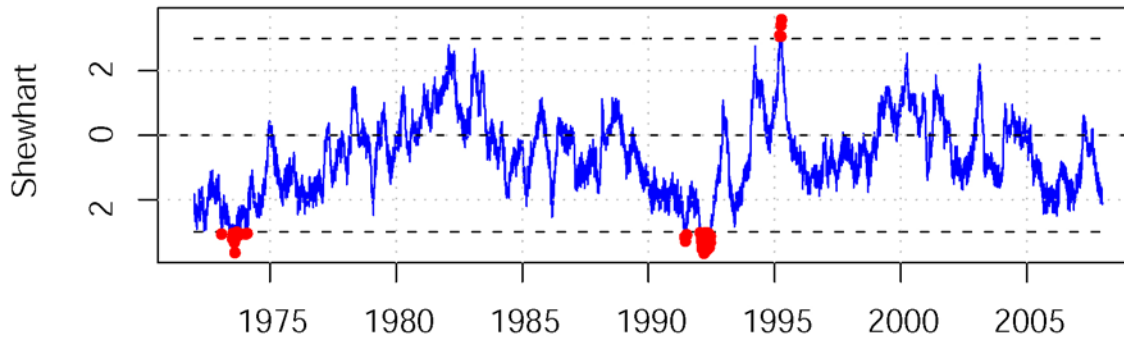


Combined FIR Dicusum-Shewhart (2)

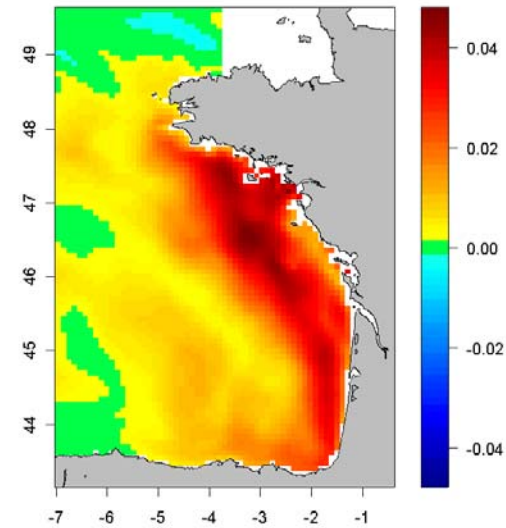
- PC2 (eq fresh water height): $k=0.75$; $h=120$



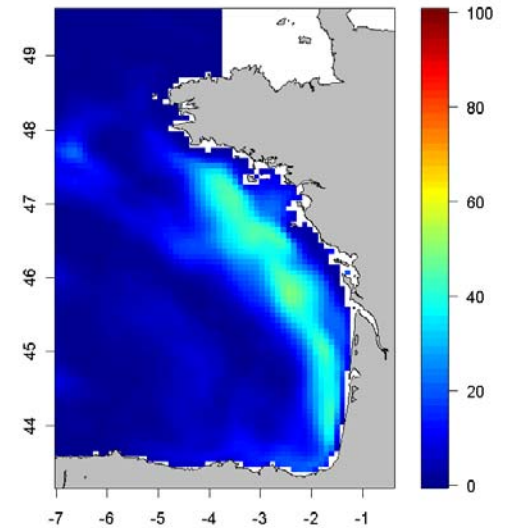
- $ARL(0)=1640$, $ARL(d)=104$.



EOF 2 (14%)

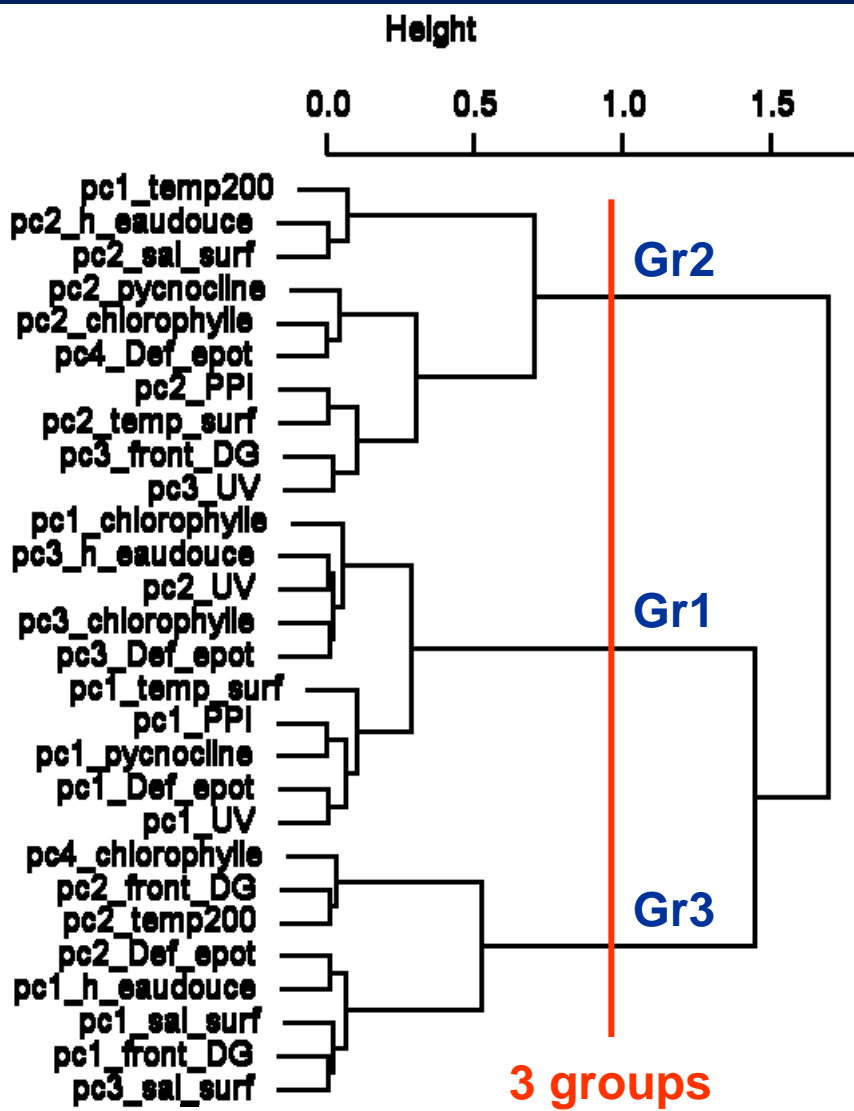


Local variance ref 2

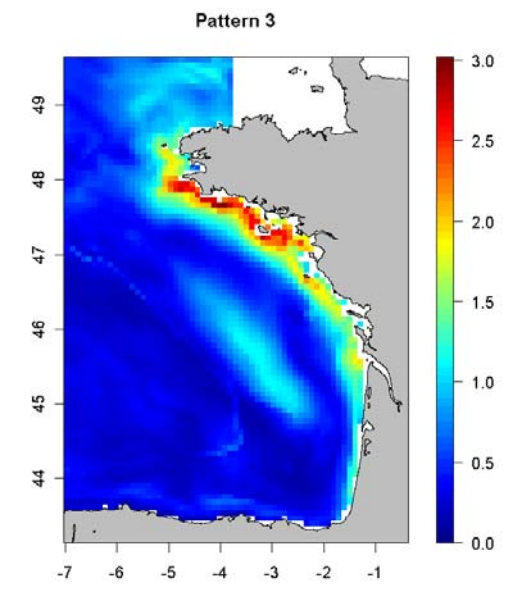
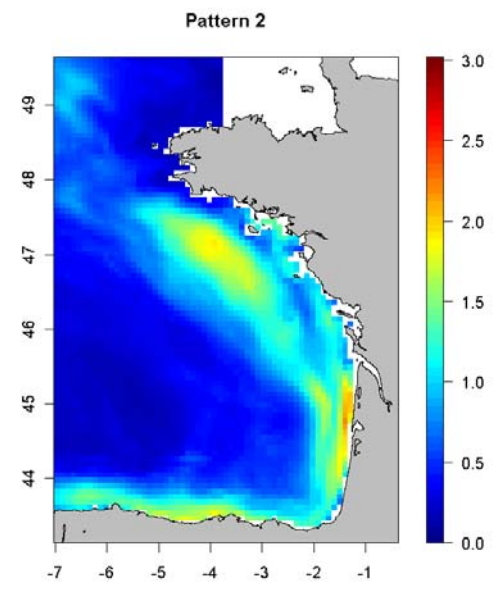
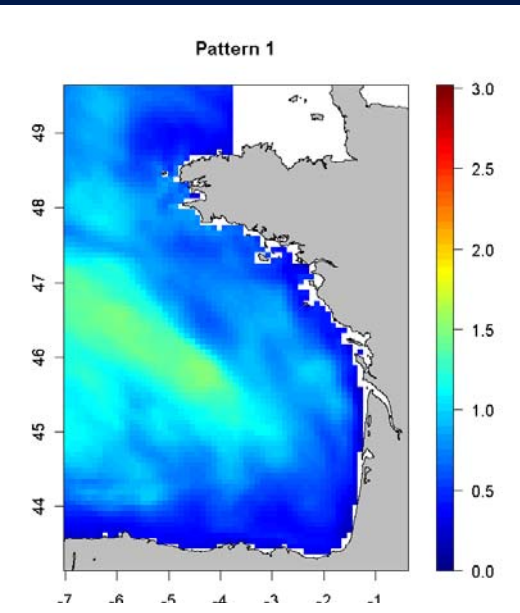




Clustering the indices

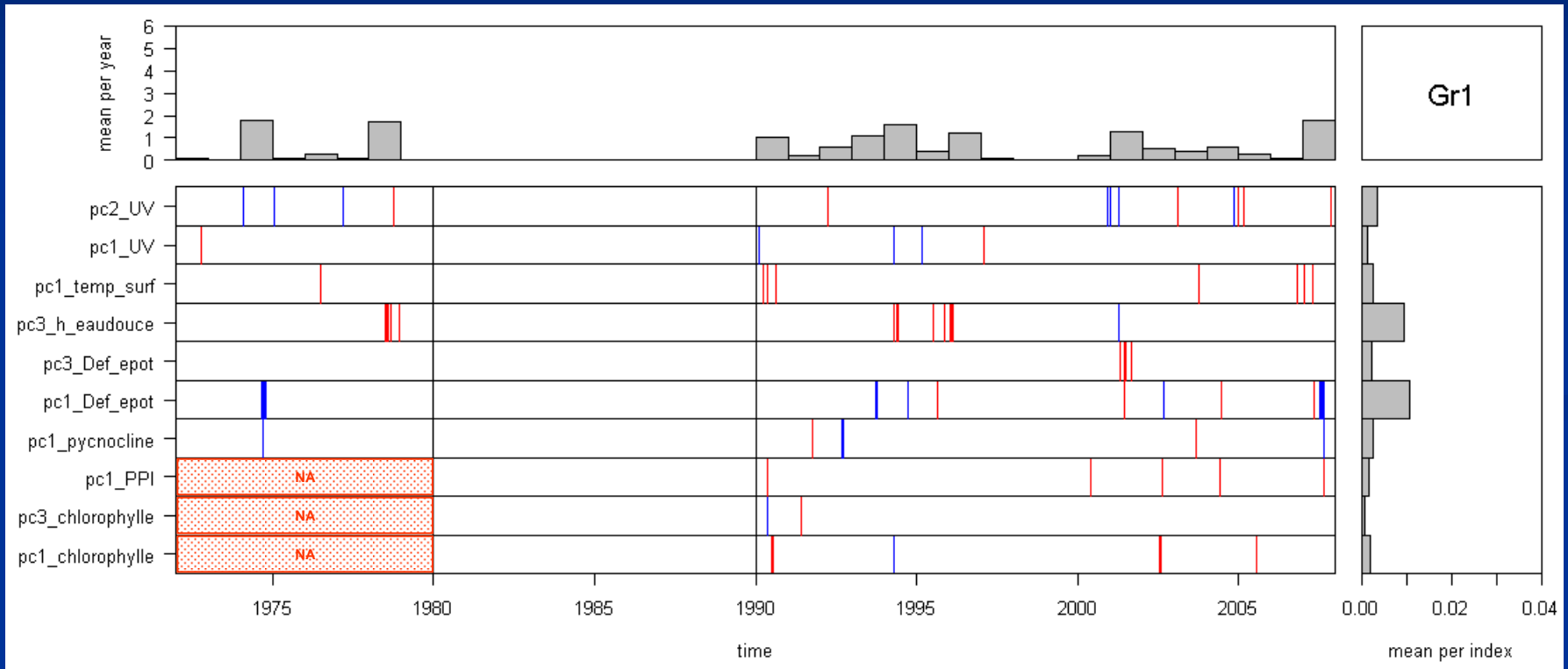


- PCA on the local variance maps.
- Hierarchical clustering on the PCA variables
 - Ward's method



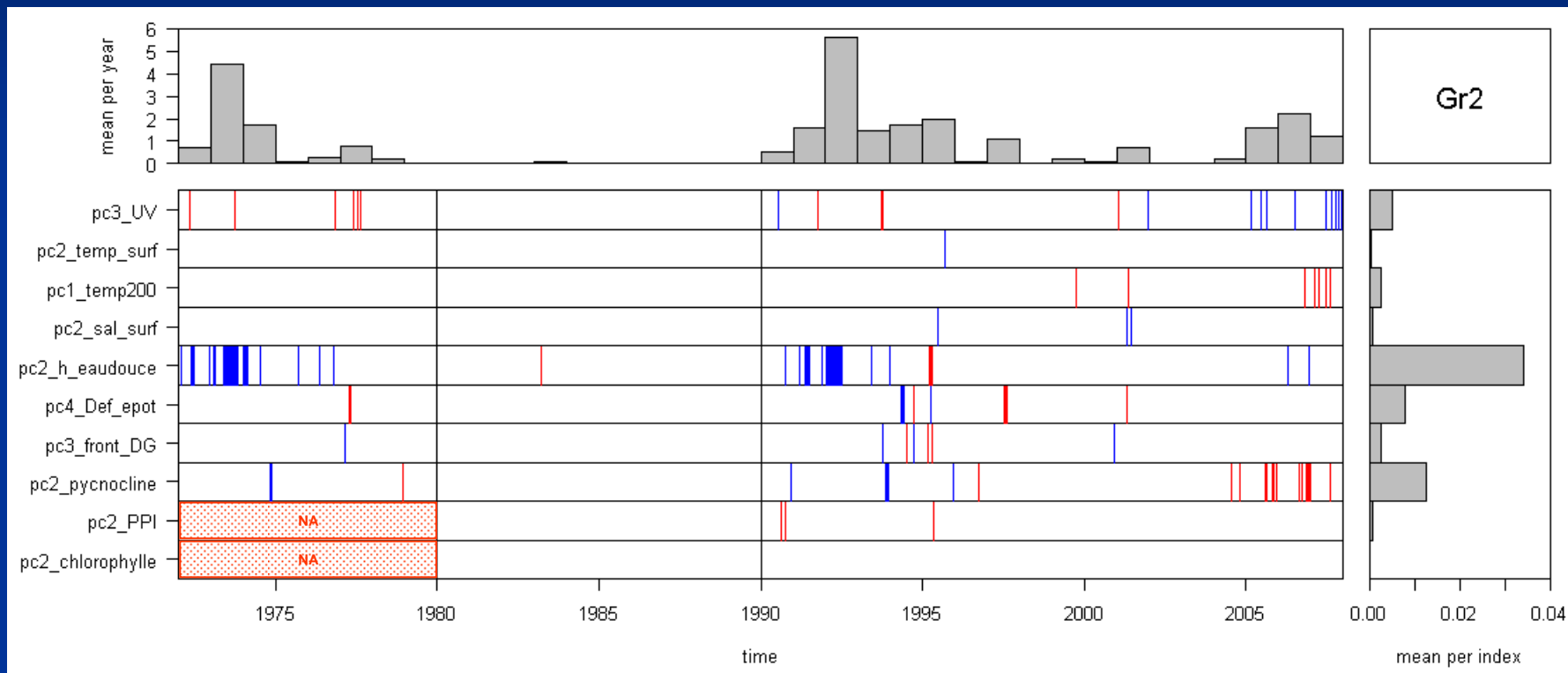


■ Group n°1 : off shelf



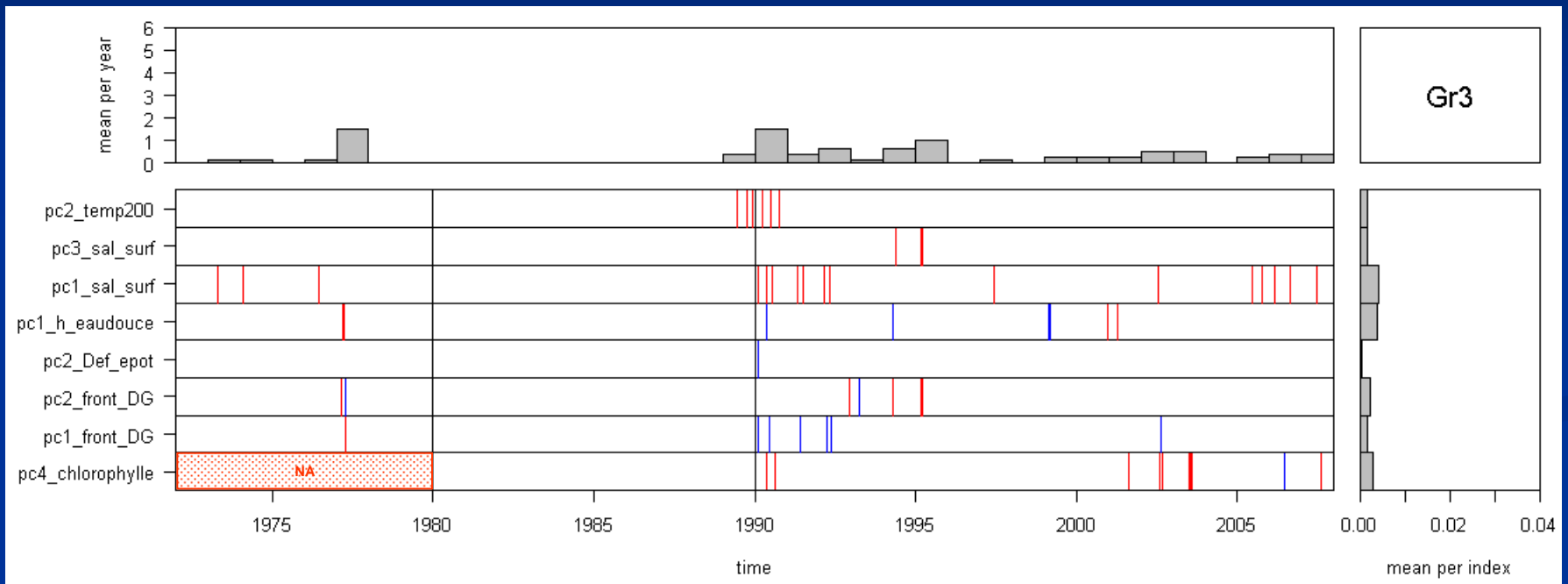


■ Group n°2 : outer part of the continental shelf





■ Group n°3 : Inner part of the continental shelf





- Operational monitoring procedure → traffic light table of the environment :
 - Alarms identified by geographical zone
 - Off shelf :
 - High variability in the alarm occurrence.
 - Outer part of the continental shelf :
 - More stratification (pycnocline) en 2004-07
 - Alternation of dryer/wetter years (eq fresh water height)
 - Higher bottom temperature in 2006-07
 - Inversion or reduction of the coastal current with respect to the seasonal pattern
 - Inner part of the continental shelf :
 - Alternation of dryer/wetter years (surface salinity)
 - High values of chlorophyll in 2001-03, 2007
 - Few alarms for the years 1997-99.

- Coupling with pelagic populations traffic light table
 - Functional relationship should be investigated based on research surveys data



Thanks for your attention

