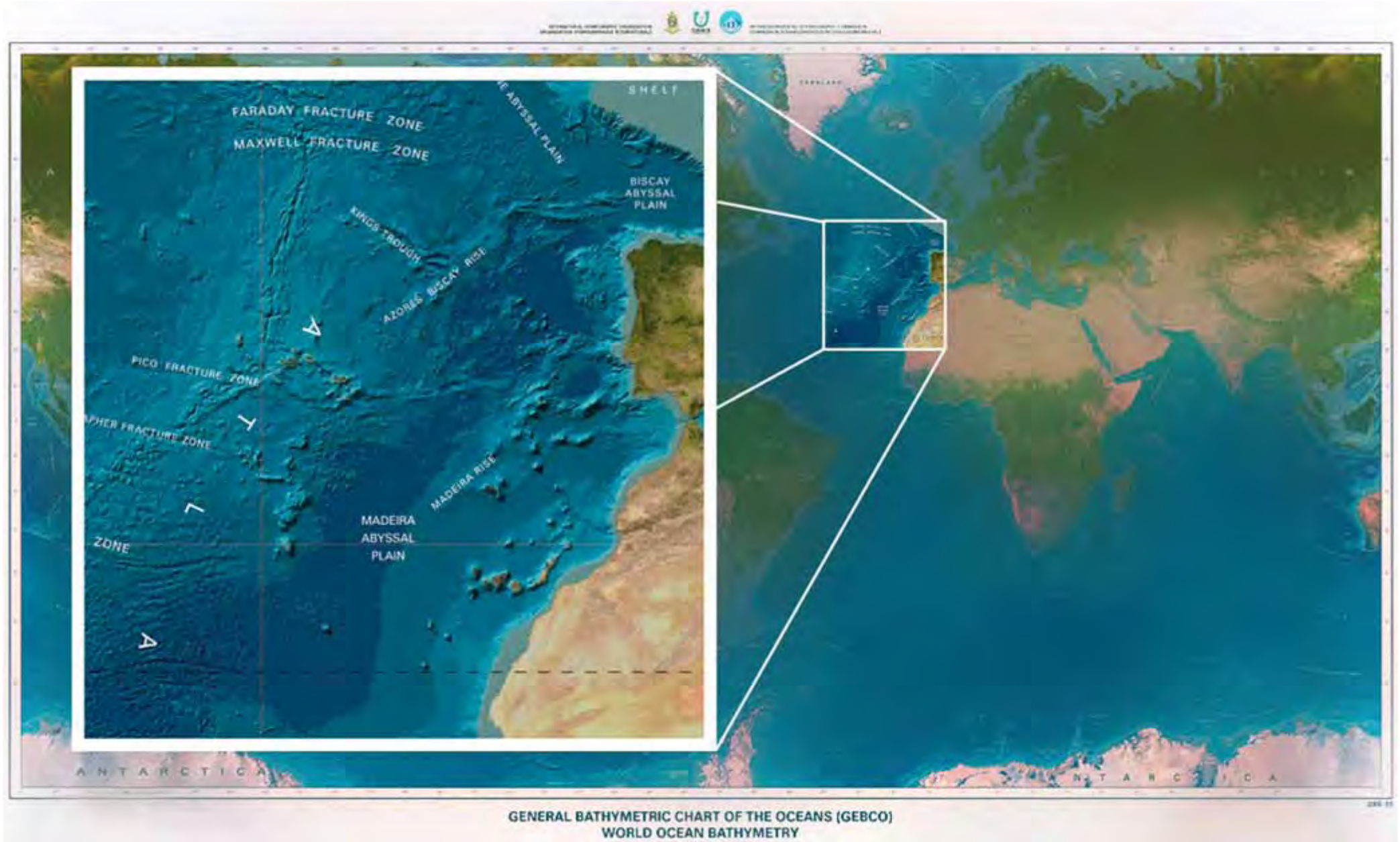
Saint Petersburg State University
Laboratory of regional oceanography

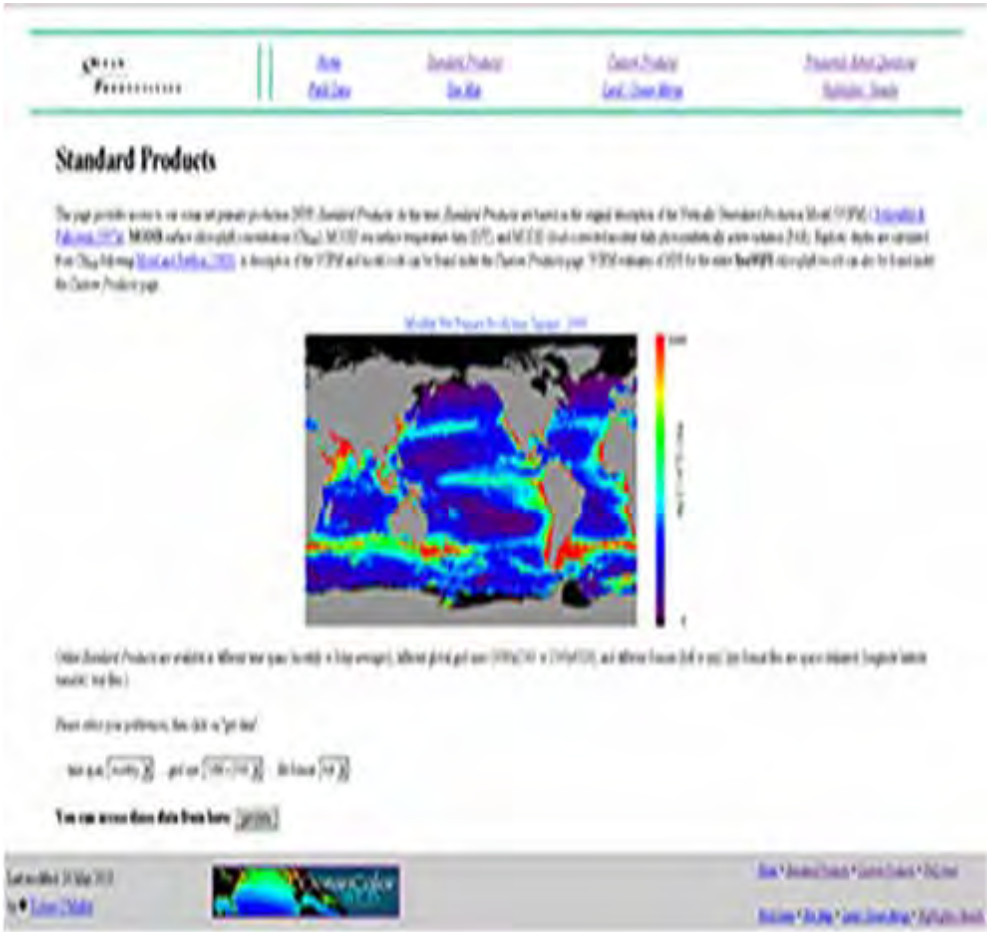
Tatyana Belonenko

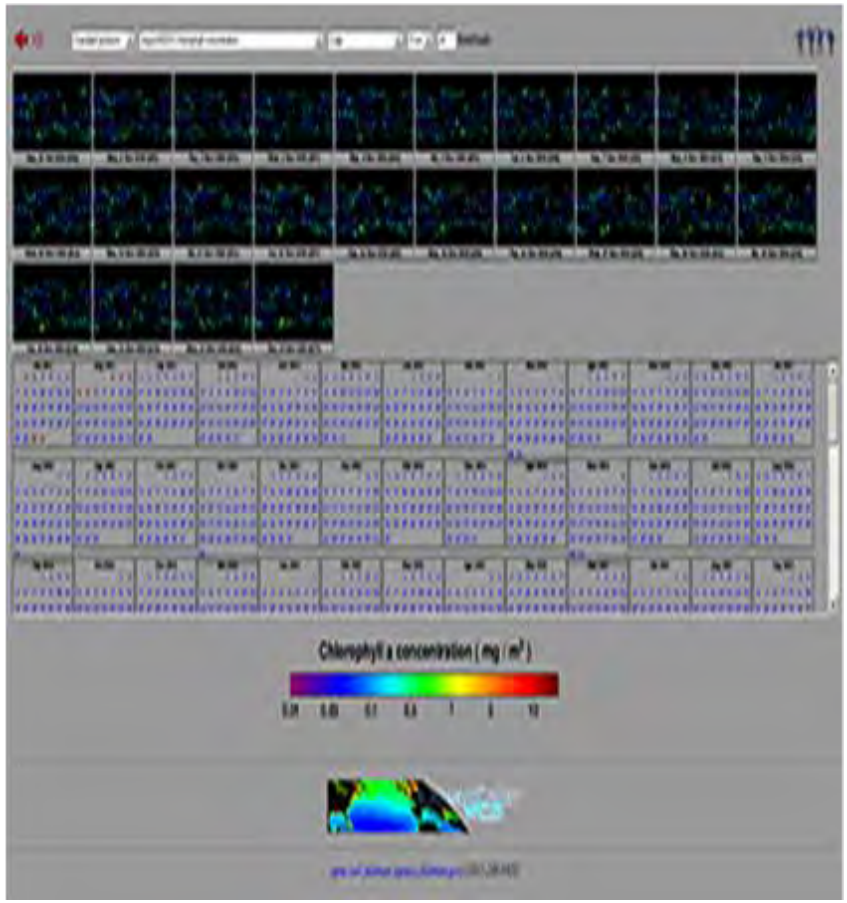
Non-stationary cycles of primary productivity in the northeastern Atlantic

The study purpose was the spatial-temporal variability of primary productivity in the Azorean area of the Atlantic.

The study area is within 20-50º N and 5-40º W

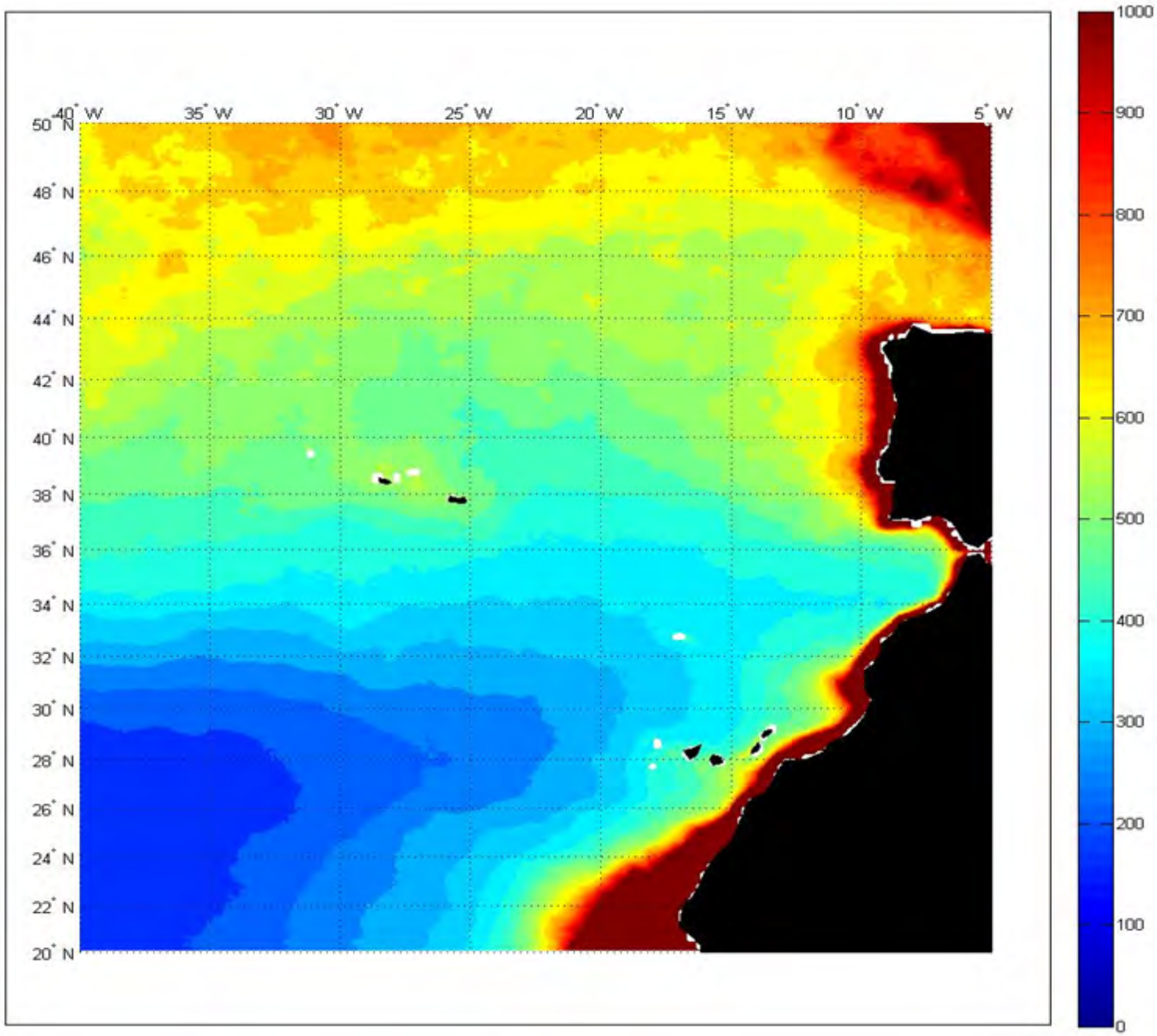






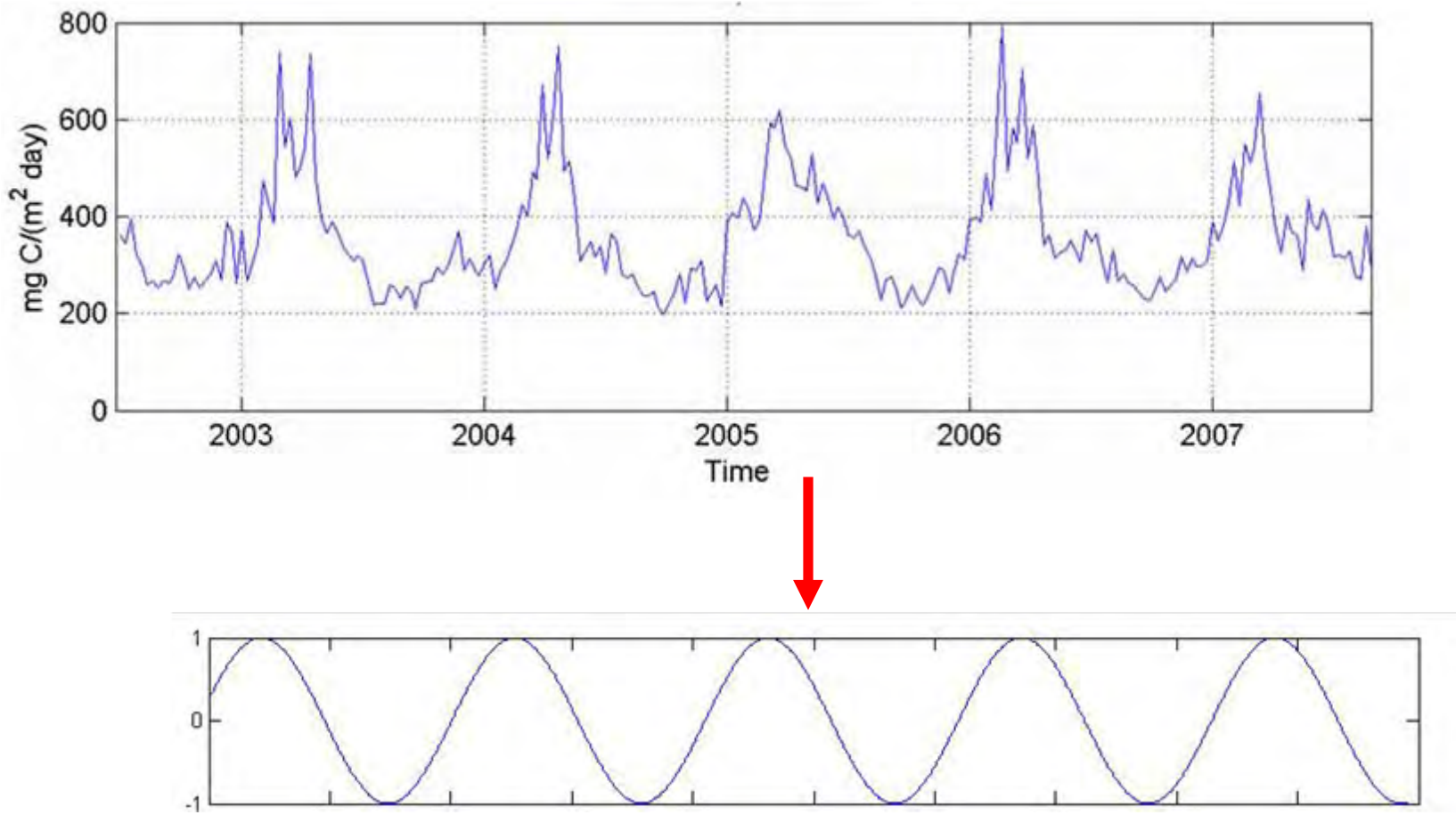
***Behrenfeld, MJ, PG Falkowski**. Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnology and Oceanography 1997a, Volume 42: 1-20*

http://www.science.oregonstate.edu/ocean.productivity/index.php



Multi-year mean distribution of primary production in mgC/m2/d

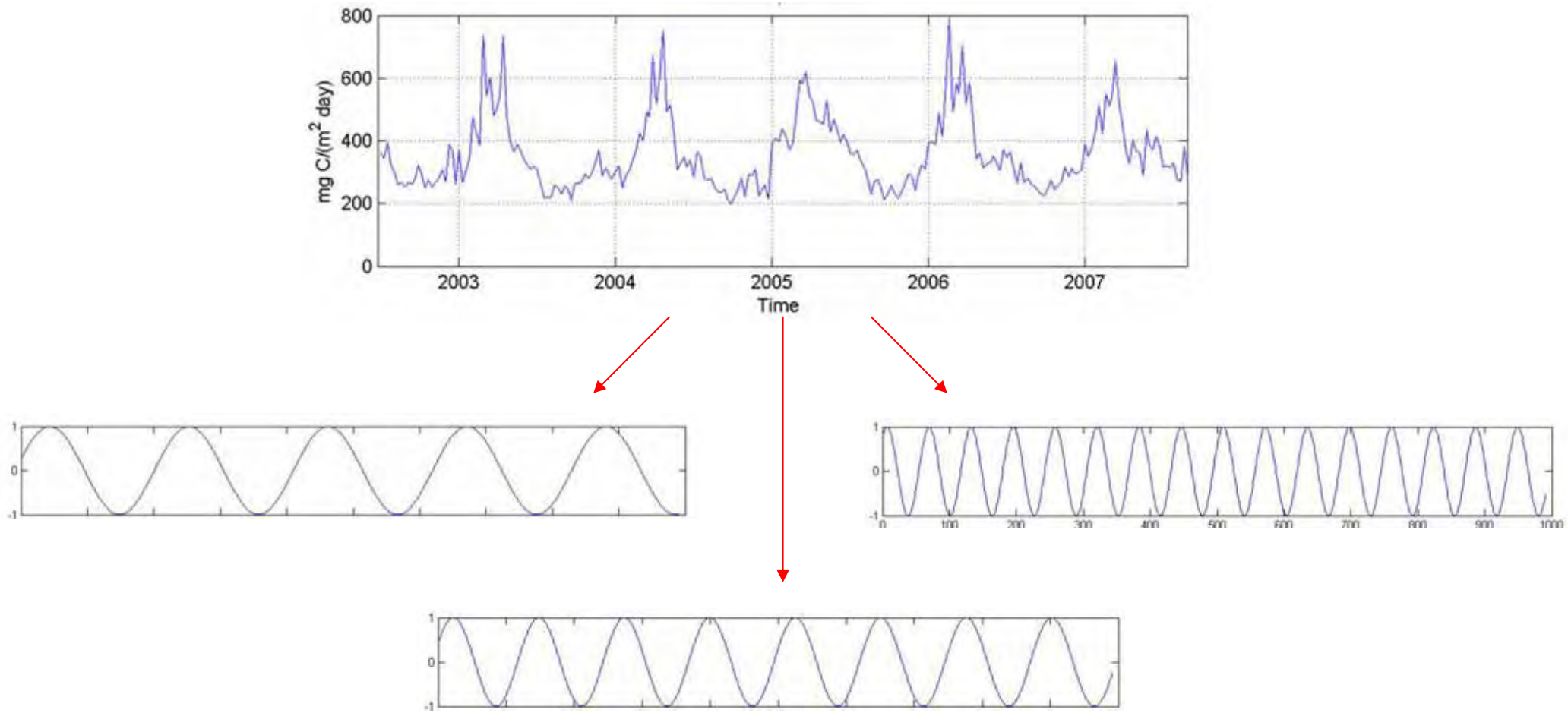
Process periodicity



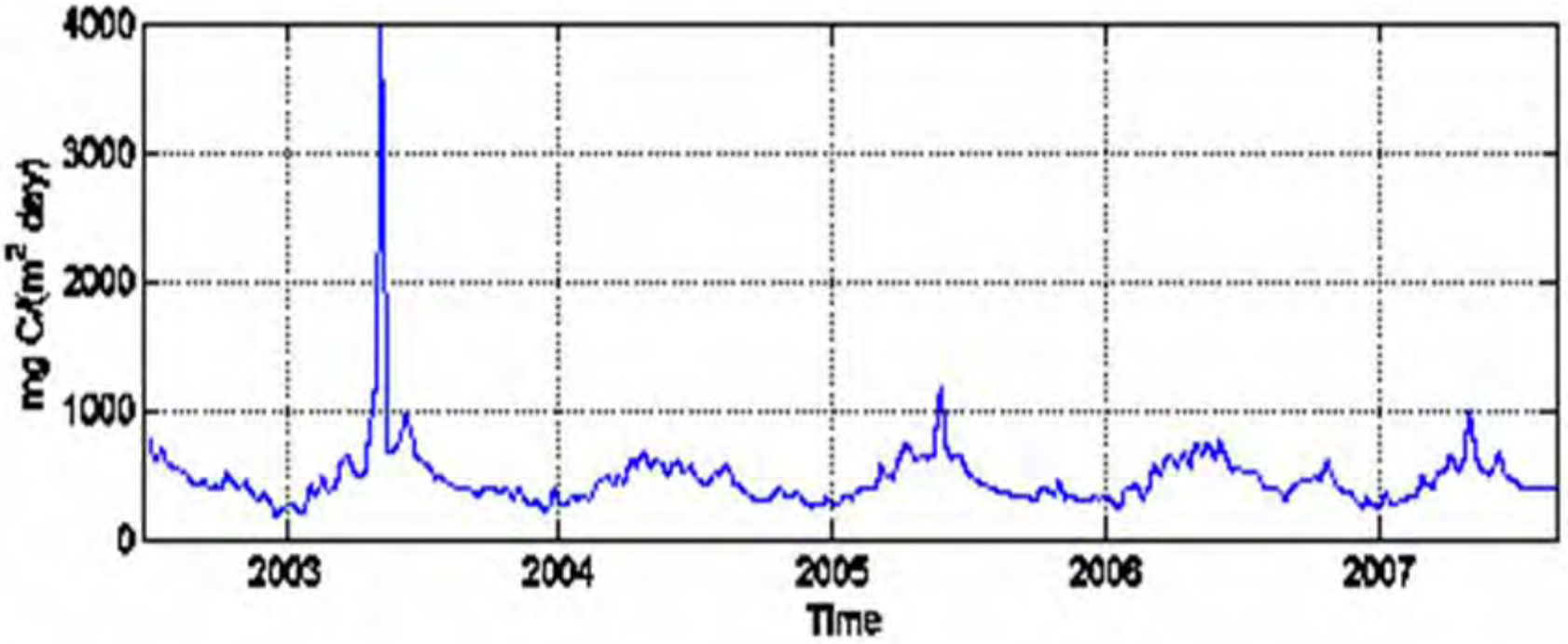
Spectral analysis principle:

processes can be approximated with a cosine curve

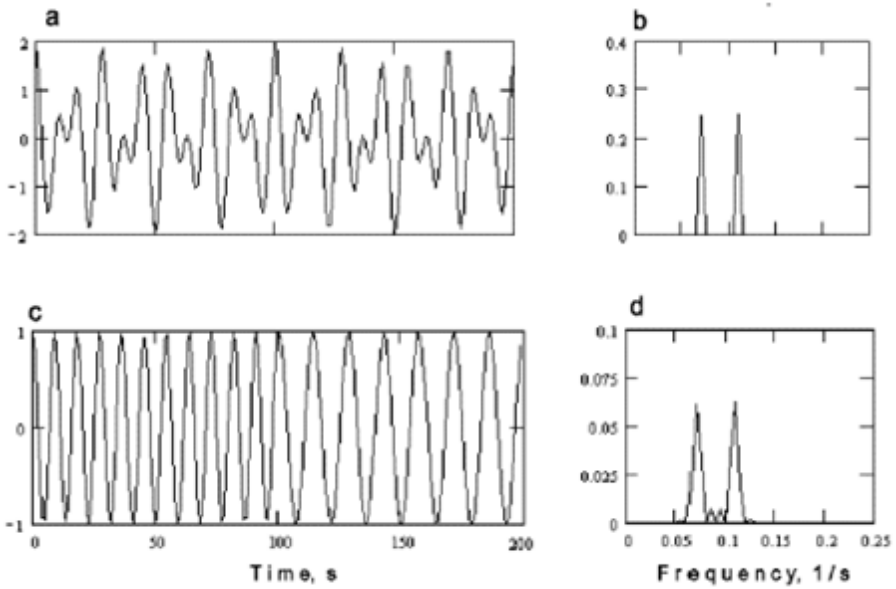
Complex processes



A main flaw of the Fourier analysis is not allowing studying the unsteady processes

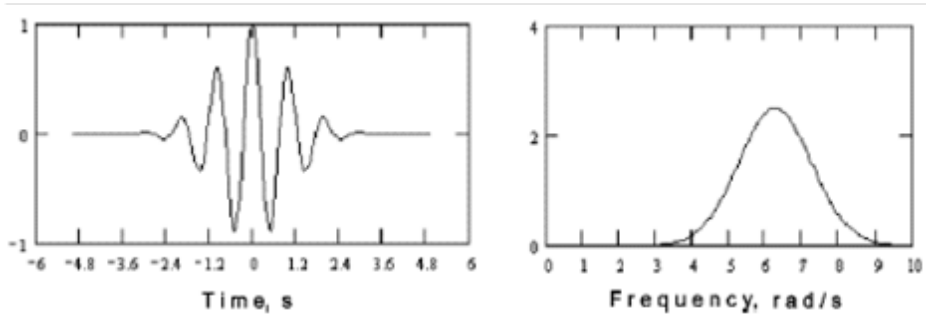


Wavelet-analisys method



$$W(a,b) = \frac{1}{|a|^{1/2}} \int_{-\infty}^{\infty} f(t)\Psi^{*}\left(\frac{t-b}{a}\right)dt$$

$$a, b \in R, \quad a \neq 0$$



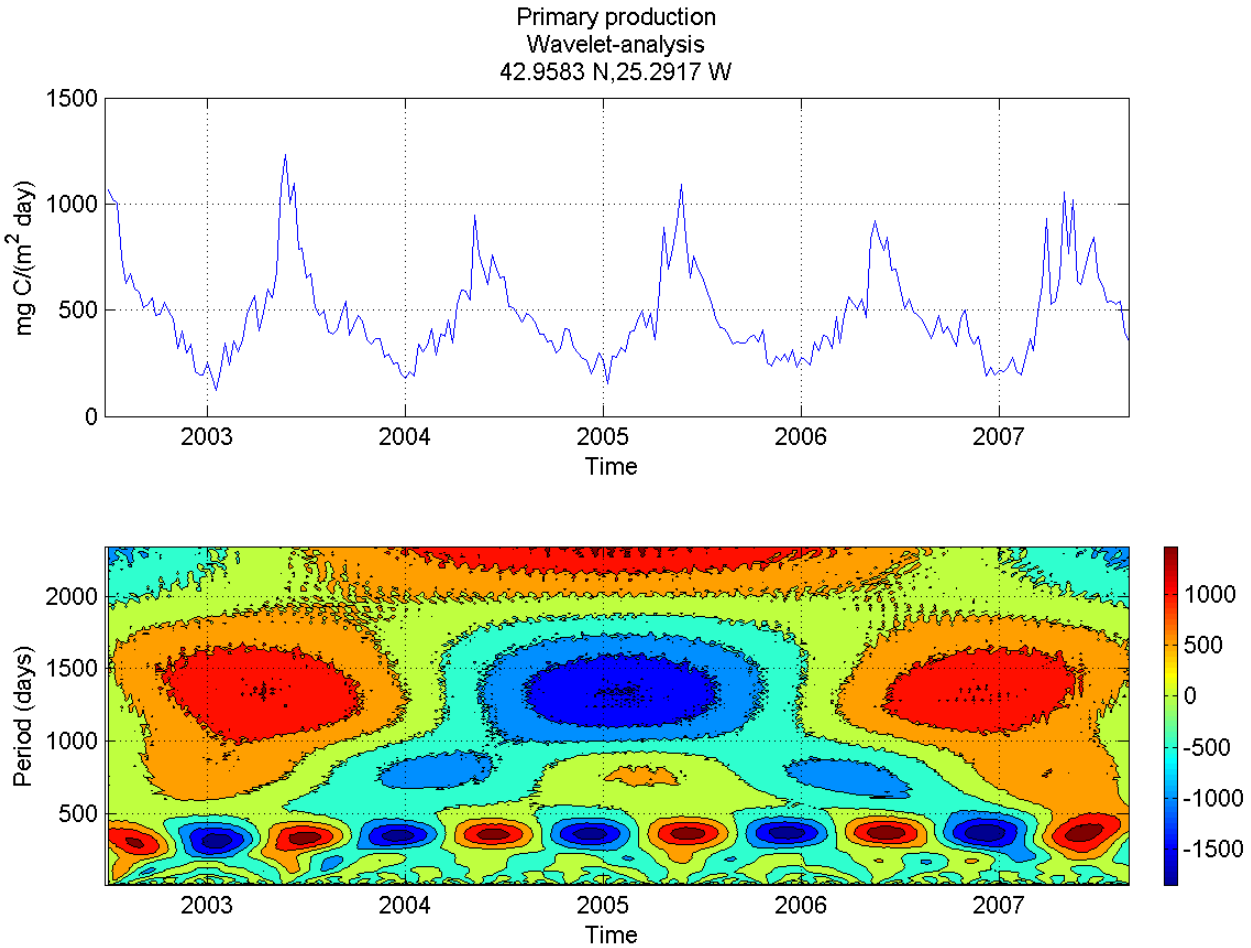
Ambiguity of the Fourier transform:

a) a time series generated as the sum of two sinusoids, 0.062 and 0.105 Hz, and *b)* the spectrum diagram of the sum;

b) c) a time series designed as a succession of the same sinusoids and *d)* the resulting spectrum diagram.

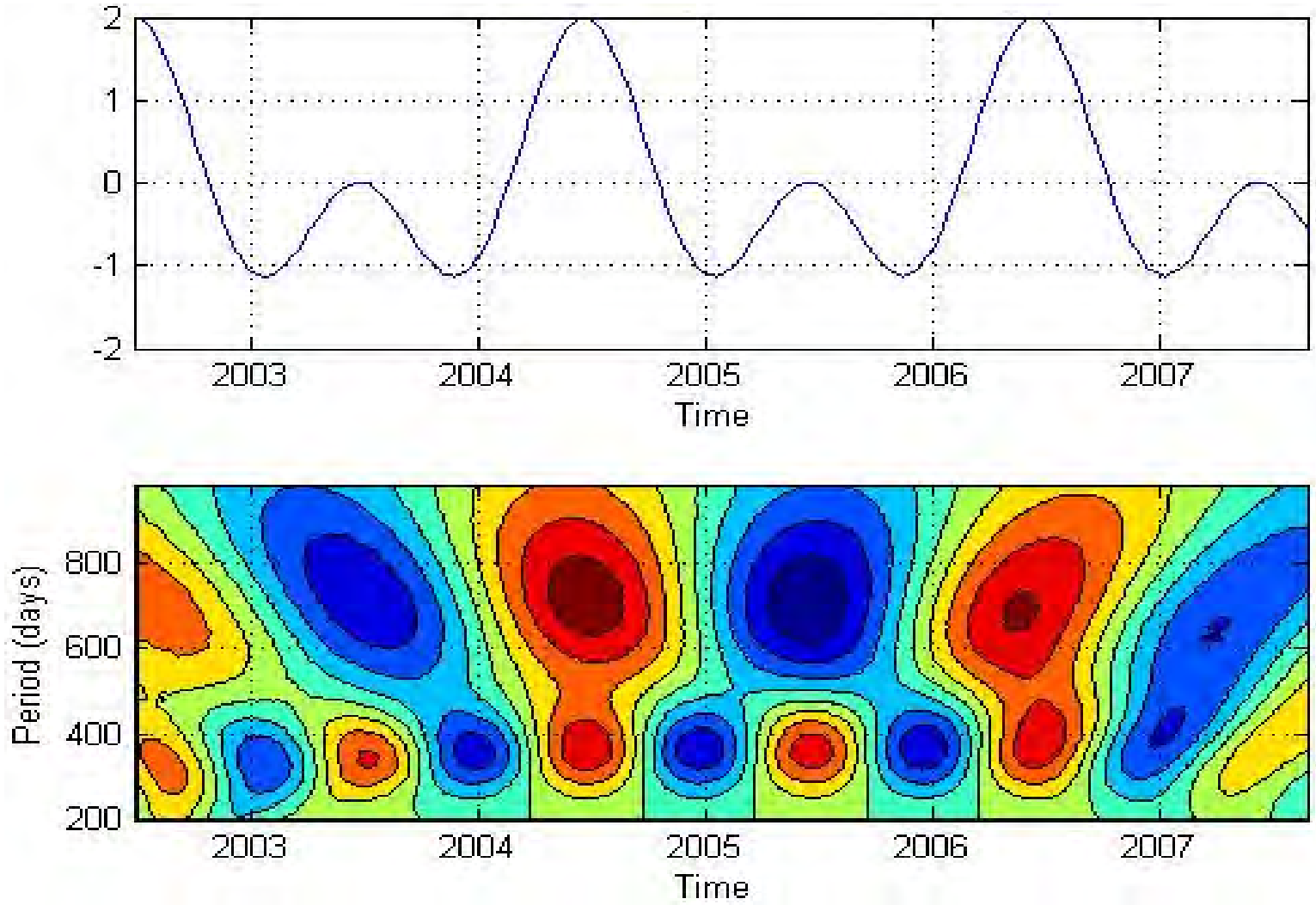
The real part of the Morlet wavelet (*left*) and its Fourier transform (*right*).

A case of the primary production variation at a point of the studied area and the resulting wavelet analysis



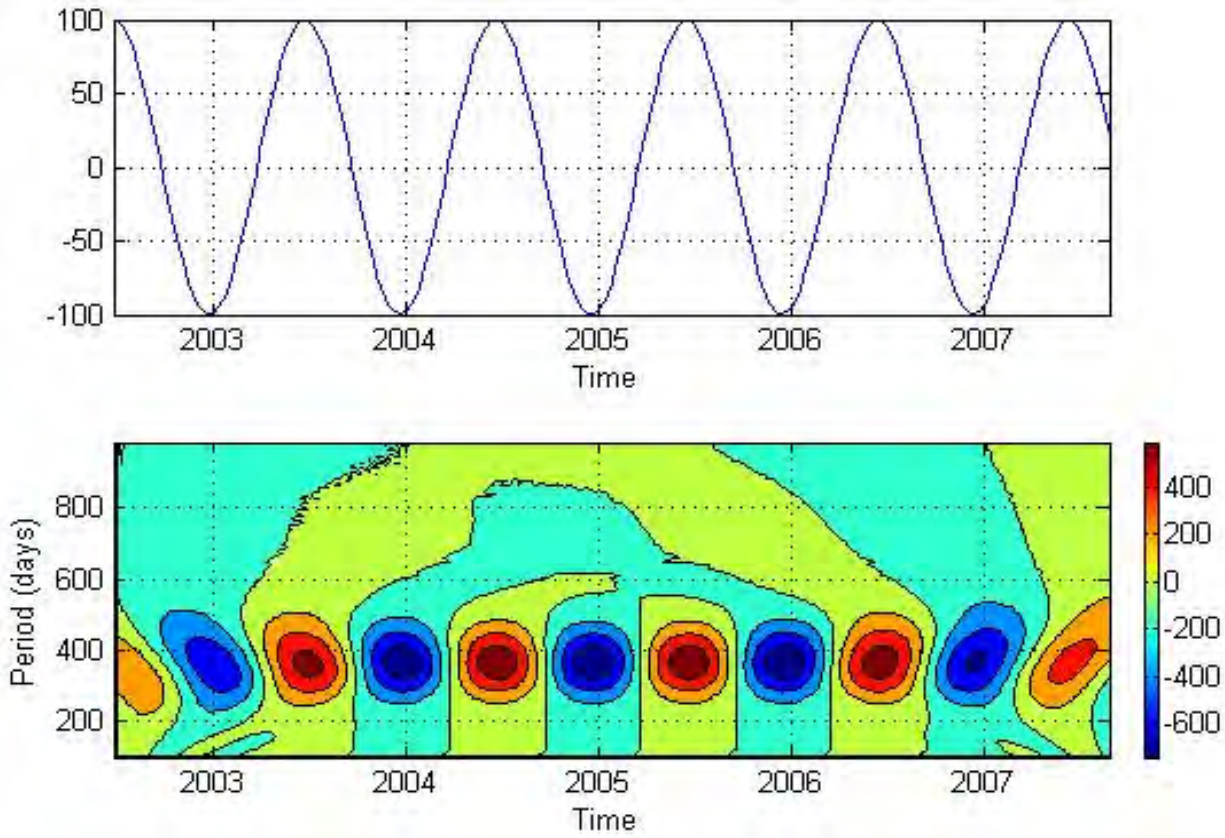
Let's consider several tests comprising the time series in the form of a sum of harmonics. It will help to understand better the results attained with wavelet analysis. Here is shown the **sum of two harmonics** with periods 1 and 2 years, as well a wavelet transform of the sum.

$$p = \cos(2\pi t/(365/8)) + \cos(2\pi t/(2\cdot 365/8))$$

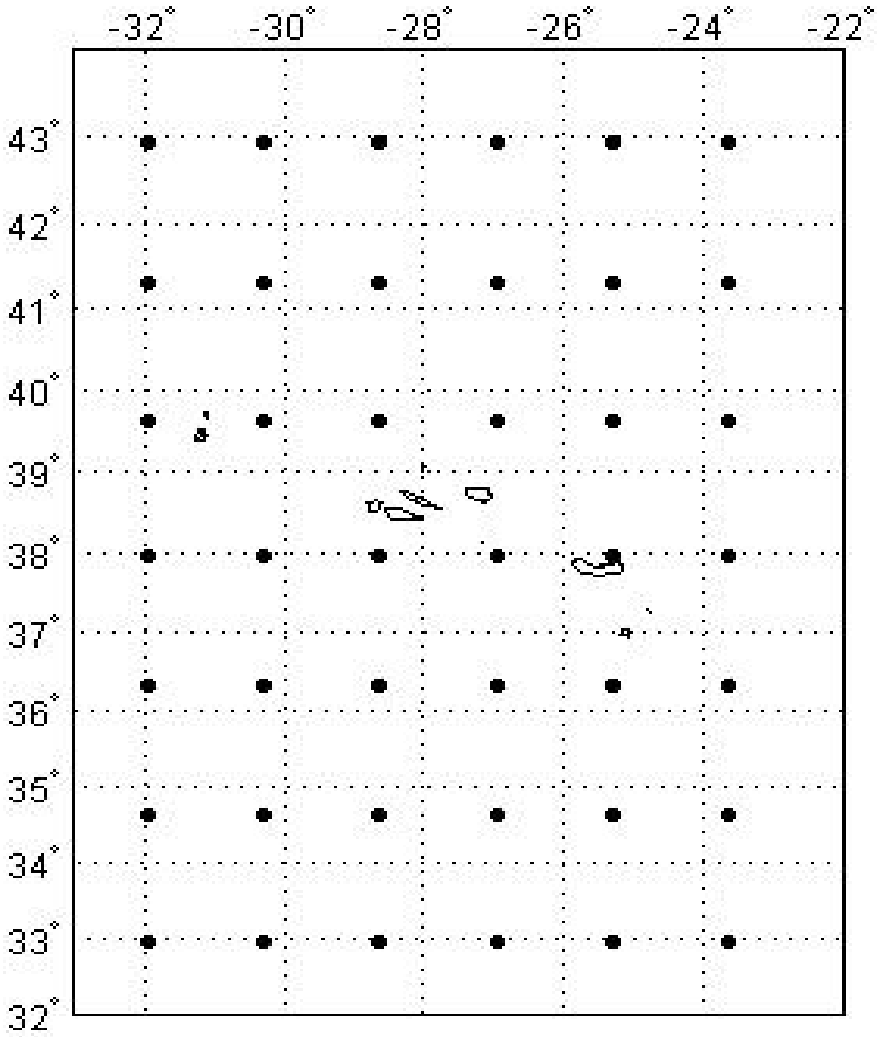


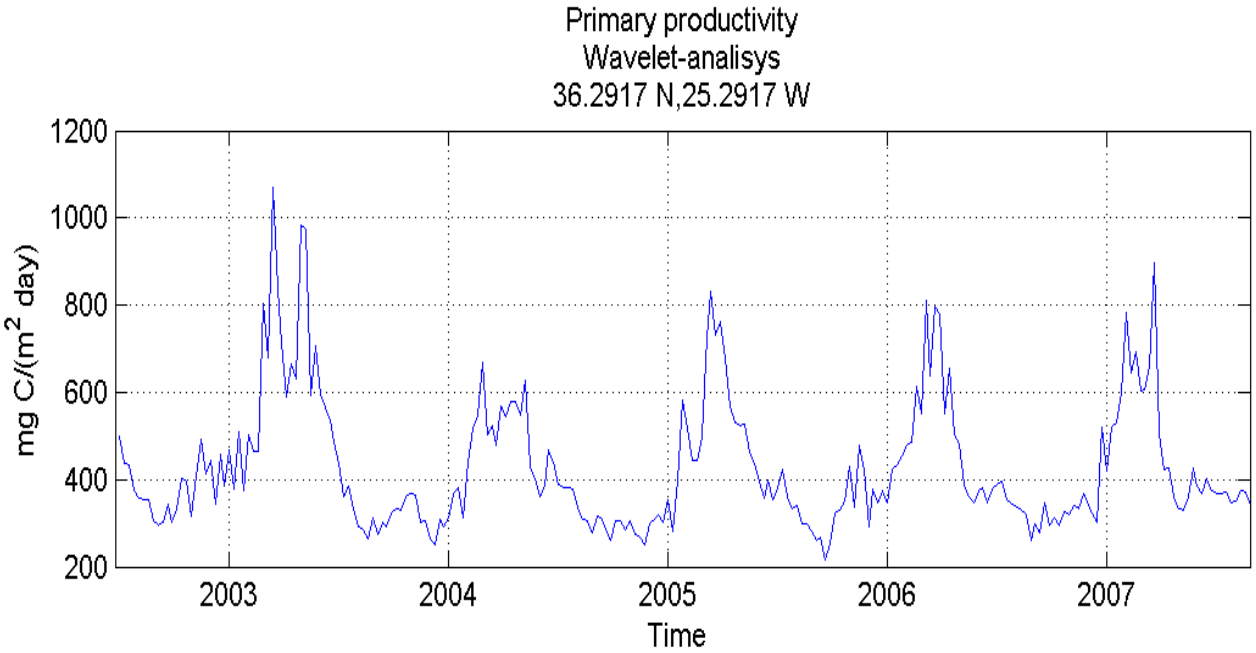
A 1-year harmonic and its wavelet transform

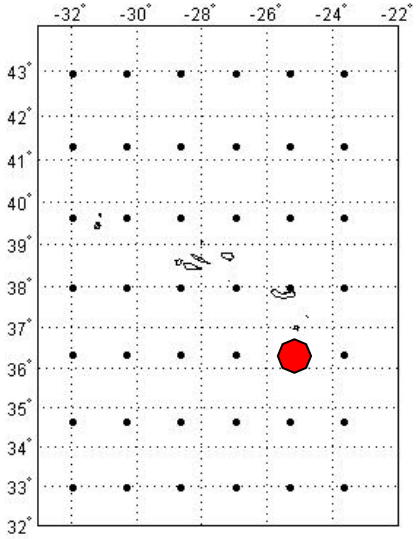
$$p = 100\ \cos(\ 2\pi t\ /(365\ /\ 8))$$



42 points of wavelet-analysis




Primary productivity
Wavelet-analisys
36.2917 N,25.2917 W
mg C/(m2 day)
1200
1000
800
600
400
200
2003
2004
2005
2006
2007
Time


-32°
-30°
-28°
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42°
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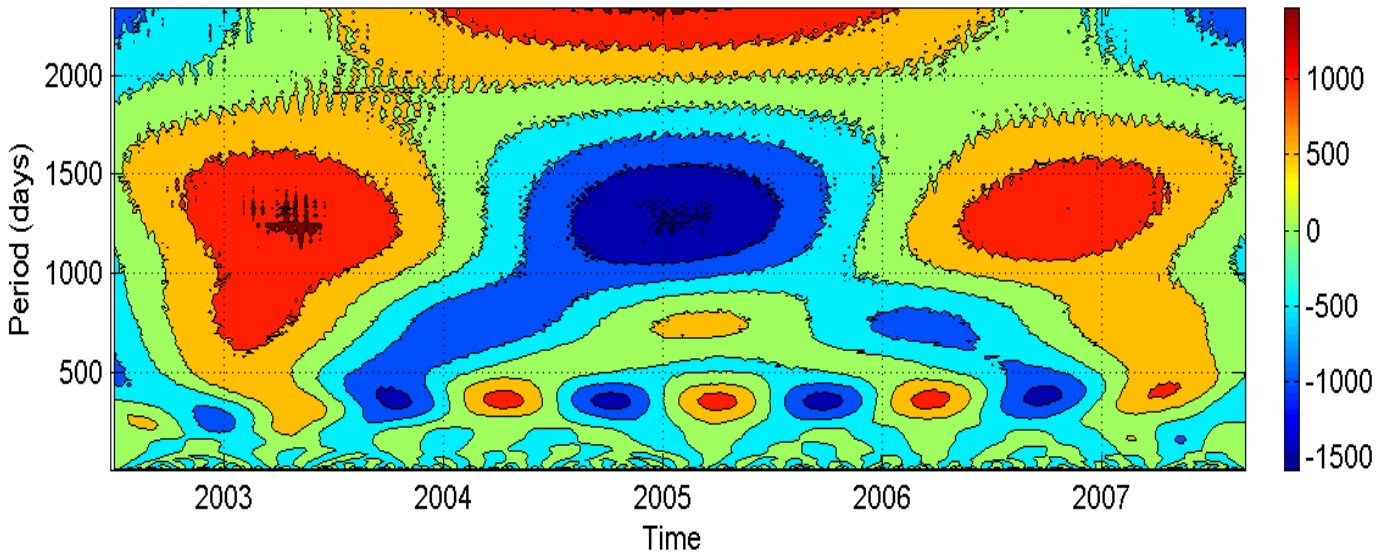
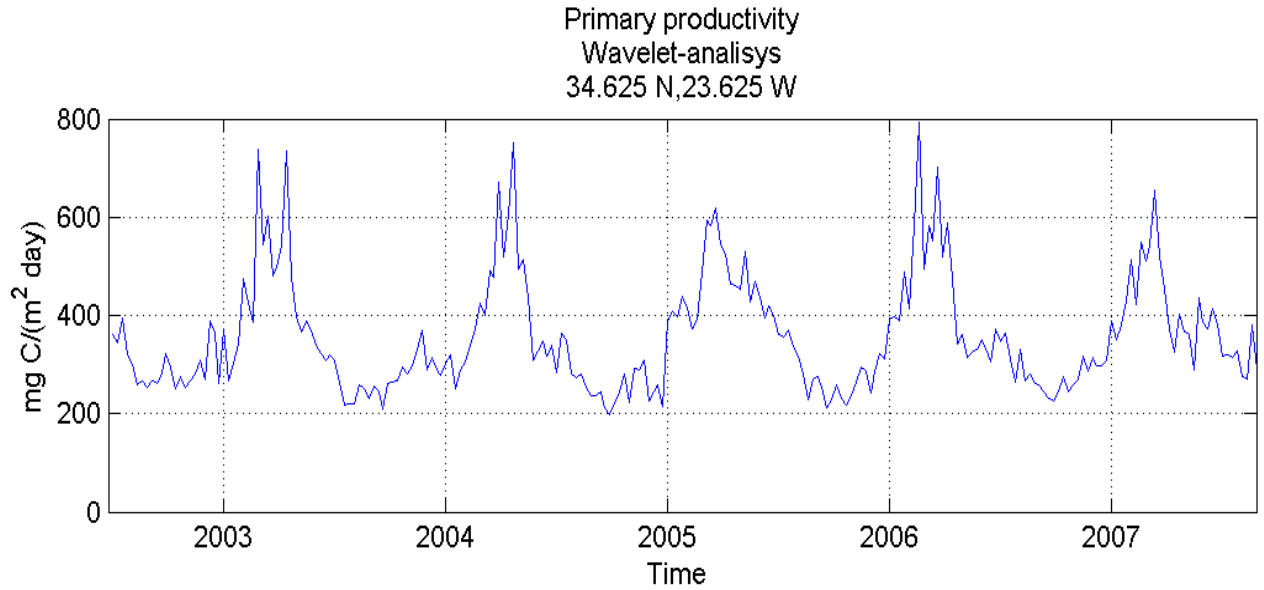
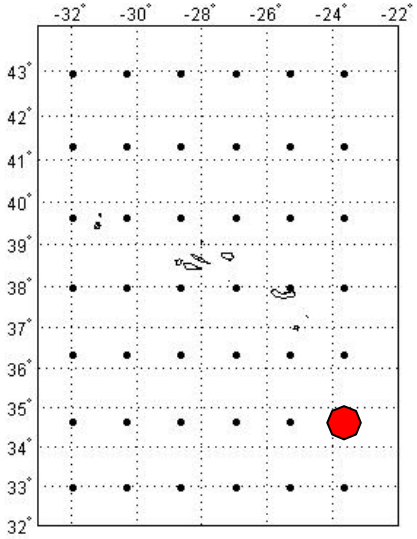
36°
35°
34°
33°
32°


Period (days)
2000
1500
1000
500
2003
2004
2005
2006
2007
Time
1000
500
0
-500
-1000
-1500


Primary productivity
Wavelet-analisys
34.625 N,23.625 W
mg C/(m2 day)
800
600
400
200
0
2003
2004
2005
2006
2007
Time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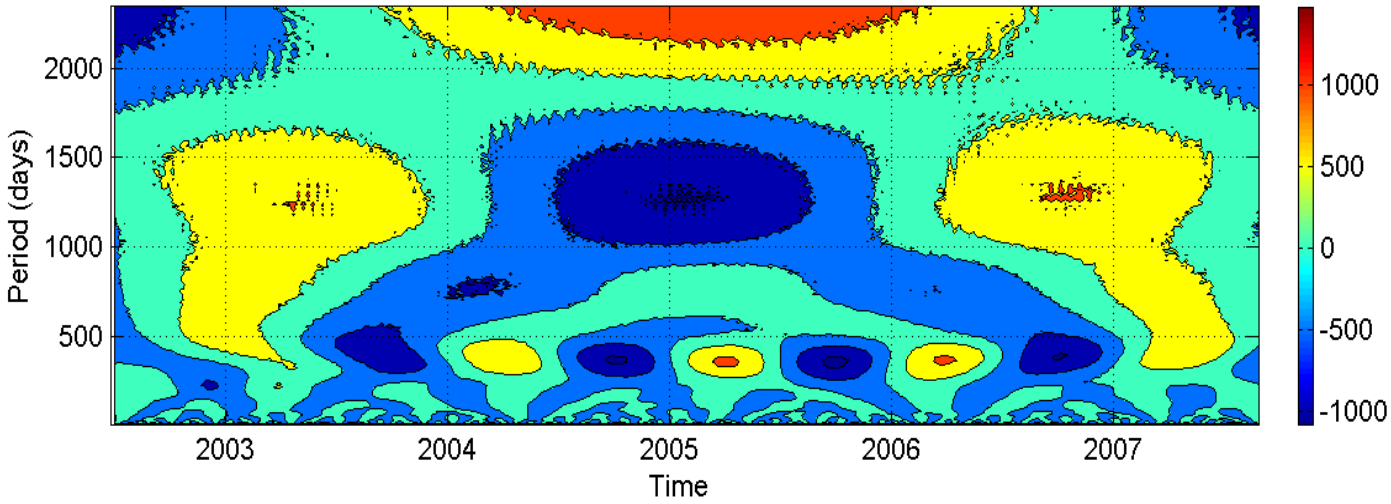
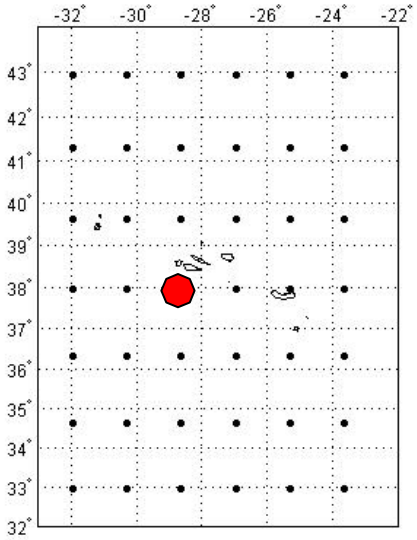

Period (days)
2000
1500
1000
500
2003
2004
2005
2006
2007
Time
1000
500
0
-500
-1000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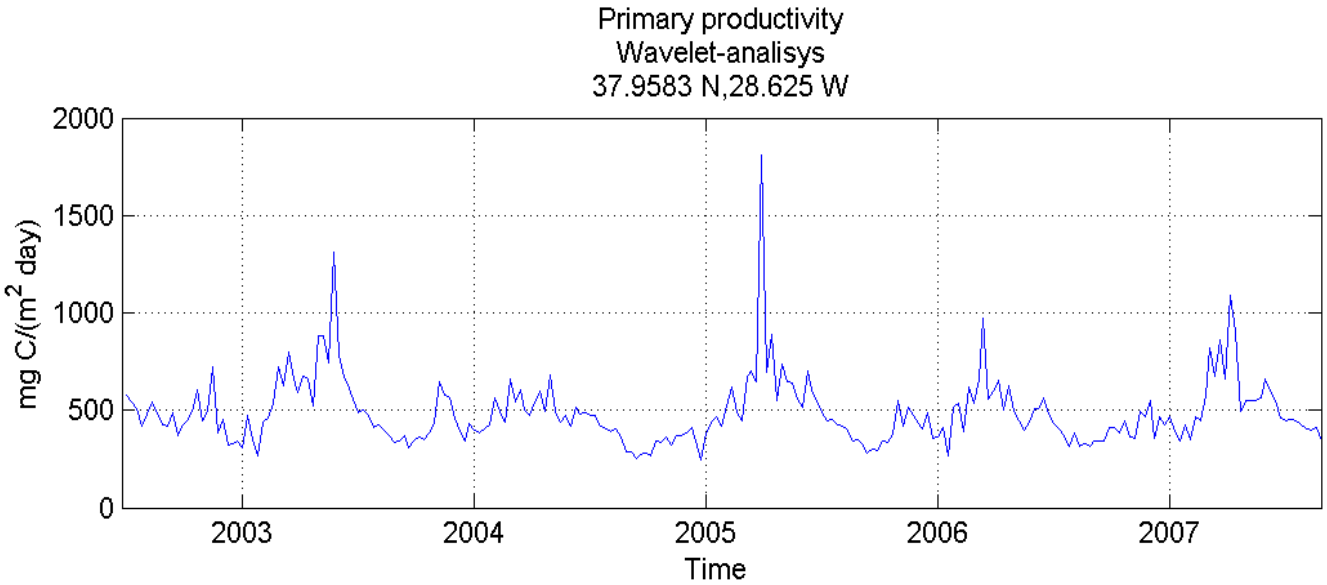
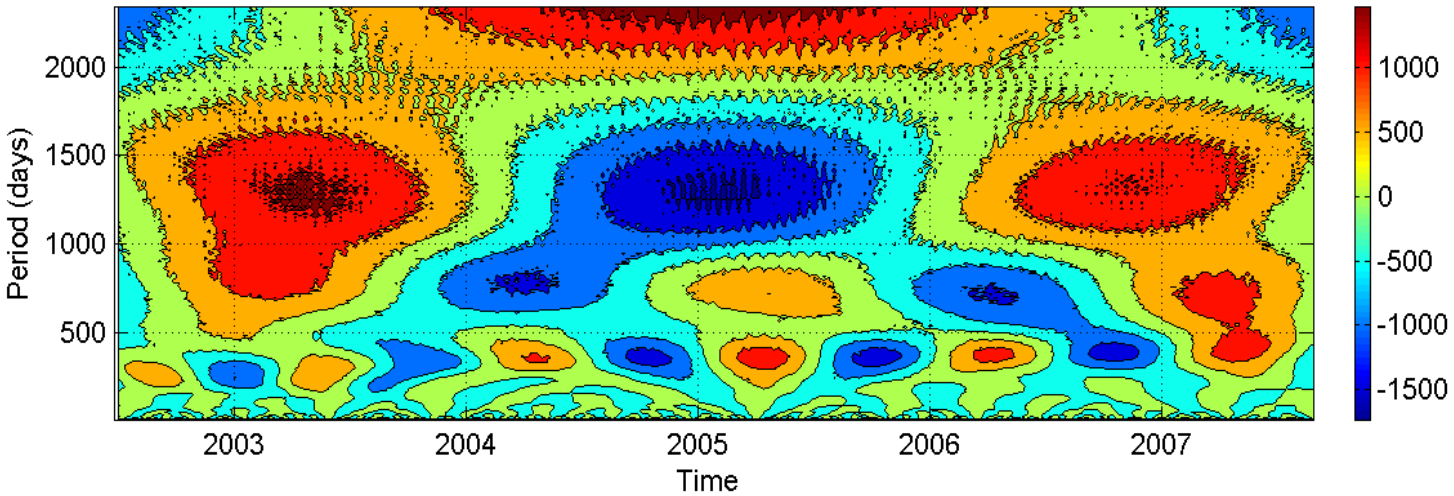
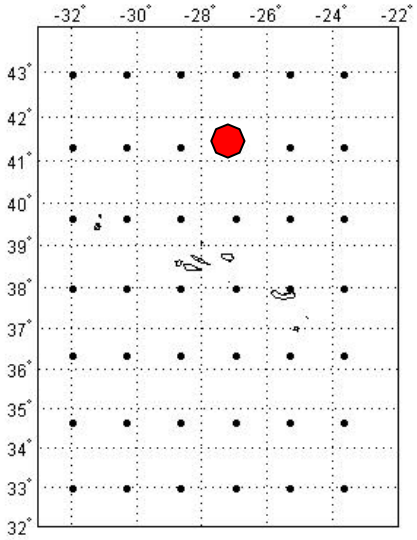
32°


Primary productivity
Wavelet-analisys
37.9583 N,28.625 W
mg C/(m2 day)
2000
1500
1000
500
0
2003
2004
2005
2006
2007
Time


Period (days)
2000
1500
1000
500
2003
2004
2005
2006
2007
Time
1000
500
0
-500
-1000
-1500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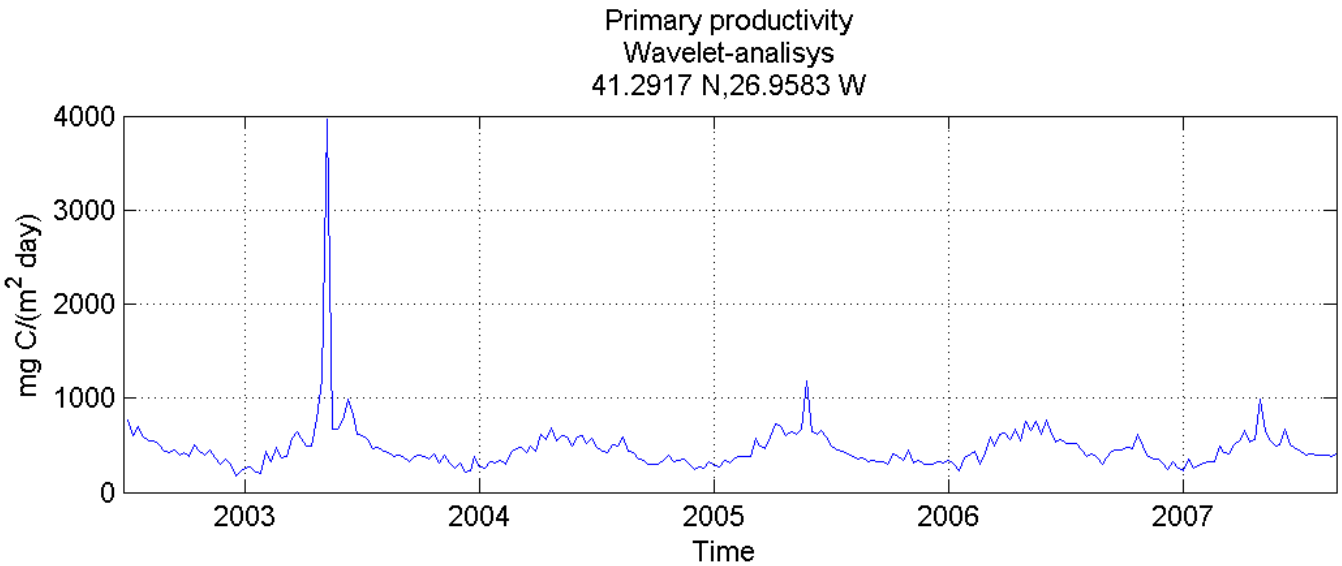
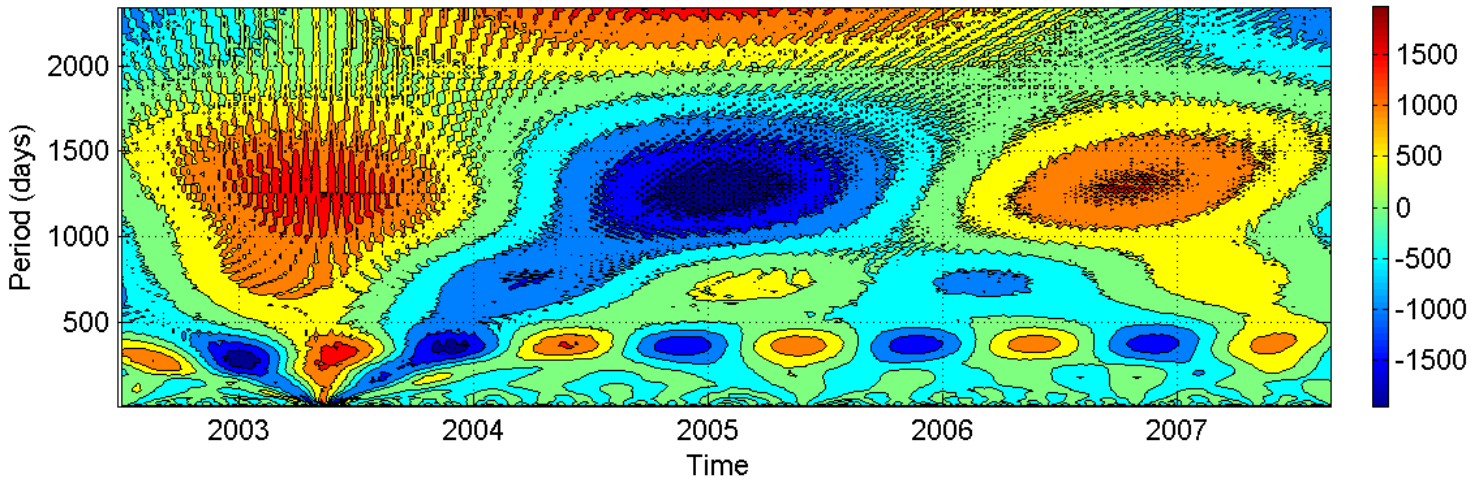
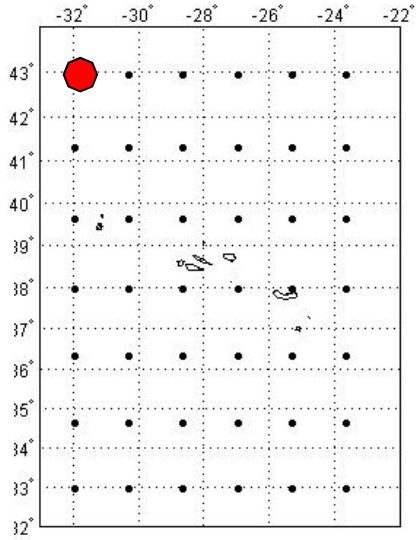
32°


Primary productivity
Wavelet-analisys
41.2917 N,26.9583 W
mg C/(m2 day)
4000
3000
2000
1000
0
2003
2004
2005
2006
2007
Time


Period (days)
2000
1500
1000
500
2003
2004
2005
2006
2007
Time
1500
1000
500
0
-500
-1000
-1500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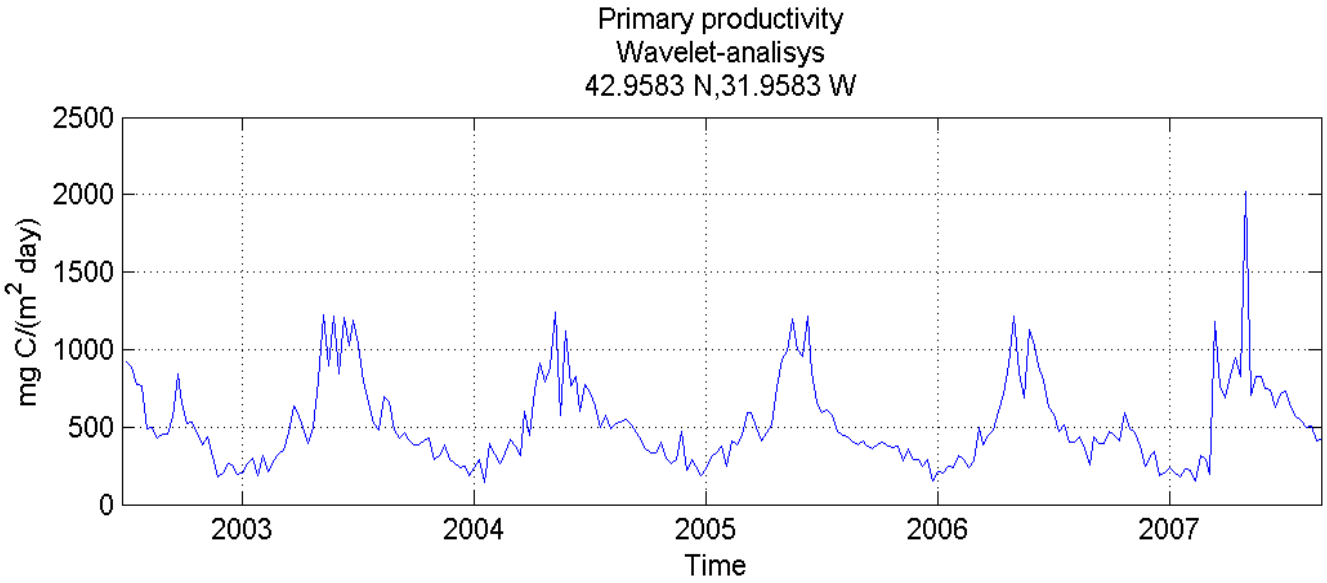
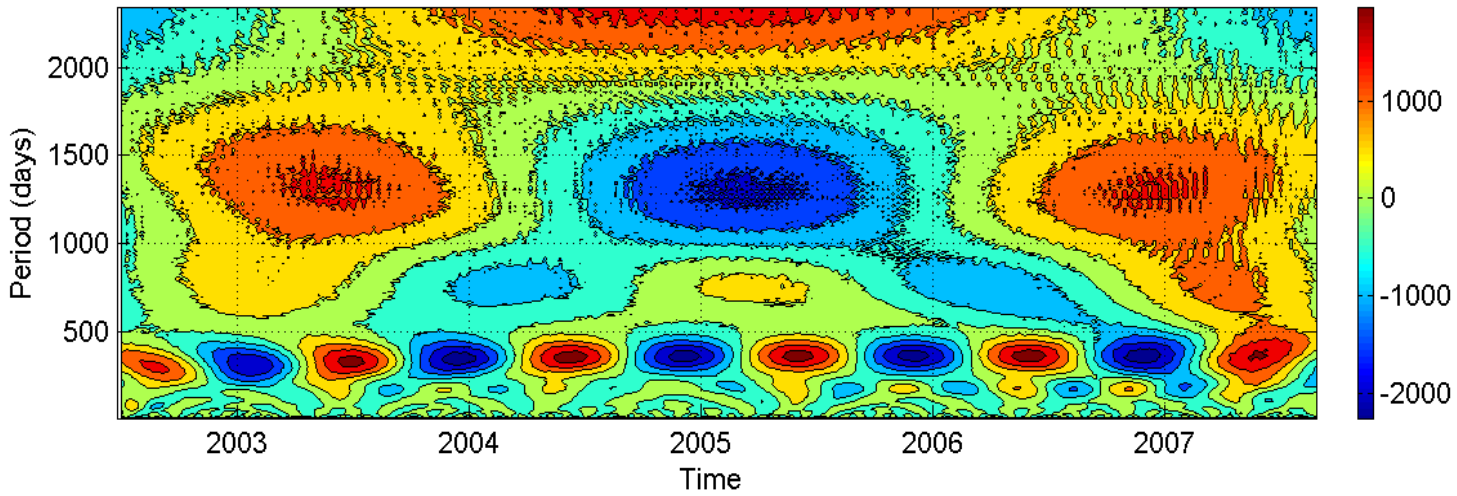

Primary productivity
Wavelet-analisys
42.9583 N,31.9583 W
mg C/(m2 day)
2500
2000
1500
1000
500
0
2003
2004
2005
2006
2007
Time


Period (days)
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1500
1000
500
2003
2004
2005
2006
2007
Time
1000
0
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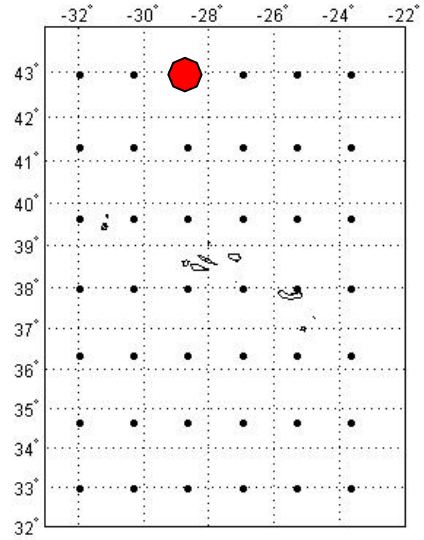
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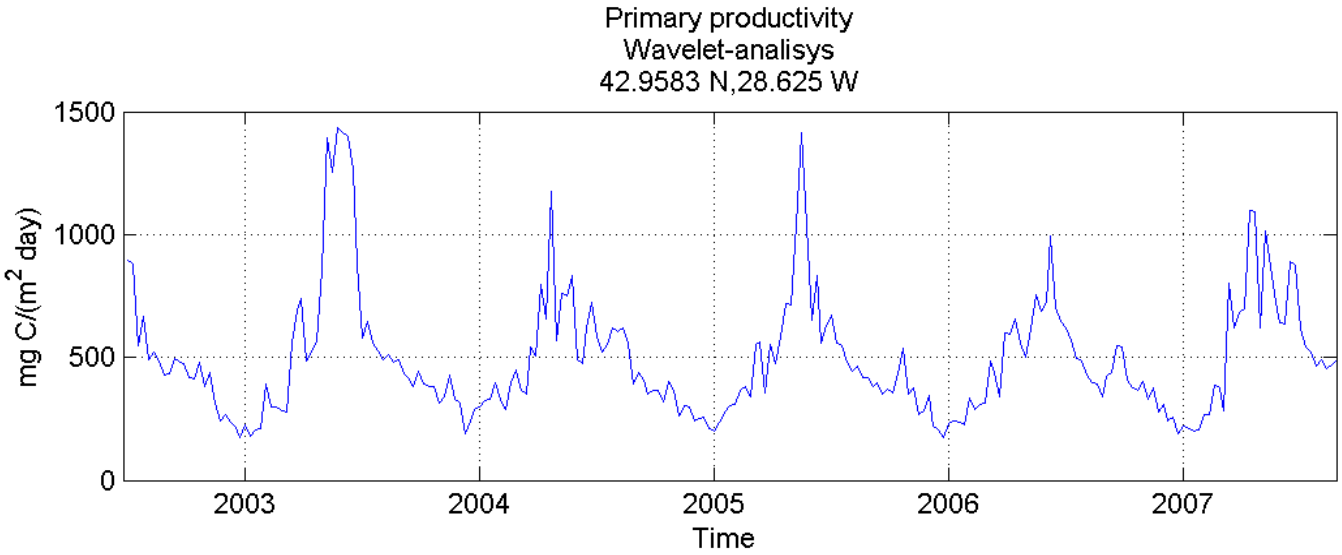
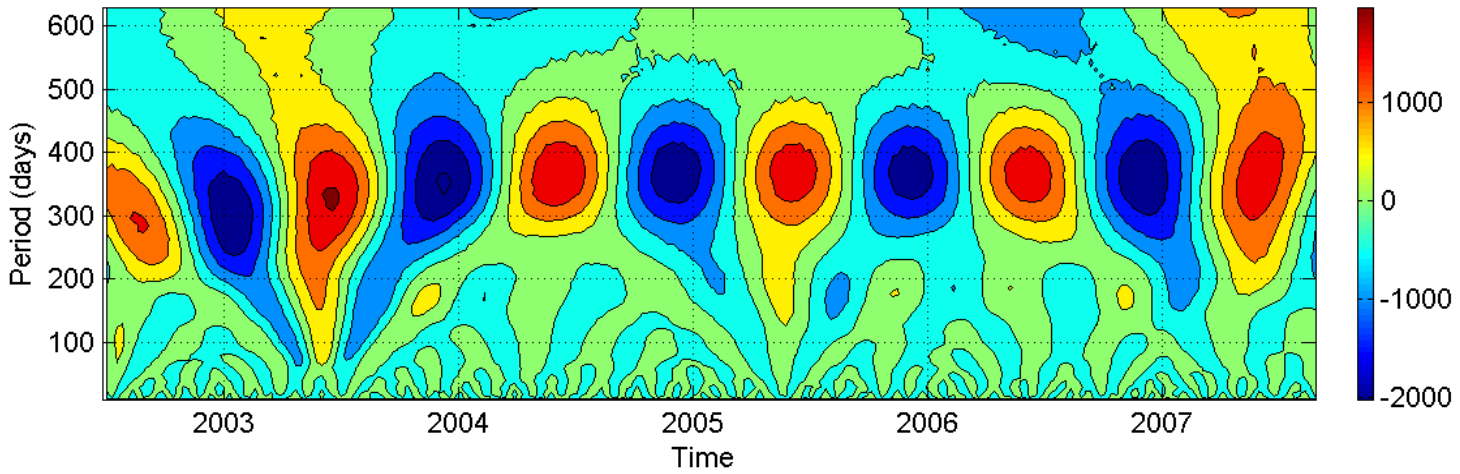
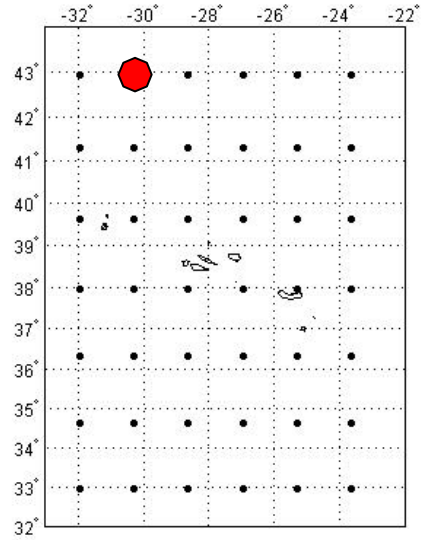
32°


Primary productivity
Wavelet-analisys
42.9583 N,28.625 W
mg C/(m2 day)
1500
1000
500
0
2003
2004
2005
2006
2007
Time


Period (days)
600
500
400
300
200
100
2003
2004
2005
2006
2007
Time
1000
0
-1000
-2000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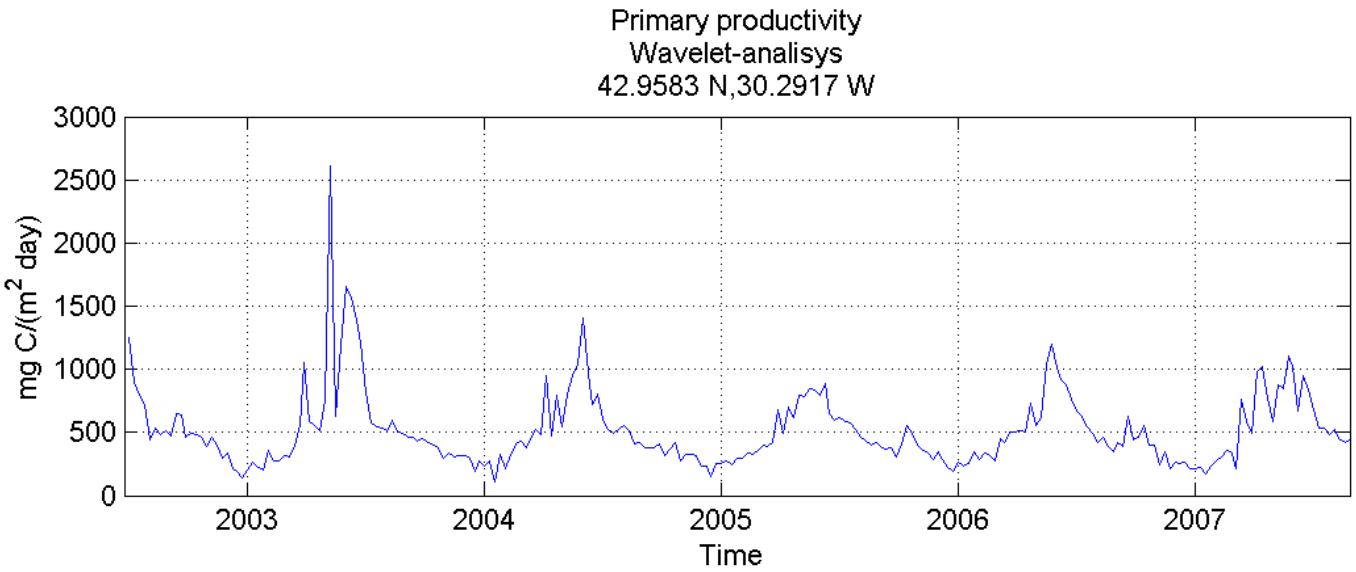
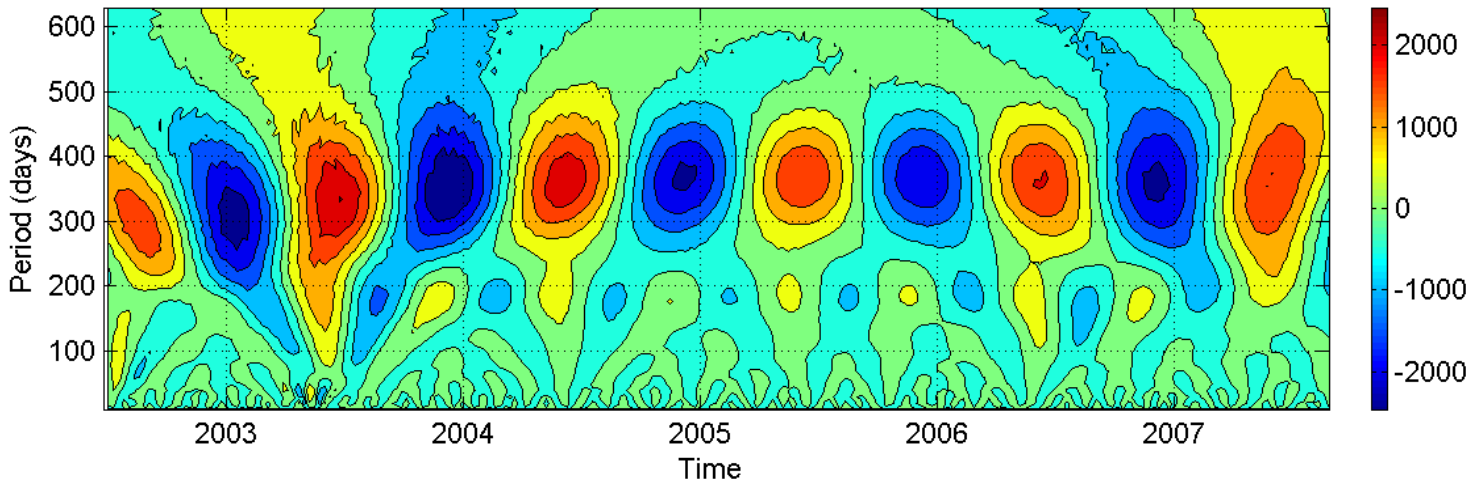
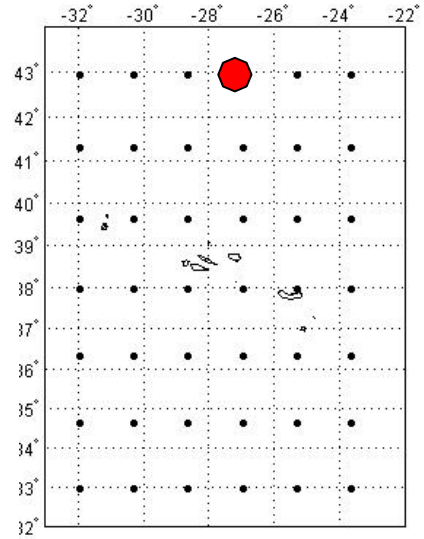

Primary productivity
Wavelet-analisys
42.9583 N,30.2917 W
mg C/(m2 day)
3000
2500
2000
1500
1000
500
0
2003
2004
2005
2006
2007
Time


Period (days)
600
500
400
300
200
100
2003
2004
2005
2006
2007
Time
2000
1000
0
-1000
-2000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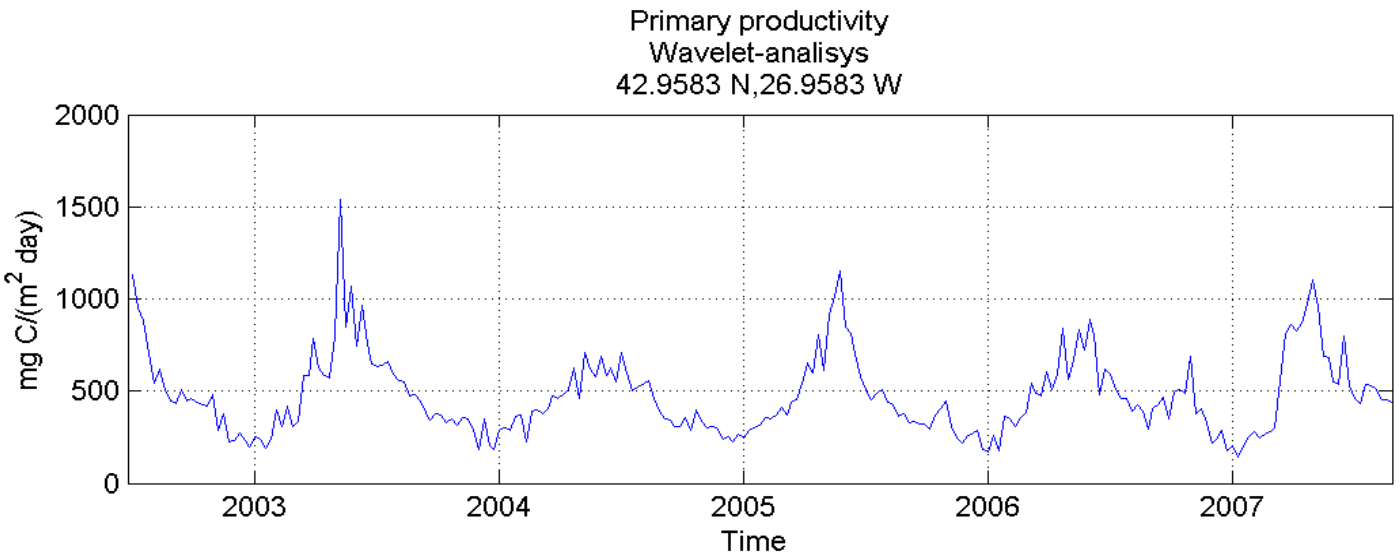
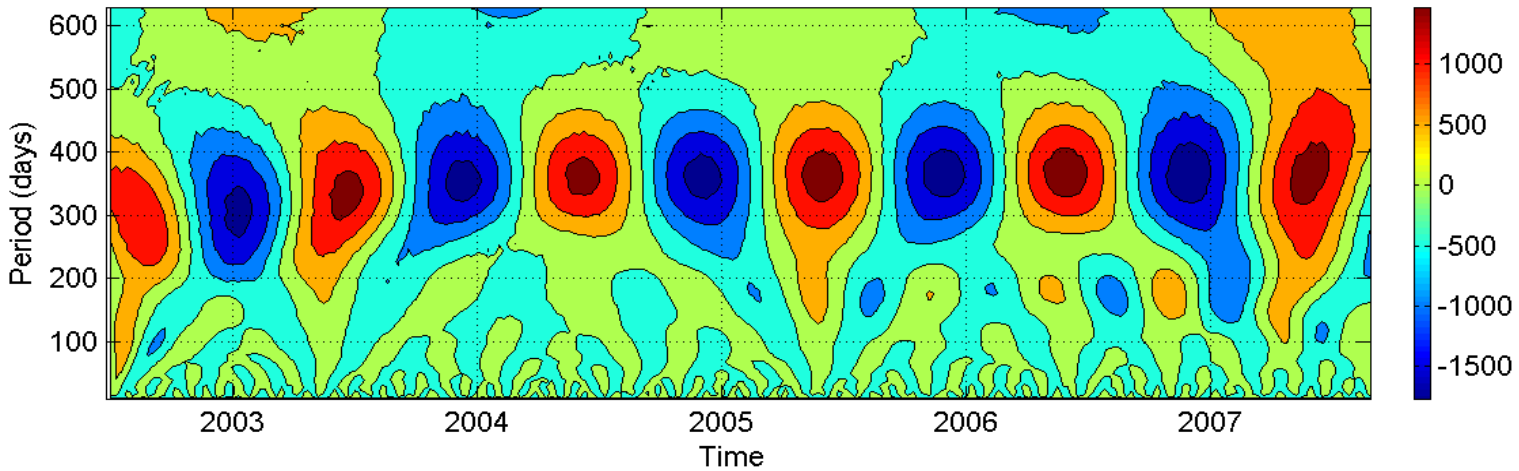
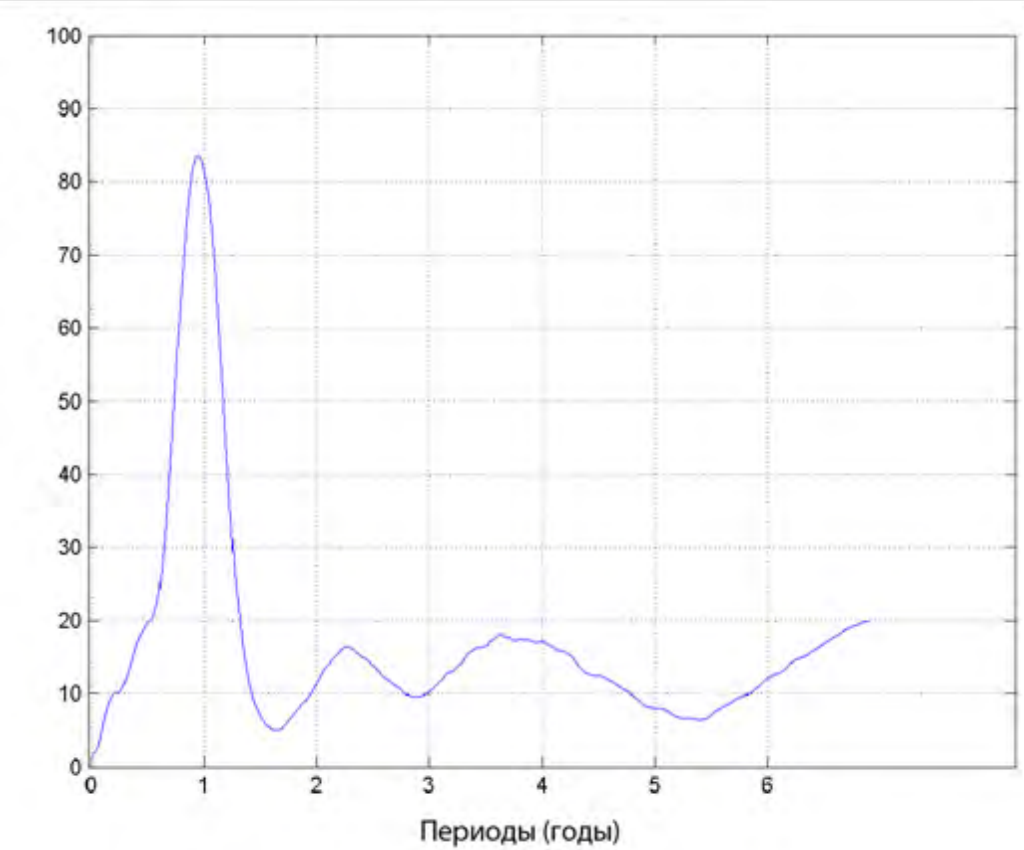
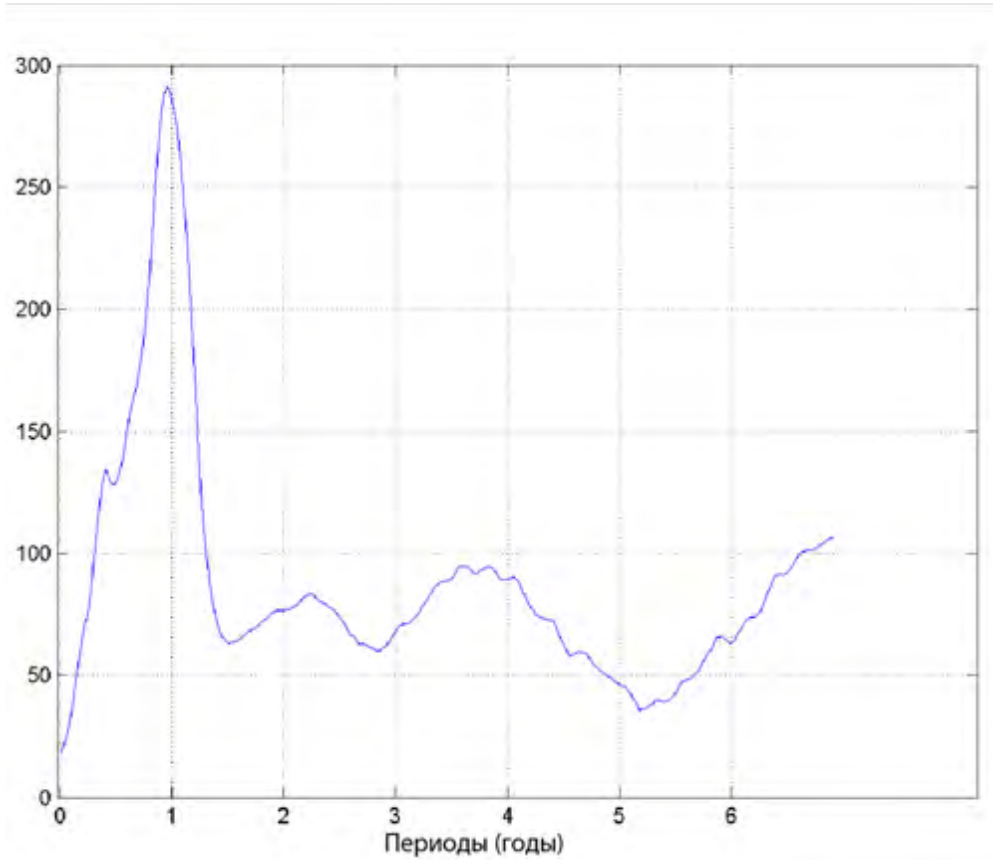

Primary productivity
Wavelet-analisys
42.9583 N,26.9583 W
mg C/(m2 day)
2000
1500
1000
500
0
2003
2004
2005
2006
2007
Time


Period (days)
600
500
400
300
200
100
2003
2004
2005
2006
2007
Time
1000
500
0
-500
-1000
-1500

Time-averaged wavelet amplitudes to characterize, at different points, individual contributions from each scale of variability in general, during the entire time span analyzed

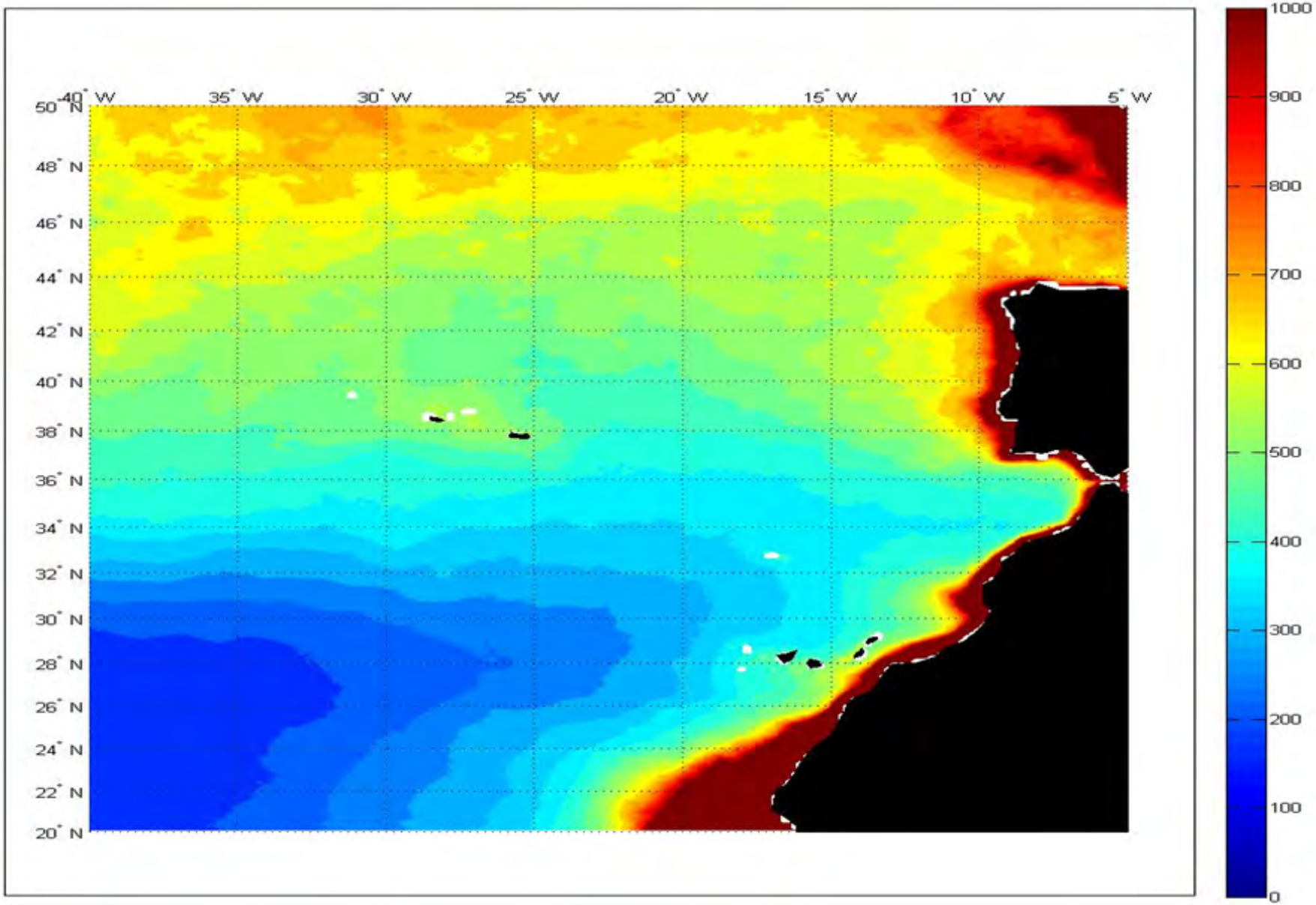




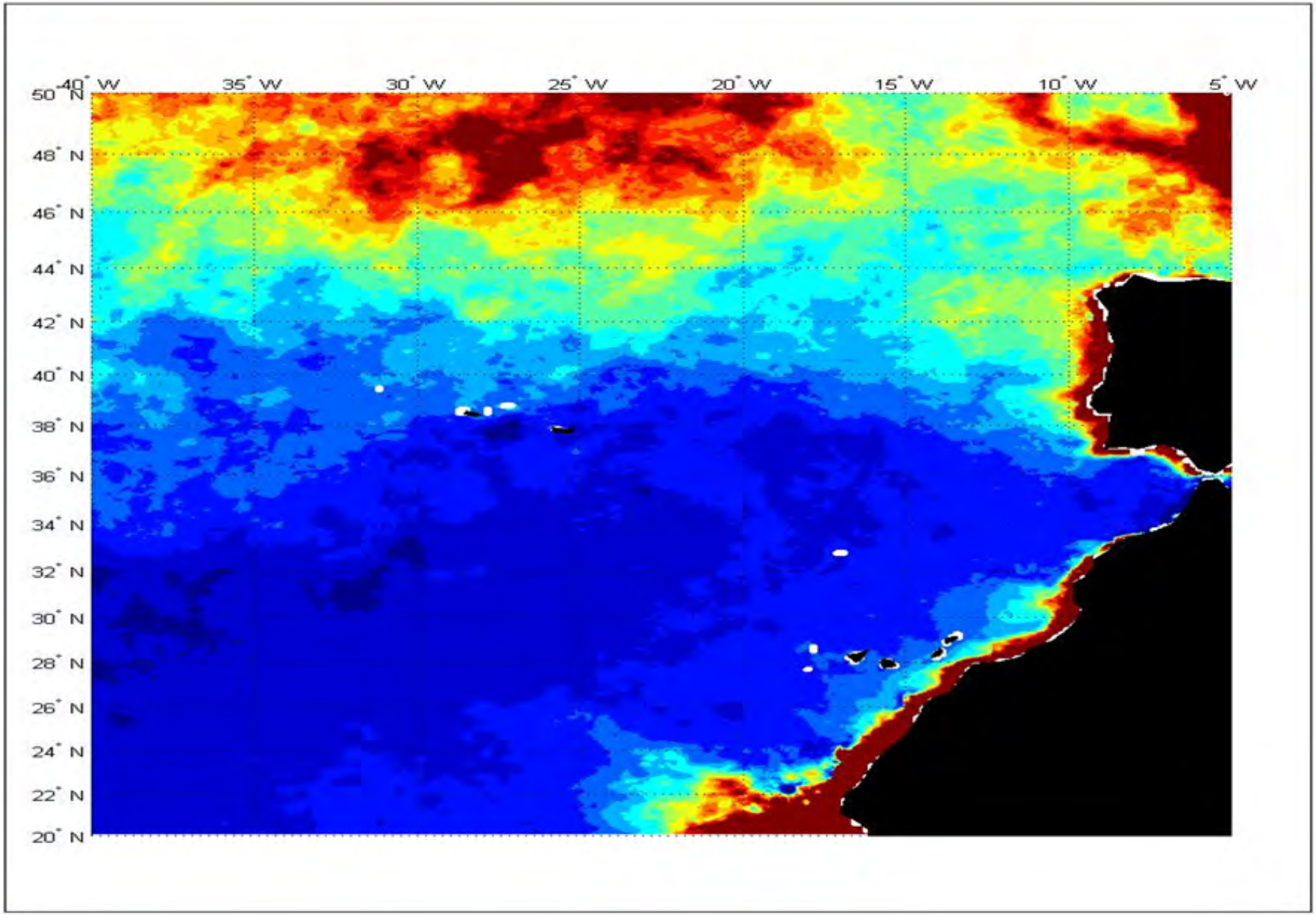
50^{o} N, 30^{o} W

31^{o} N, 10^{o} W

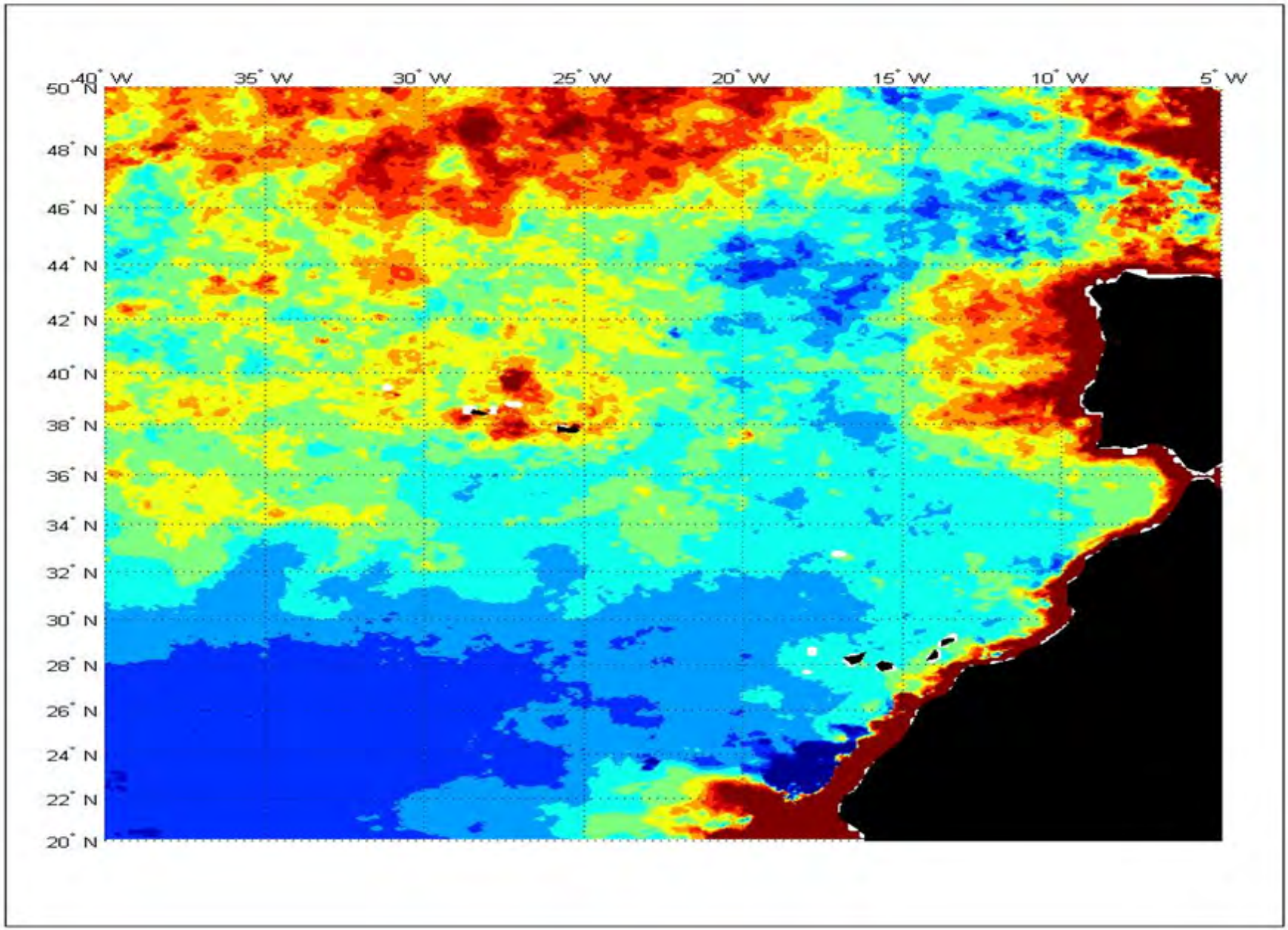
This slide shows mean multiyear primary production distribution in the area.
Here are mapped the primary production magnitudes averaged over entire time span in study.



The next four slides represent spatial distribution of primary production on different scales, namely: **0.5 year**



1 year


40° W
35° W
30° W
25° W
20° W
15° W
10° W
5° W
50° N
48° N
46° N
44° N
42° N
40° N
38° N
36° N
34° N
32° N
30° N
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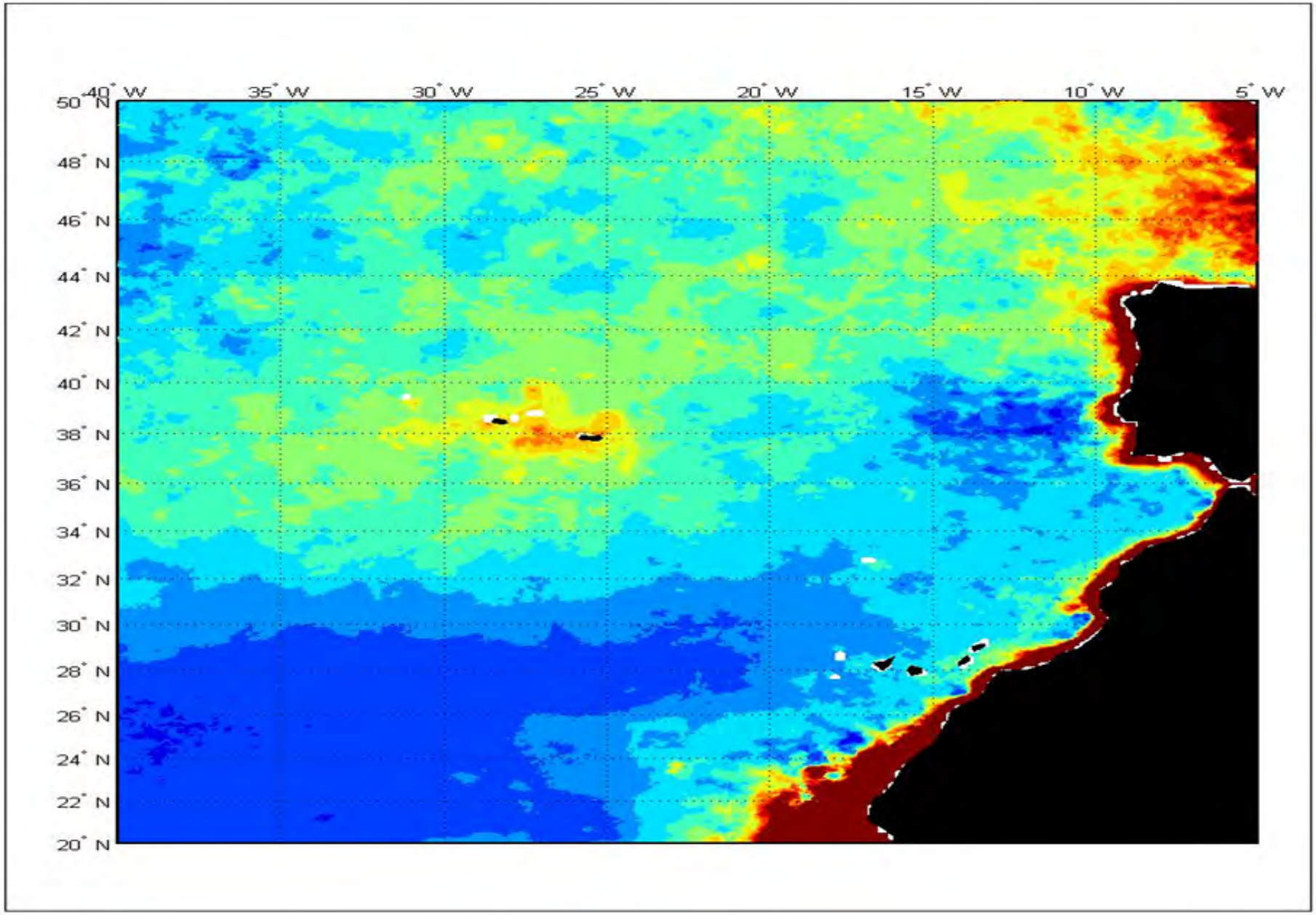
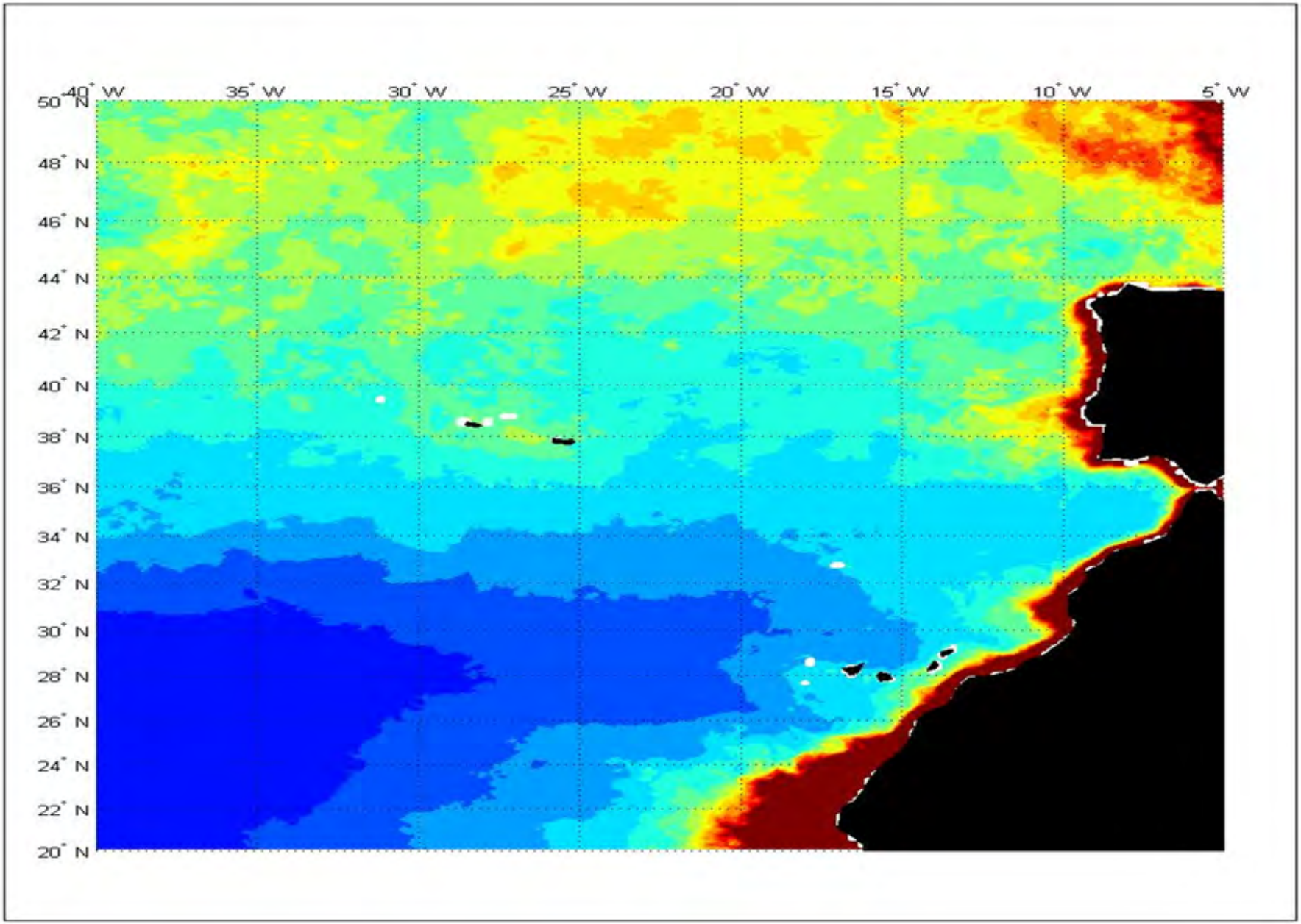
26° N
24° N
22° N
20° N

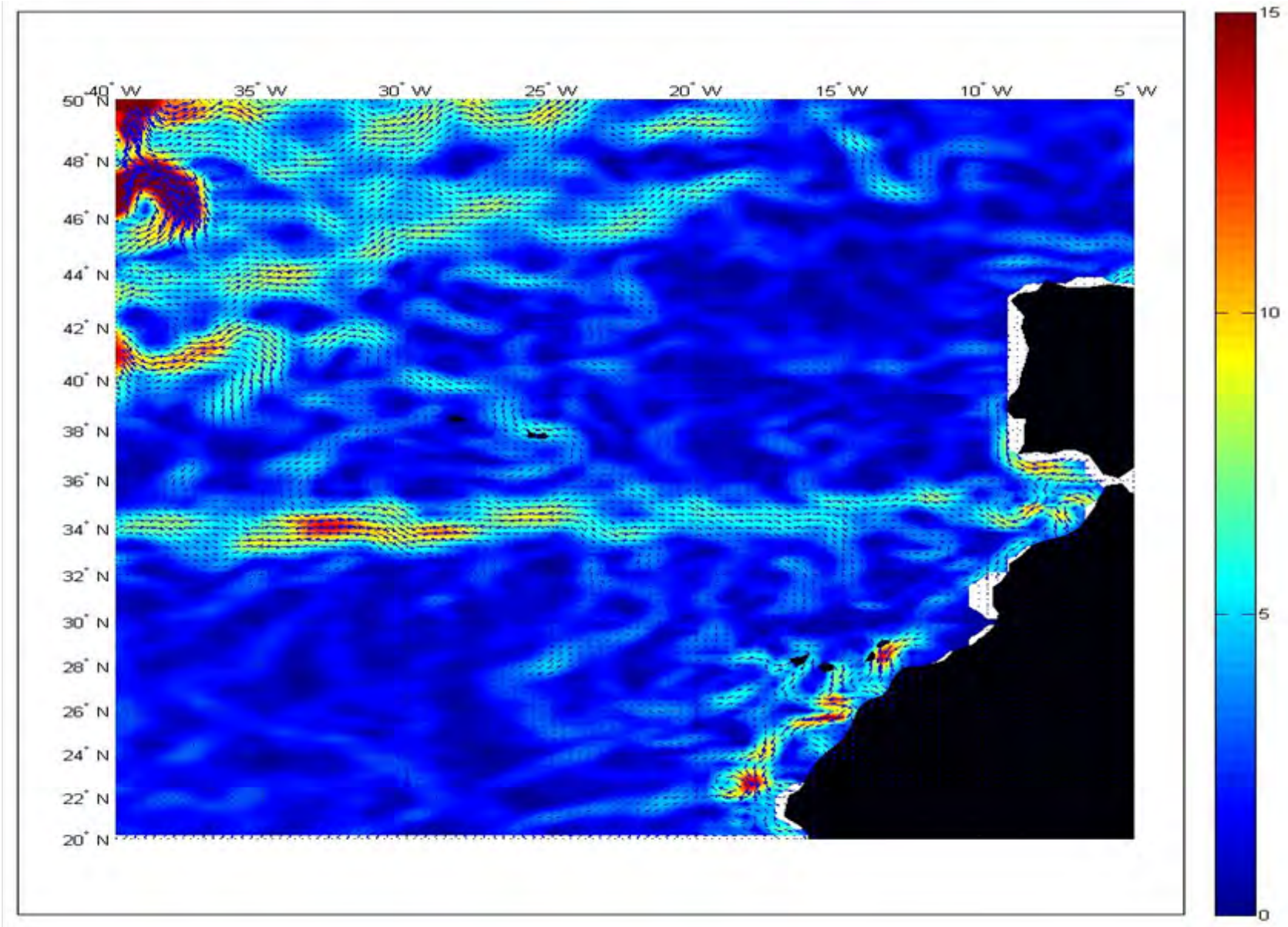
2 years


40° W
35° W
30° W
25° W
20° W
15° W
10° W
5° W
50° N
48° N
46° N
44° N
42° N
40° N
38° N
36° N
34° N
32° N
30° N
28° N
26° N
24° N
22° N
20° N

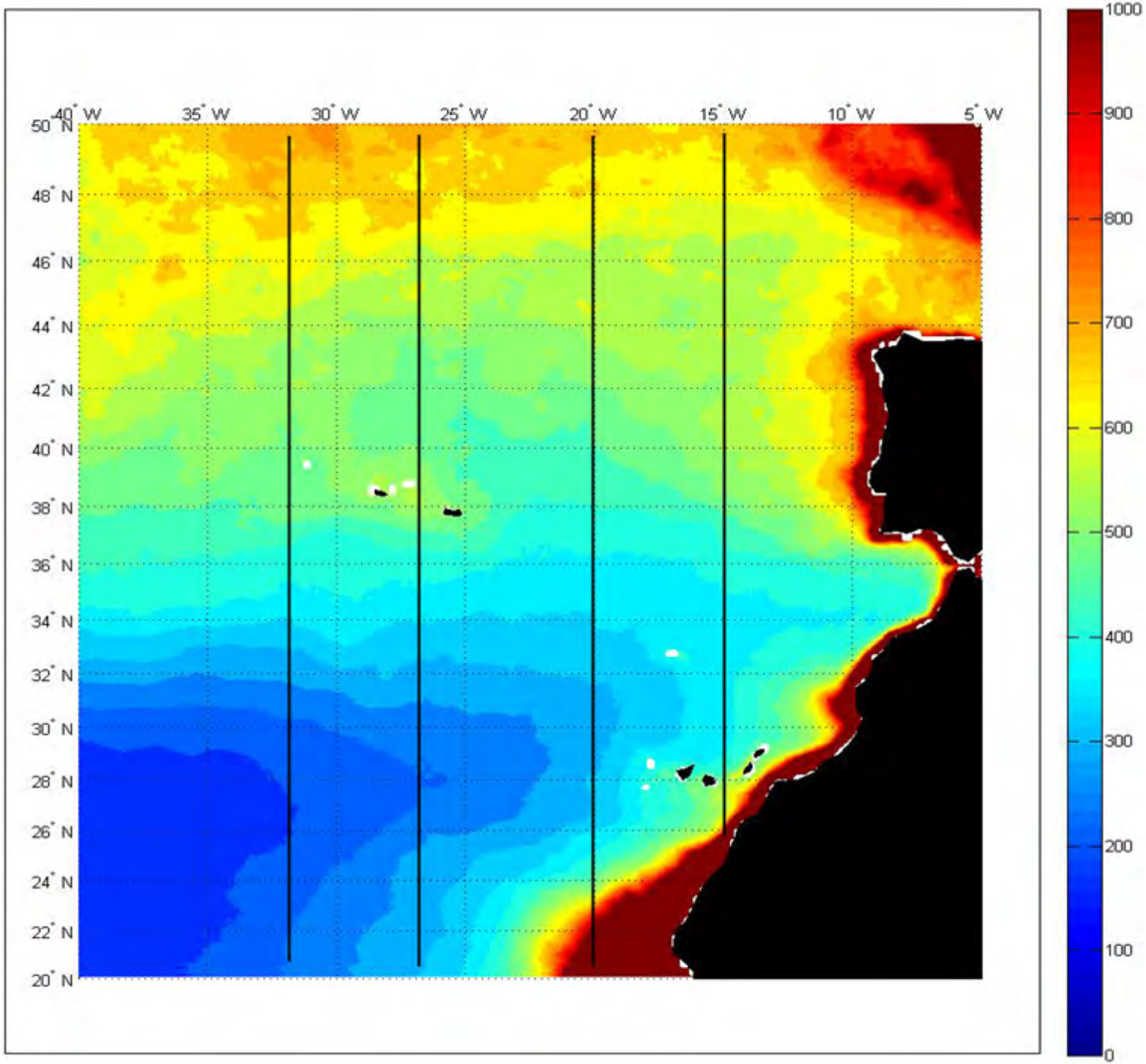
4 years

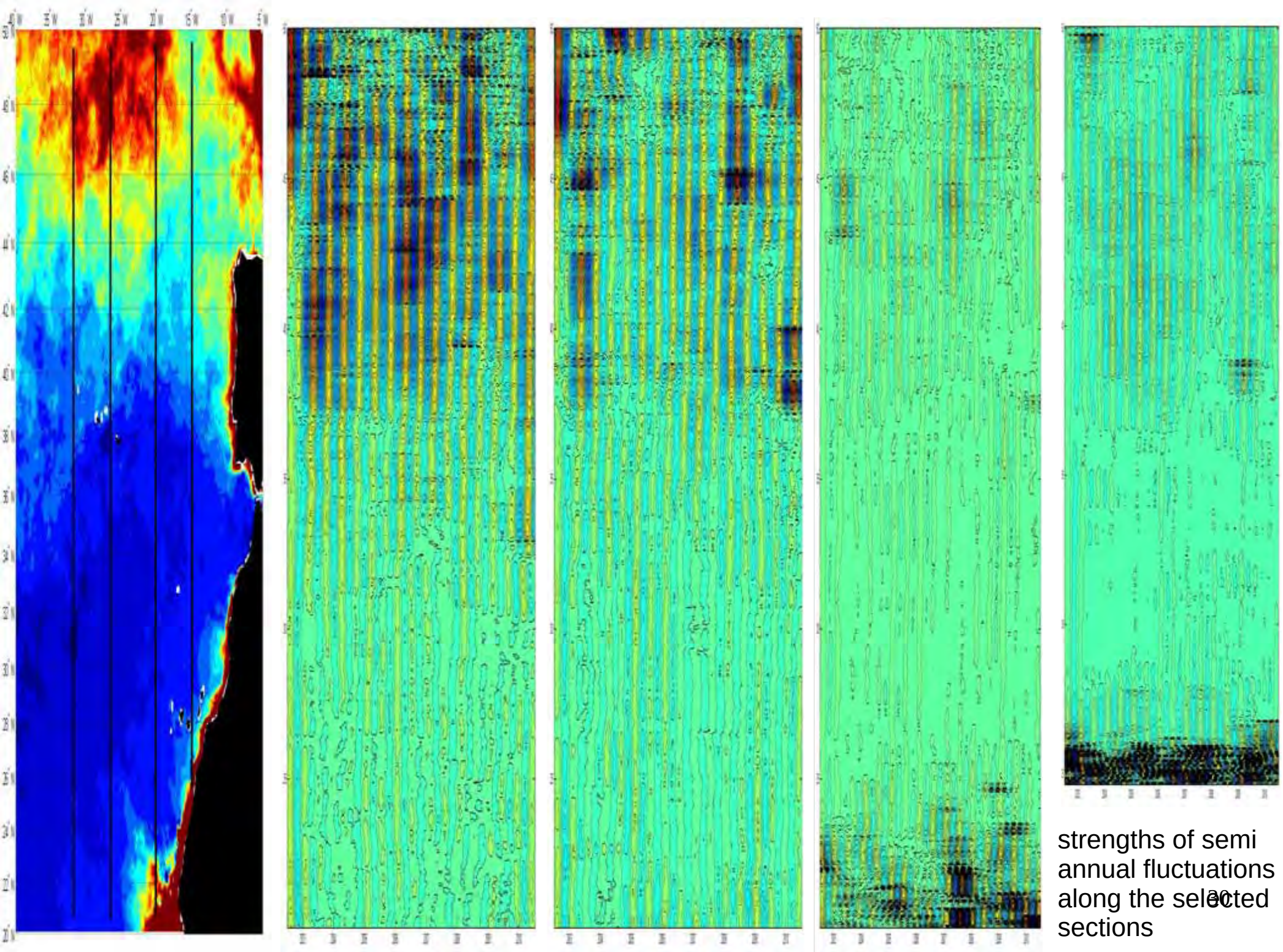

40° W
35° W
30° W
25° W
20° W
15° W
10° W
5° W
50° N
48° N
46° N
44° N
42° N
40° N
38° N
36° N
34° N
32° N
30° N
28° N
26° N
24° N
22° N
20° N

The geostrophical currents estimated from altimetry-measured sea surface slopes

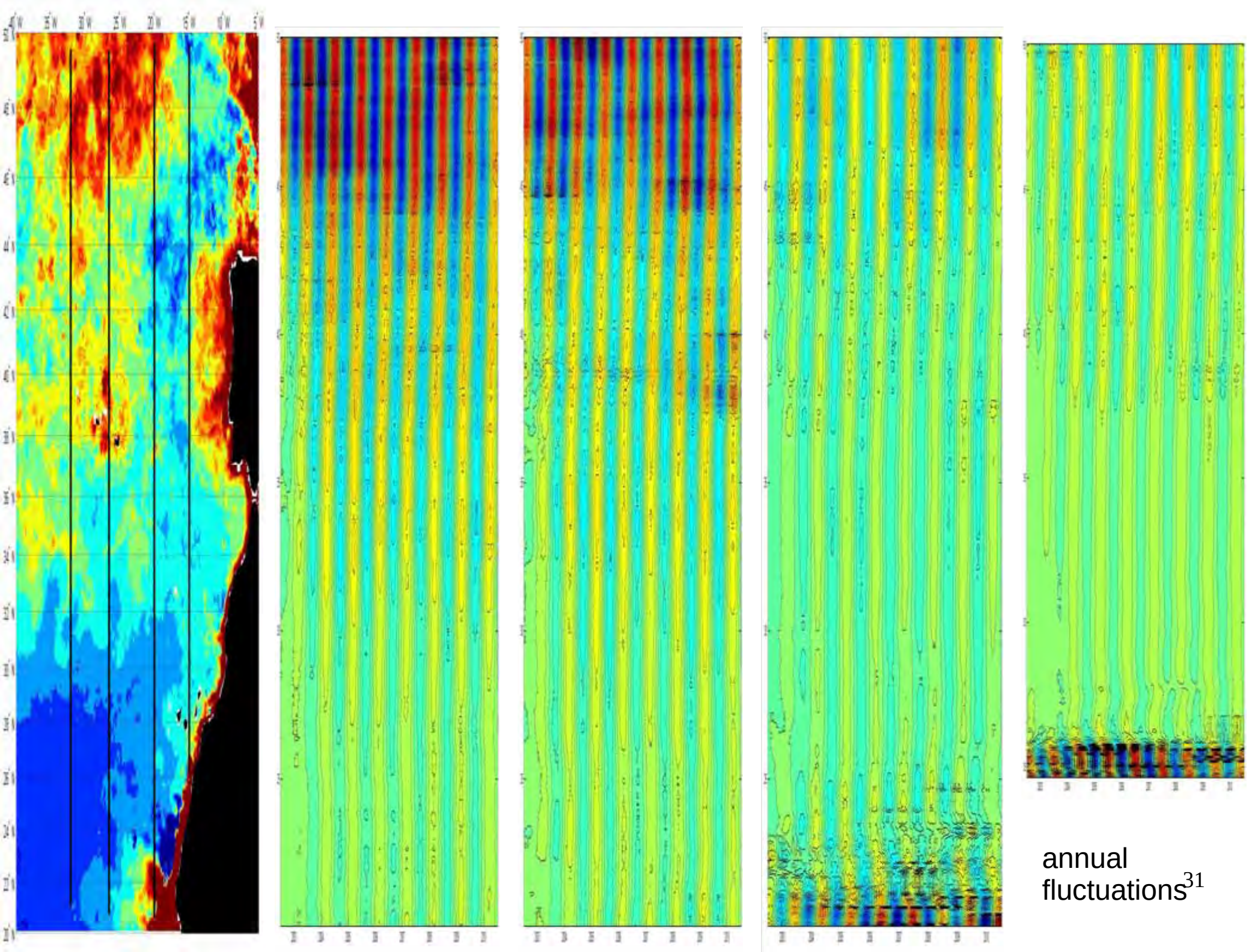


The sections' layout

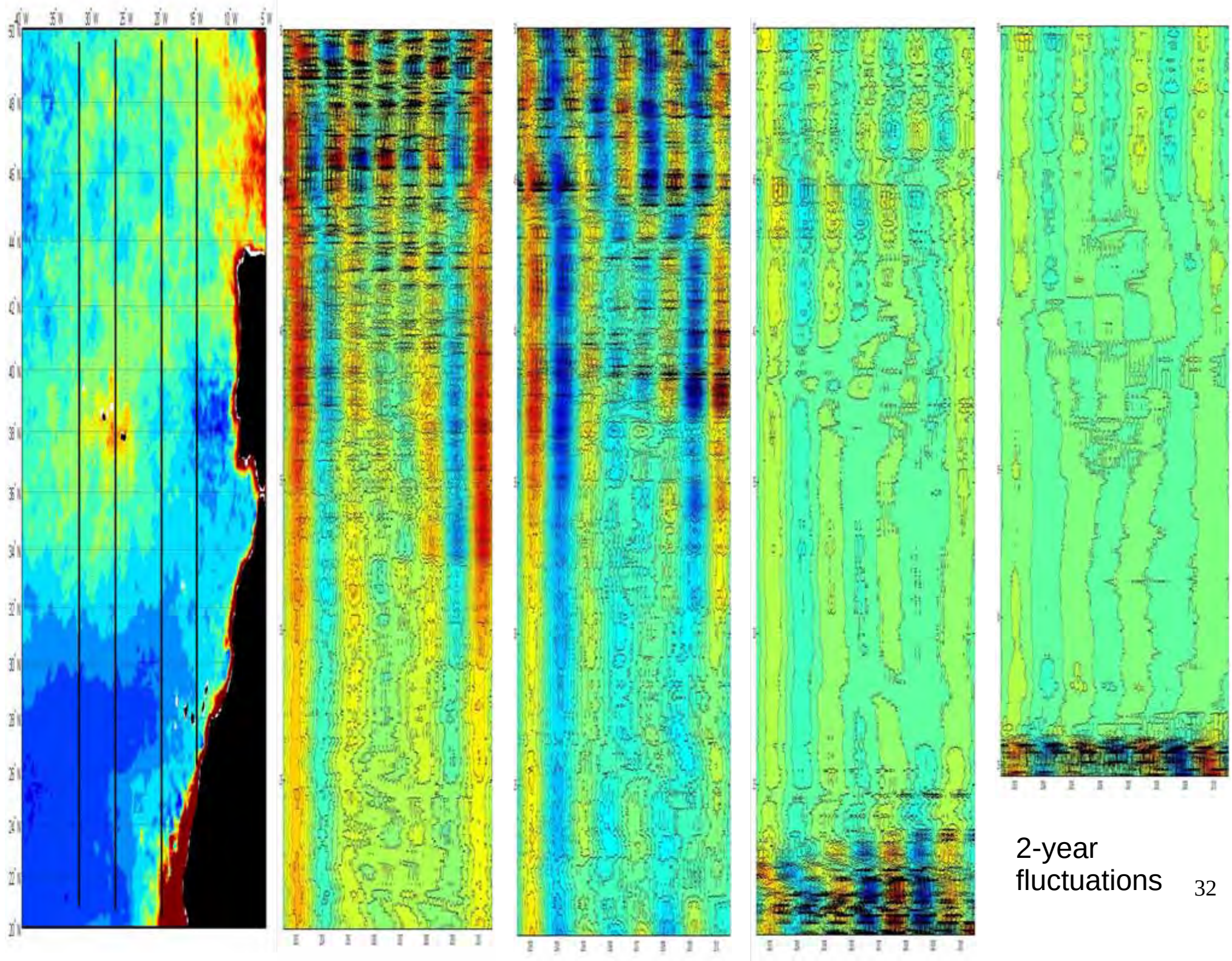




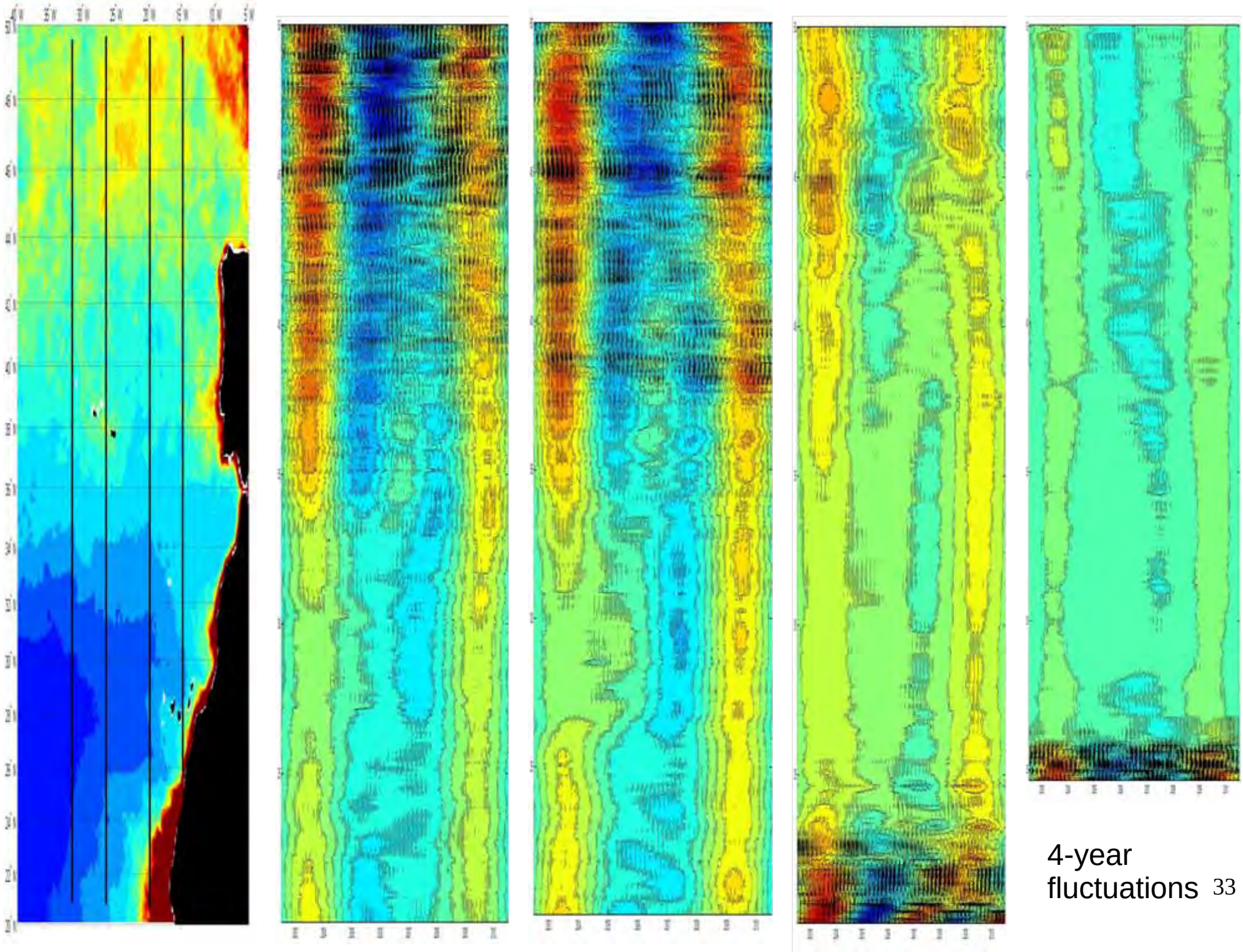
strengths of semi annual fluctuations along the selected sections



annual fluctuations



2-year fluctuations



4-year fluctuations

Conclusion

•Non-stationary cycles of the primary production are present in the studied region, having variability scales 0.5 year, 1 year, 2 years and 4 years.

•Longitudinal wavelet diagrams of the detected primary production cycles do reflect essential non-stationarity of variability in the semiannual cycles.

•At the latitudes 35-36° N and near 37° N, biotic fronts are developed, dividing the studied water area onto the northern part with higher primary production values and the southern part with lower primary production values. The northern part is distinguished by markedly increased primary production variability on each scale.

•The expressed spatial inhomogeneity of semiannual cycles shows itself individually in each of the longitudinal sections. The presence of a biotical front in the Azorean region at 37 ° N is reflected in isopleths of semiannual cycles, while the isopleths themselves provide information concerning spatial-temporal variability of the biotical front.

LAMAR