Committee 6
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The Human Body As A Crossroad Between Inner and Outer Vibrations: Examples of Biological Rhythms

Claude Gaudeau de Gerlicz
Scientific Director
Institute of Bioinformatics andBiotechnology
Tours, France

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THE HUMAN BODY AS A CROSSROAD BETWEEN INNER AND OUTER VIBRATIONS : EXAMPLES OF BIOLOGICAL RHYTHMS

Authors :

GAUDEAU Claude(1), GOUTHIERE Laurent(1)(2), BOBOLA Philippe(1), MOUSSA Chiraz(1), BORYS Michel(1), ROBERT Eric(1), VILLAIN Fabrice(1)(3).

(1) Société de Bio-Informatique et de Bio-Technologie
32, rue Emile Zola
37000 TOURS
Tél : 02.47.05.27.04
Fax : 02.47.66.89.20

(2) Etudiant au CNAM de Tours
Société de Bio-Informatique et de Bio-Technologie
32, rue Emile Zola
37000 TOURS
Tél : 02.47.26.44.79

(3) Institut Universitaire rt Technologique de Tours
Département Génie Electrique et Informatique Industrielle
Avenue Monge
37000 TOURS

SUMMARY

The rhythmic or cyclic activity is one of the most fondamental property of the living systems since the most elementary creatures (bacteries, cells, etc...).

May be the environment rhythmicity is at the life origin and as well the swell variations, sea waves, boilings of volcanic origin, have allowed molecular structures encounters which would have only weak probability to meet each other and to gather in order to form complex structures of the alive creatures.

So as, biologic rhythms study provokes for more than twenty years an increasing interest in the scientific surroundings. Those studies show relations between living organisms rhythms and those of the environment which are much more narrow than we would have thought first.

But, there is also an epidemiologic interest that is to say that if cycles have endogenous or exogenous shape or due to an interaction between both of them.

That's why a methodology should take place to analyse those cycles. The chronology is planning to measure objectively the temporal structure of living creatures and to research mechanisms by stimulating them. Different methods are used, particularly the Cosinor one, and the moments of 3rd order when systems have non-linear shapes. The chronology aims to describe first rhythmic phenomenons, then to understand by using models.

It is certain that most of biologic systems have cycles, that is due largely to the succession of the light and the darkness. During this presentation, we will study infracircadian rhythms (cardiac, respiratory, digestive, etc...) that when they are in phase and at the same frequency as sound rhythms (musical) come into resonance and provoke delight.

The ultracircadian rhythms (monthly rhythms, annual rhythms, pluriannual rhythms) : Those rhythms as being in general conditioned by the environment fluctuations implying biometeorological factors but as well bio-geophysical factors which are narrowly conditioned by the cosmic and planetary environment (planetary modulation of the solar activity and the solar wind).

KEY-WORDS : rhythms, biologic, Cosinor, circadian rhythms, solar activity, bio-geophysic, planetary modulation.

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INTRODUCTION

Since long time biological rhythms (brain wave, respiratory, and cardiac rhythms) have been considered as a life property.

But the concept according which the living organisms are governed by rhythms different from respiratory and cardiac rhythms are dated from 1962. Jurgen Ashoff (biologist) and Michel Sifre (speleologist) showed that in a cavern at the end of two months without light stimulation, a human being still shows and a 25 hours proper sleep alternation.

Since 1967, F. Halberg and A. Reinberg, and numerous other searchers, decided to individualize the chronology which could be defined as the study of the temporal characteristics of biologic phenomenons ; it leads to an objective knowledge of temporal structures of organisms and of its alterations.

This morphology in the time is the necessary complement to morphology in the space, that is to say that of the anatomy : both are registered in individual genetic inheritance of different species.

Some rhythms were put forward at all organization levels (complete organism, organ systems, organs, tissues, cells, molecular stuctures) and at all temporal scales (μs, ms, s, hours, days, years) and concerning all alive creatures from the eucaryotes to the human beings.

A. Reinberg wrote : "Biologic rhythms can be considered as a fundamental alive material property". Probably at the life origin, it is a group of rhythm properties of the environment (Volcanic boilings, tides, sea waves ...) that allowed the molecular meeting the life birth, and from which the life has kept traces (in memory).

Aswering, susceptibility, and resistance capacities of different organs, which have their own rhythms, vary in periodic and foreseeable way.

In a 24 hours scale, for instance metabolic ducts aren't all open at the same time, as we will see in dermato-pharmacology, medicine and food effects vary according to its administration hour in the body.

1- MULTISCALE RHYTHMS ANALYSIS AND SIMULATION

The study of biological rhythms and of their interaction with the environment fluctuation as well as the global simulation from the most elementary components needs a brandnew methodology : the multiscale analysis and simulation.

1.1 Global models or macro-models

Following to the Descartes' advices, we cut the problem in parts sufficiently easy to be individually solved.

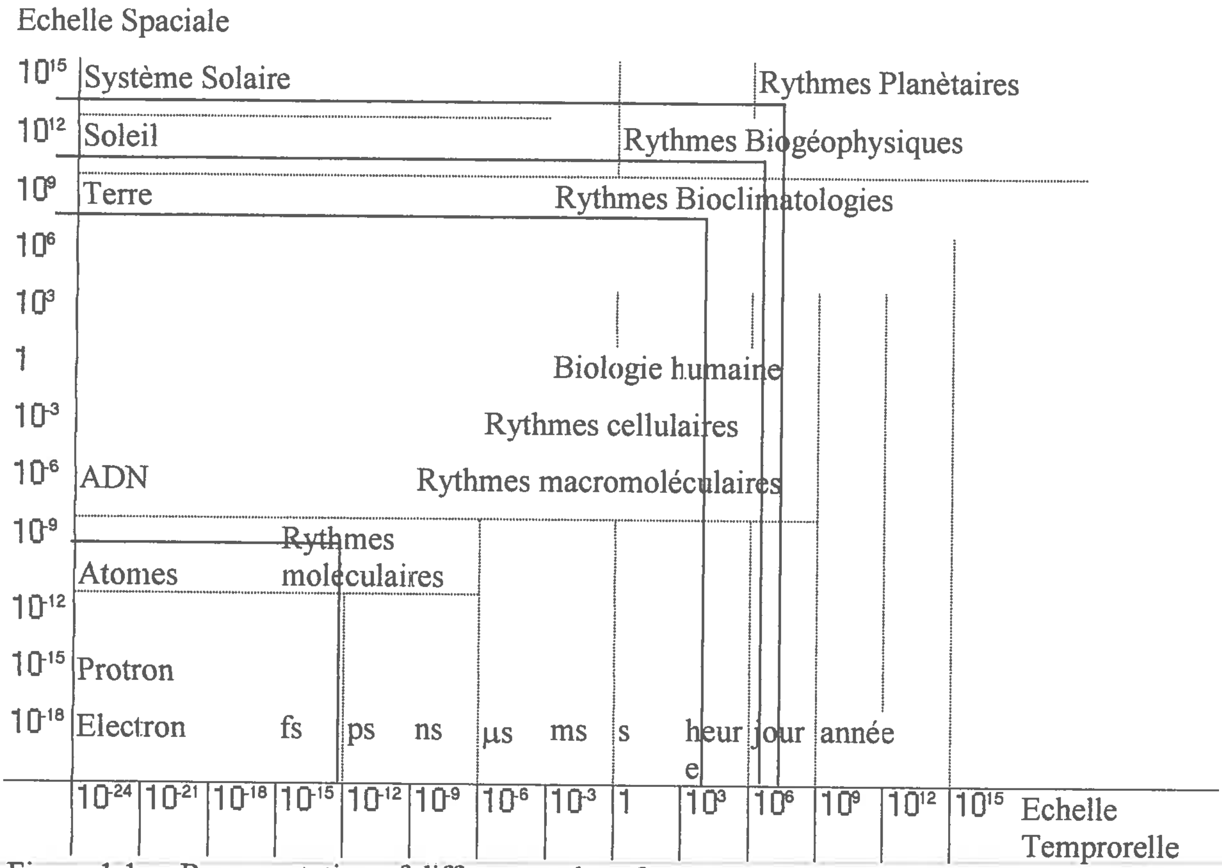


Figure 1.1-a :Representation of different scales of proposed observation

In this methodology we will make :

1- a classification of different scales of proposed observations (the microsecond, the second, the minute, the hour, the day, the month, the year, etc...).
(Figure 1.1-a : Spatio-temporal scale)

2- For each time or space scale, we will look for the most adapted simulation tools and models and what can be their individual contribution to solve proposed issues.

3- To set out links between temporal and spatial scales in admitting simplifications indeed interactions are extremly complex (like the biologic influence of the planetary modulation of the solar activity). High frequences imply very wide spatial structures (cosmic radiance).
(figure 1.1-b : SADT diagram)

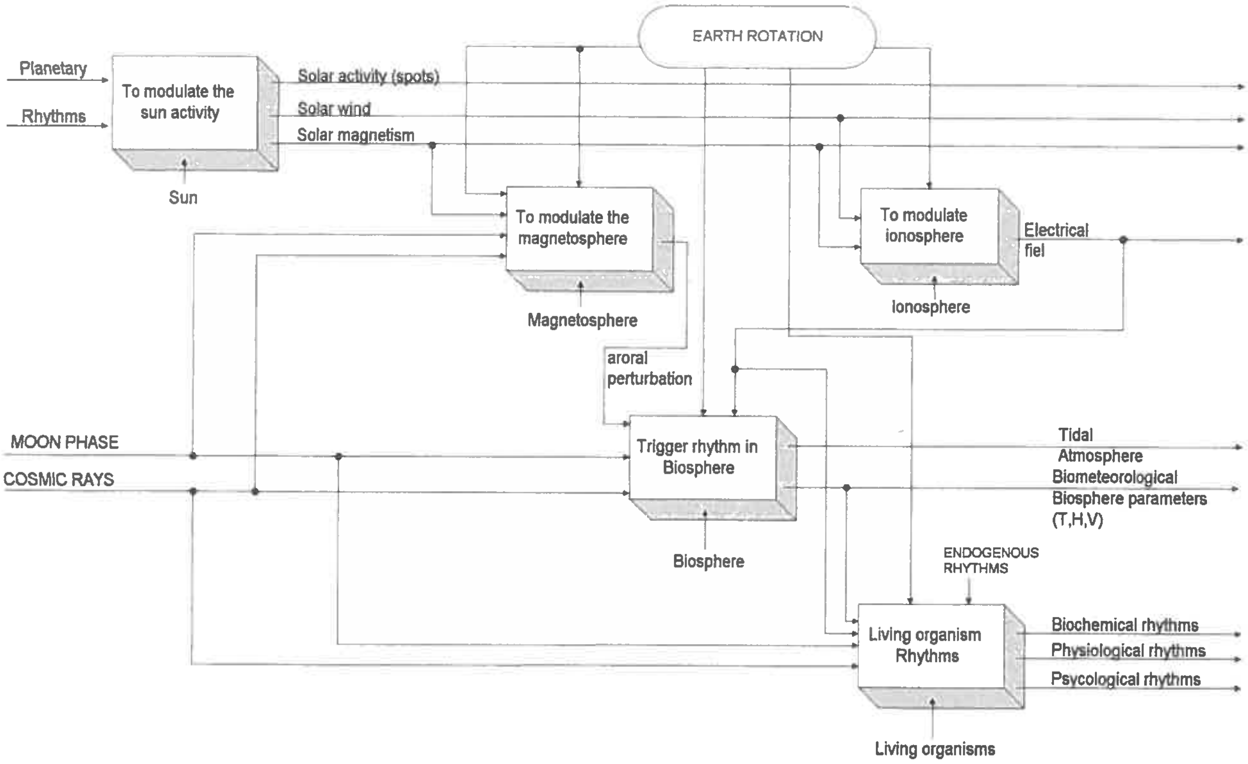


Figure 1.1-b : SADT representation of the outer environmental rhythms conditioning biological rhythms (planetary).

We will draw up a brief panorama of different scales implying a wide transdisciplinary, we will examine the possible set out of models which include two scales micro and macro in which the behaviour is formulated from data upon the microstructure and global answers mechanisms.

Different element categories suffering from rhythms do not have the same structure at the microscopic scale and at the macroscopic scale. We are in front of a multiplicity of scales and a complexity of phenomenons.

In the simulation, we get back given informations to a certain scale and we use them again as incomings for a code dealing with a superior spatio-temporal scale.

For this step the help of informatic methods like the SADT one (Structured analysis and design) will be very useful.

1.2 Models or micro-models

As given the multiple possibilities of adaptation of organized systems and the complexity of surrounding situations and of multiplicity of surrounding rhythms, it must be taken into account in the answer of the observed biologic system of :

- the real situation of the environment (proportional factor)
- previous situations which they might have fragilized (weakened) or reinforced the organism during the former cycles (integrative factor)
- the situation variability (differential factor)

If we are far from having studying and understanding the whole environment factors which intervene in the stimuli of biological systems, some of them still blurt outfrom our researches.

In a previous work Fontaine, Gaudeau, and Col. have tried to take into account the environment factors which is conditioning the answer of living organisms. (figure 1.2-a)

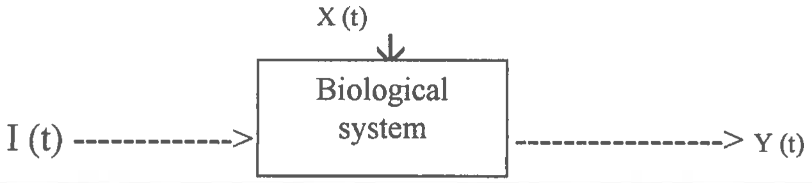
First of all, they tried an average answer, a whole of rhythmic disturbances characterized by an index (for instance : meteorological index).

In a system regulated as all living systems are, the answer Y (t) of a system can be described according to :

- references of the system X (t) (endogenous rhythms which references are varying all along the time)
- periodical disturbances or pseudo-periodic of the environment I (t) = F (P (t))

$$\alpha_1 \int Y(t)\,dt + \beta_1\, Y(t) + X_1 \frac{dY}{dt} = \alpha_2 \overbrace{\int P(t)\,dt + \beta_2\, P(t) + \Gamma_2 \frac{dP(t)}{dt}}^{I(t)} + \alpha_3 \int X(t) + \beta_3\, X(t) + \Gamma_3 \frac{dX}{dt}$$

X (t) = reference function of the system
P (t) = exterior disturbances of the system



In order to modelize meteorological variations of the environment operating on the living organisms, we have adopted the following disturbance function module :

$$P(t) \rightarrow \begin{bmatrix} H(t) \\ T(t) \\ V(t) \end{bmatrix} \qquad \text{so } I(t) \rightarrow F \left\{ \int_{t-k}^{t} \begin{bmatrix} H(t) \\ T(t) \\ V(t) \end{bmatrix} dt, \begin{bmatrix} H(t) \\ T(t) \\ V(t) \end{bmatrix}, \frac{d}{dt} \begin{bmatrix} H(t) \\ T(t) \\ V(t) \end{bmatrix} \right\}$$

Where we have selected among the used variables in order to define convenient areas :

- moisture H (t)
- temperature T (t)
- the air motion V (t)

$$I(t) = [\,\alpha'_1\ \alpha'_2\ \alpha'_3\,] \begin{bmatrix} \int_{t-k}^{t} H\,dt \\ \int_{t-k}^{t} T\,dt \\ \int_{t-k}^{t} V\,dt \end{bmatrix} + [\,\beta'_1\ \beta'_2\ \beta'_3\,] \begin{bmatrix} H(t) \\ T(t) \\ V(t) \end{bmatrix} + [\,\gamma'_1\ \gamma'_2\ \gamma'_3\,] \begin{bmatrix} \frac{dH}{dt} \\ \frac{dT}{dt} \\ \frac{dV}{dt} \end{bmatrix} + C$$

The coefficient αi, βi, γi will be determined by statistical method.

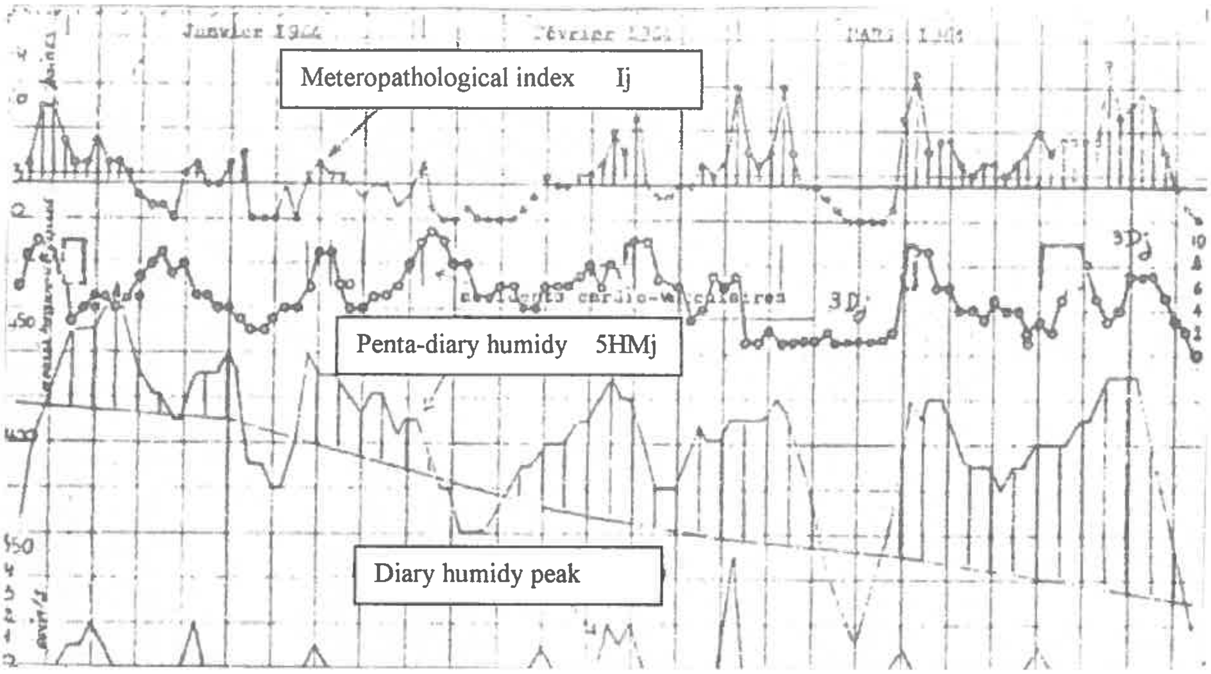


Figure 1.2-a : meteorological and mortality index : from up to the bottom :

- meteopathological index : Ij
- diary mortality variation : 3Dj (smoothed over 3 days)
- penta-diary humidity variations over 5 days : 5HMj
- humidity peak

Characterization of references X (t) : those references can be defined relatively to the climate period to which the living system had been exposed for the first time to the environment fluctuations.

1.3 Statistic tools

On one hand, to understand these mechanisms, one has to observe them, and on the other hand to modelize them to be able to analyse them. A basic tool : COSINOR.

Observation : Each experience or collected observations have to be realized in specific precise conditions.

- 1) The synchronization of observed subjects
For example : the rest and activity alternation for a synchronizer role.

- 2) The acquisition of an adequat temporal range for each physiologic variable. With the COSINOR method datas do not need to be set out in time, however the observations duration must be superior to the rhythm period.

- 3) The structure in tested model and the statistic analysis
One can use the non-linear models in case of a multiplicity of different periods in interaction between them and test the models by bispectral analysis and third moment methods.

2- TYPOLOGY OF RHYTHMS

2.1 infra-circadian rhythms

The human body owns a multifold of rhythms : encephalogic, cardiac, respiratory, and digestive rhythms, with different interactions between those rhythms.

Rhythms are a fundamental component of the cellular activity, for instance the cellular calcic metabolism which is an oscillatory kind process, indeed it would exist a risk to maintain for a long time an intracellular concentration too high in calcium.

The oscillations period depends on the intensity of a hormonal inductive signal. The period modulation could correspond to an encoding system by frequency : different hormones would generate intracellular oscillations according to a frequency which would bring the proper "signature" to each of them (Wood, 1987).

-2.2 The environment rhythms intervene not only during the human life but also at the birth moment and during the pregnancy.

Cells have their own parameters, surrenal glands have as well their own parameters and keep their in vitro circadian rhythm.

peri

If we place an element of 3 cm of the digestive tube taken off an animal in a nutritive environment. A light traction made on this element will start a penstallic rhythmic activity every 2 or 3 minutes. This activity is controlled by a whole nervous system in the wall (the Messner and Anerbach plexus, C.Gaudeau, 1975). It is the same thing for the cardiac cell but with a rhythmic activity much more speed.

The rhythmic activity is an intrinsic property of the cell.

If encephalogic, cardiac, and respiratory rhythms (rhythm α, β, etc...) are well known, it is not the case concerning electrical digestive rhythms which were parrticularly highlighted by J.Thouvenot. Each organ of the digestive system has its own rhythm, those rhythms are in interaction with the respiratory system as the following figure shows it

The respiratory activity is not only modulating the duodenum functioning peculiarly, but it also deals with a digestive disturbance from gastric or colic origin which have repercussion on the respiratory rhythm (figure 1.3-a).

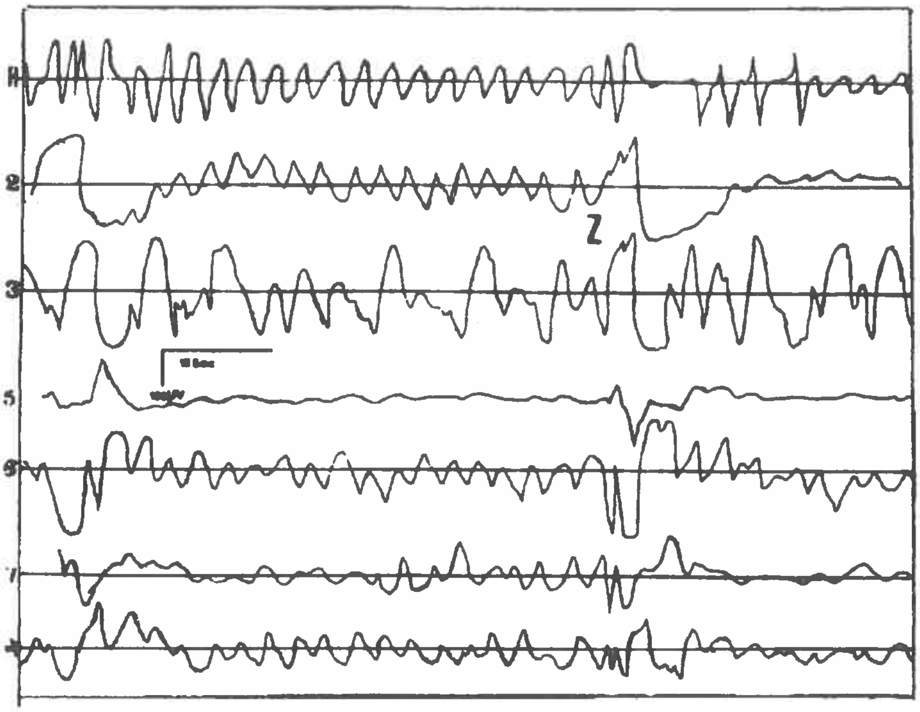


Figure 1.3-a : record showing the relation between respiratory activity and digestive electrophysiology.
From up to the bottom :

- -R : respiration
- -2-3 : epi and hypogastric record (gastric activity 3,5-4,5 cycle / minute)
- -5-6 : right and left hypocondre derivation
- -7 : left iliaque gap (colic activity : 0,73 / minute)

The respiration modules the digestive activity and colic activity blocks by biofeedback the respiration.

One will never give enough importance to the relations between the cardiac rhythm and the music. If we appreciate physiologically the tempo, it means that is almost corresponding to the cardiac frequency.

Besides it was often said that we appreciate the music with "ones guts", melodies and theme variations are recognized in the digestive rhythms.

2.2 Circadian rhythms

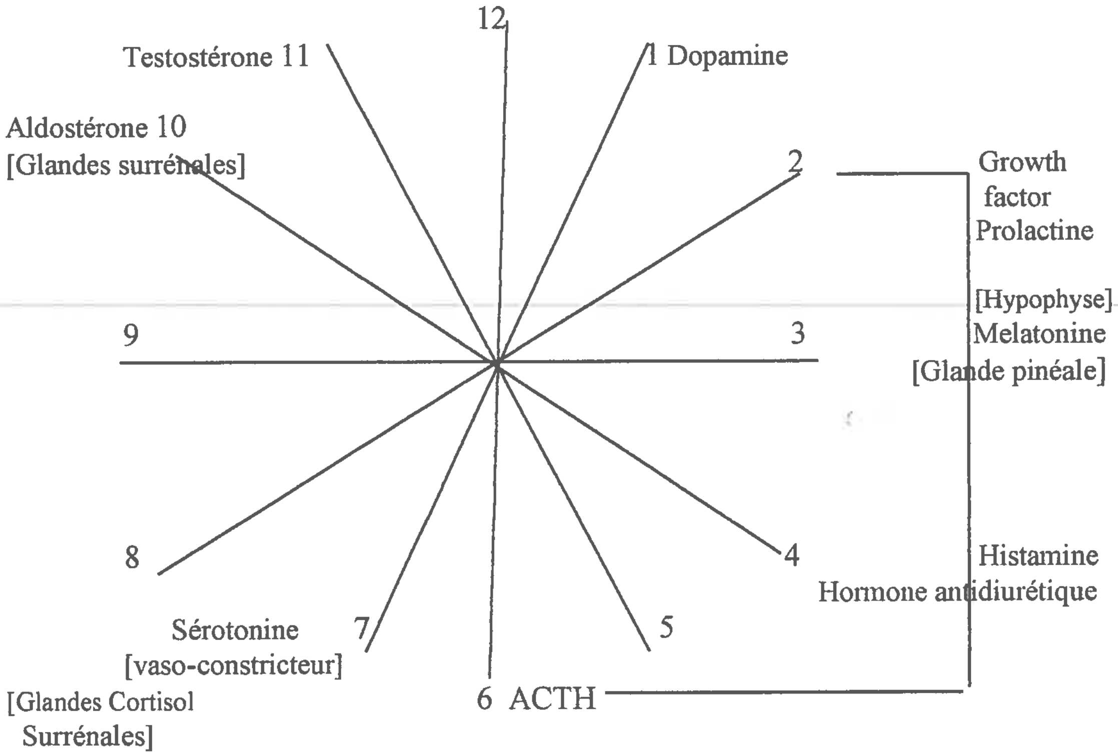
2.2.1- Endogenic circadian rhythms

The environment intervenes to synchronize intern "melodies" as an orchestra leader which is the Earth rotation around itself and around the sun.(figure 2.2.1-a)

Does it exist a central metronome ? It is evocated the suprachiasmatic nucleus (Martin Ralph, University of Virginia, showed, through an experiment on hamsters this role of (orchestra) leader, but this is not alone, surenal in vitro glands keep their circadian secretion rhythm.

It is from the genes part that we have to look for the score. A gene responsible for circadian rhythms appears in the suprachiasmatic nucleuses of the drosophile fly ; a gene "per" is active only during the night. Other genes called " cefos" are entering into the suprachiasmatic nucleuses.

The light information inhibits during the day the secretion through, the pineal gland, of the melatonine and it is reinforced during the night concerning people who are suffering from the time lag. Used in therapeutics, the melatonine is able to re-synchronize the circadian rhythms.



Netherlands these were seldom noticed before A.D 1916, but german sources are cited by Link in 1619, 1646.

The 11 years sunspot is not a sinius curve and its phase is "early" when the amplitudes of the cycle are strong. In the first half of the XXth century its maxima occurs about every 10 years : 1907 / 1917 / 1937 / 1947. Reminders source A.D 800 are between 5 or 6. So that, weaker longer cycles appear for the second half of the century. 1968-69 was a maximum 11 years after 1957, and the cycles of a length about 12 -13 years occur a year after.

Sunspots dates have been compared with meteorological events :

Shove (1972) showed a remarkable alternation of West and East winds in the equatorial stratosphere with a period of 2,2 years. In one year in the equatorial stratosphere the wind is East (Krakatora easterlies in 1883 - but also in 1909,7 - 1911,8 - 1914,1).

2.7.1 Biennial oscillations

-Biennial oscillations are associated with strong solar maxima.(figure 2.7.1-a)
-Triennial oscillations are associated especially with weak solar maxima.

Longer cycles of 80 years and 200 years occur in solar activity in the past two millennium and since A.D 1200 meteorological cycles about this length have been found in ice core data.

In 1937, Scott S. Forbush has underlined that the more intensive the solar wind was, the less was the cosmic ray which targets the Earth. The warm solar plasma which freezes the magnetic field, is devying primary cosmic rays, before they reach Earth.

K. Lassen, E Friis-Christensen and H. Svensmark had highlighted from 1860 to 1995 period, the relation between the solar cycles duration and the temperature variations in the northern hemisphere : when the cycles are shorter the temperatures increase, when maximas are near, the solar wind is more dense and it limits the clouds formation which are shaped by the cosmic ray and which re-send the solar heat.

C. Wilson has allowed to explain the phenomenon : the moisture air become dust and frozen by depression, kind of condensations if it is bombed by X-rays : The more intensive the cosmic ray is (minimum of solar wind) the more intensive the Earth cloud cover is (The NASA Goddard Institute Study on the cloudy areas from 1984 to 1990). Clouds freeze the climate by absorbing and by reflecting the solar radiations.

Measuring the sunspot activity but with the solar corposcular radiation and with the sectorial structure of the interplanetary magnetic field depending on it.

26 months cycle of tropospheric and stratospheric parameters (insérer image de la Terre).

Vittels supposed that the cause of this 26,5 months cycle is due to the superposition of the synodic sun period of 27,3 and the non-synodic period of 29,3 (27,3 x 29,5 = 805,35 days or 2,205 years)

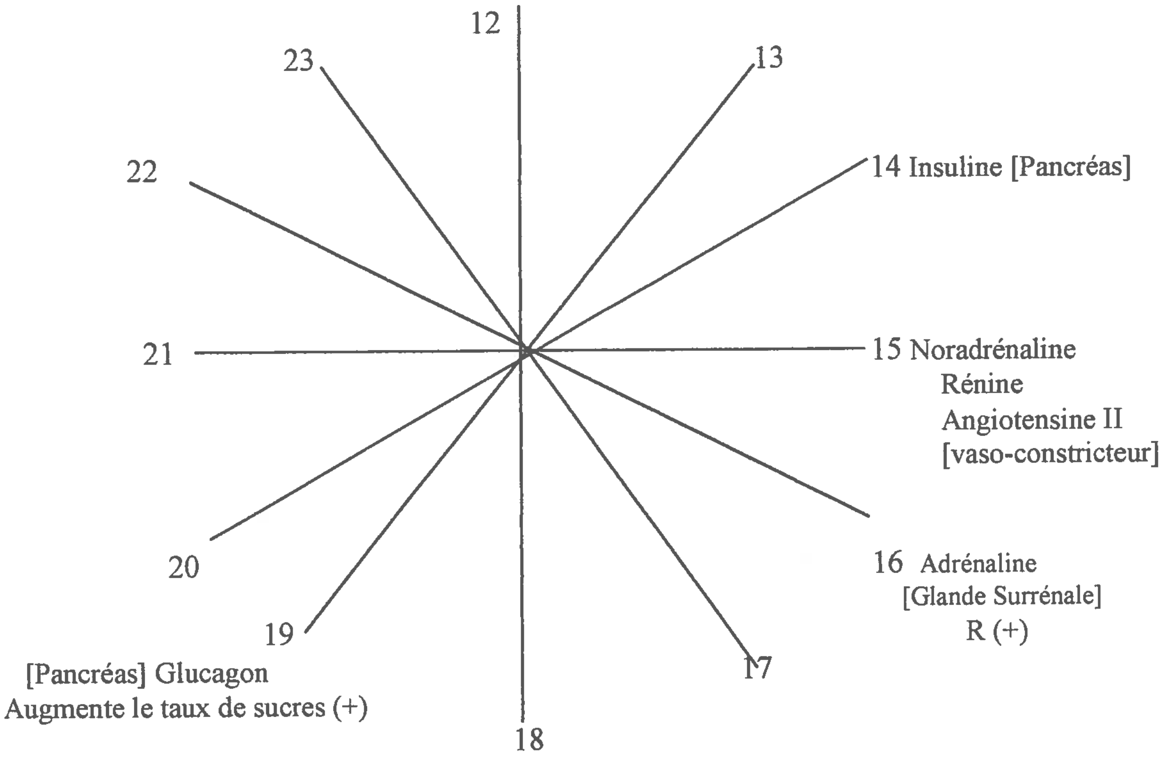


Figure 2.2.1-a : Graphic indicating secretion maxima of principal substances which are circulating in the blood environment during the day.

2.2.2- Inter-individual variability

However, proper rhythms of the body can vary from a person to another. As Alain Reinberg underlines it, some people can perfectly tolerate night schedule work, others have rapidly showed intolerance troubles, persistent tiredness, sleep troubles.

2.2.3- Chronotherapy

If the organism products at certain hours some hormones such as the cortisol (as the cortisol at 7 a.m. or the melatonine at 3 a.m.), it would be better to give medicines chemically close to this substance at the same hours, instead of blocking the secretion because of the saturation, it will reinforce the metabolism as a cymbal blow underlines a musical sentence. Results are particularly efficient (administration in the ovulation of the LHRH against sterility every 60 or 20 minutes).

At the Chronotherapy Center of the Paul Brousse hospital (Villejuif), in the anticancerous therapeutic, the injections frequency of 4 antimitotic syringes is guided by a micro-data processor. According to the director Francis Levi, medicines are more or less well tolerated following hours of the day. The pump delivery is automatically modulated in the way to distribute the product at the moments of the day where it is well tolerated, in order to give much more important quantities at that moment.These programmed pumps deliver the treatment on the basis of (at the rate of) 4 to 5 days every 2 to 4 weeks.

For example :
The aspirin is less toxic for the stomach at 22 p.m. than at 10 a.m.

The anti-inflammatory medicines have 4 times less secondary effects in the evening. It is the same thing for medicines prescribed for the ulcer (sore) and the antihistaminic against the allergic rhinitis.

The anti-hypertension medicines are more active during the day than the night.

This method avoids to immobilize patients during 8 to 12 hours at a stretch such as for a normal chemotherapy and gives excellent results over cancers alike treated, we note two remissions upon three against one upon three with the same products injected in the classical way.

To increase the tolerance, according to Francis Levi, director of the Chronotherapy Center, medicines are more or less well tolerated following hours of the day.

To make the chronotherapy much more efficient, it is necessary to associate to an expert system of modelization some hormonal regulations (Expert Immuno, Expert Sida, Expert Cancer).

Transplant rejections would start during the second half of the night. It was observed that the immuno-suppressors used during tranplantations prevent more or less rejections according to the injection hour.

2.3 Supracircadian rhythms : outer rhythms

If the supracircadian rhythms are modulated by the Earth rotation around itself which creates the day and night alternance, the supracircadian rhythms are conditioned on one hand by :

- the proper solar activity (the sunspots in particular)
- the Earth rotation around the sun which considering its inclination creates the seasons.

2.3.1 Solar activity rhythms

The sunspots as well as other solar areas (the M centers) are responsible for geomagnetic storms through the intermediary of the solar wind and hydromagnetic shock waves are spreading over the space Sun-Earth.

The motion of active centers tied to the sun will do appearing recurrent periods equal to synodal periods of the sun.

From 26 days at the solar equator, it increases with the latitude up to raise 29 days at the 45° latitude (Chapman and Batels).

At the solar cycle starting, sunspots grow up in high latitudes, so they have a slower rotation, then as the cycle is going along, they tend to appear at lower latitudes, so with a faster rotation.

2.3.2 Geomagnetic rhythms

Geomagnetic rhythms are connected : (figure 2.3.2-a)
- with chronospheric flares on the sun (flare type or sporadic disturbances)
- sectorial structure of the interplanetary magnetic fields. This second type of disturbances are recurrent because of the pronounced tendancy in the 27 days corresponding to the solar synodal rotation. These sequences are connected with a long existence of vast unpolar magnetic regions (UMR) with weak radial sun magnetic fields.

These fields are "frozen" in the solar wind if the Earth is located on the longitude 60° to the west from the central meridian, the fields line are binding because of the solar rotation.

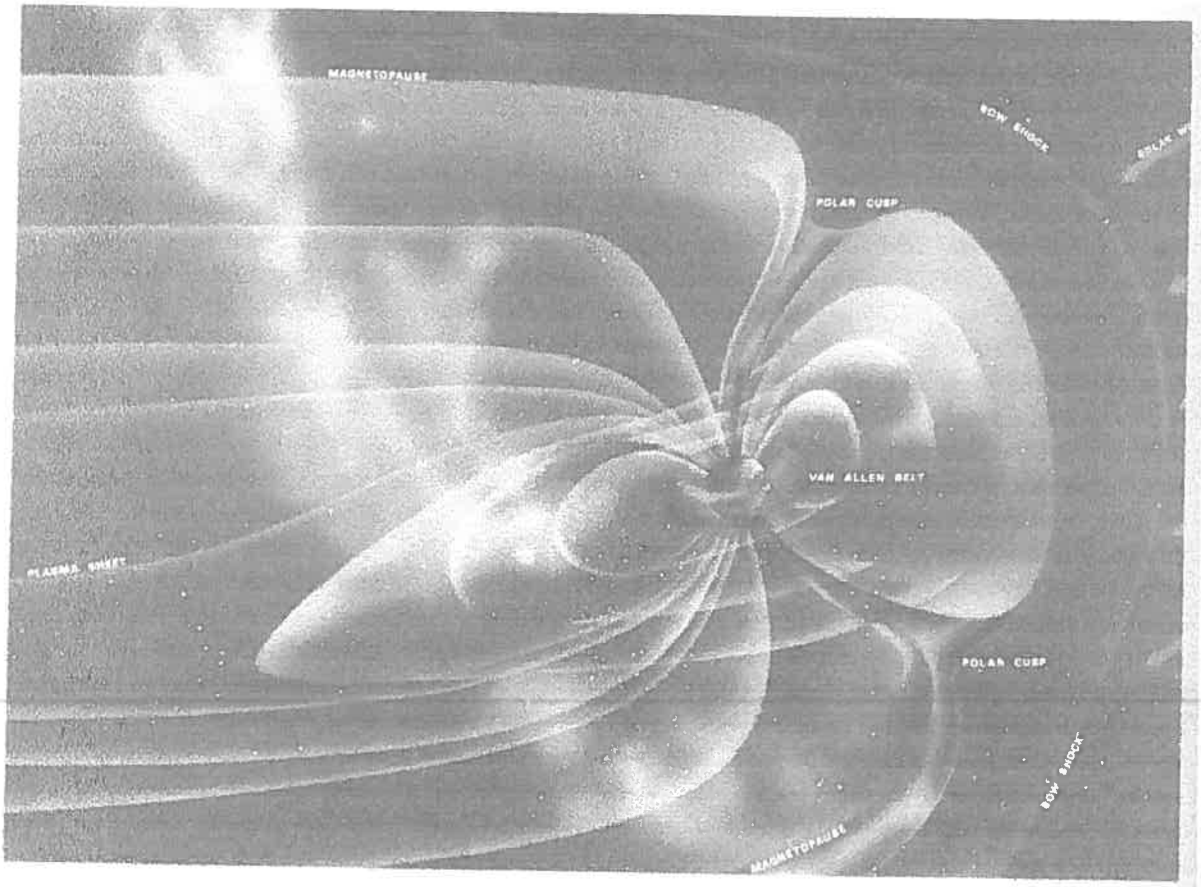


Figure 2.3.2-a : Geomagnetic field deformed by the solar wind.

Witness of the wind solar activity upon the geophysical environment, the geomagnetic is principally described by the rhythmic activity of the index Kp available for the whole planet.This index translates the amplitude of those variations considering one value every 3 hours.

This size is also translated by the variable Kl (j) = lg (Ap + 1) or Ap (j) is translated in gamma (10^{-5} gauss) and represents the day-to-day activity.

The moon by hidding the solar wind modules this geomagnetic activity Chernosky showed that it exists a recurrence in the geomagnetic activity of 28,5 days at the cycle starting, and of 26,3/4 at the cycle end.

A function of self-correlation (made on a period of 33 years from 1932 to 1965) gives periods range going from 27,3 days, 54,6 days, 81,9 days.

Indeed, if the sample contains periodical variations of the T period, the self-correlation function will have maxima for delay values equal to T, 2T, 3T.

This recurrence decreases in the exponential way and allows to introduce the notion of life duration for the recurrent disturbances.

If we admit that the signal $S(t)$ is under the shape $S(t) = A\exp(-t/\theta)$ or θ = time constant or average life duration of the recurrent activity and if the signals $S(t)$ measure on the curve $R(v)$ for : $v = 27{,}3$; $54{,}8$; 108 ; and 135 days.

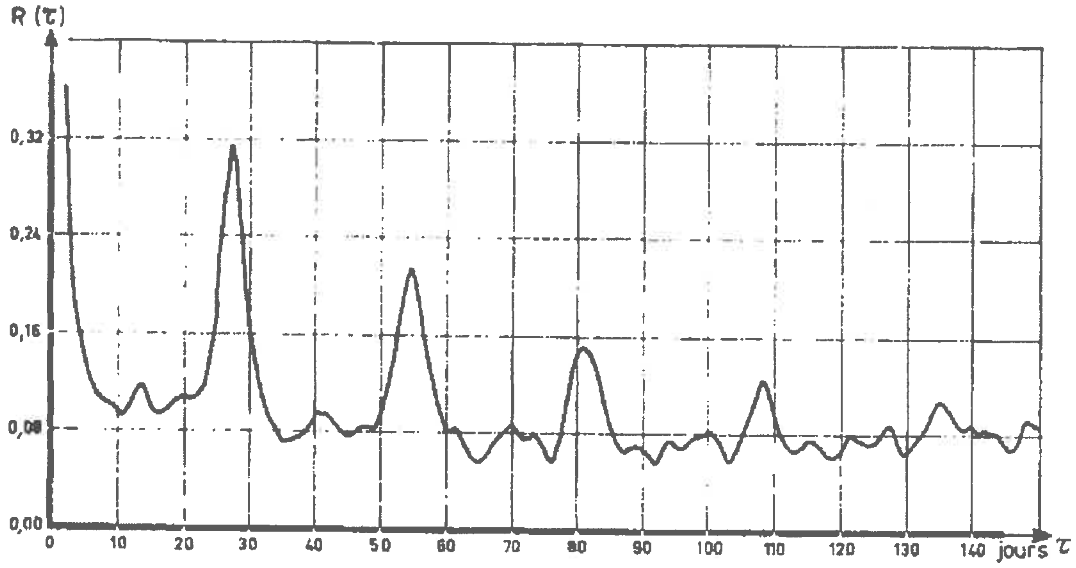


Figure 2.3.2-a : Autocorrelation of the daily geomagnetic activity K1 (j) :

The estimation gives $\theta = 56$ days $A = 0{,}40$.

The geomagnetic activity presents a recurrent part about 56 days, showed by Guez and Gaudeau (1966).

In the decreasing period activity, the recurrence at 27 days is important all along it approaches to a minimum. That recurrence is colouring with some shorter periods. Disturbances duration is longer before a minimum and shorter after.

2.3.3 Ionosphere and atmospheric rythms

The solar wind enhances ionization in the lower atmosphere and decreases it in the upper atmosphere and provokes aurorae disturbances.

Particles accelerated in magnetic tail producing aurorae disturbances in polar ionosphere (figure 2.3.3-a). Simultaneously (with a small delay) the processes will develop in stratospheric and troposphere resulting in the rhythmic atmospheric circulation disturbances which will influence practically all hydrometeorological parameters.

Magneto-ionospheric variations are connected :

- with chronospheric flares on the sun (flare type or sporadic disturbances)
- sectorial structure of the interplanetary magnetic fields. This second type of disturbances are recurrent because of the pronounced tendancy in the 27 days corresponding

to the solar synodal rotation. These sequences are connected with a long existence of vast unpolar magnetic regions (UMR) with weak radial sun magnetic fields.

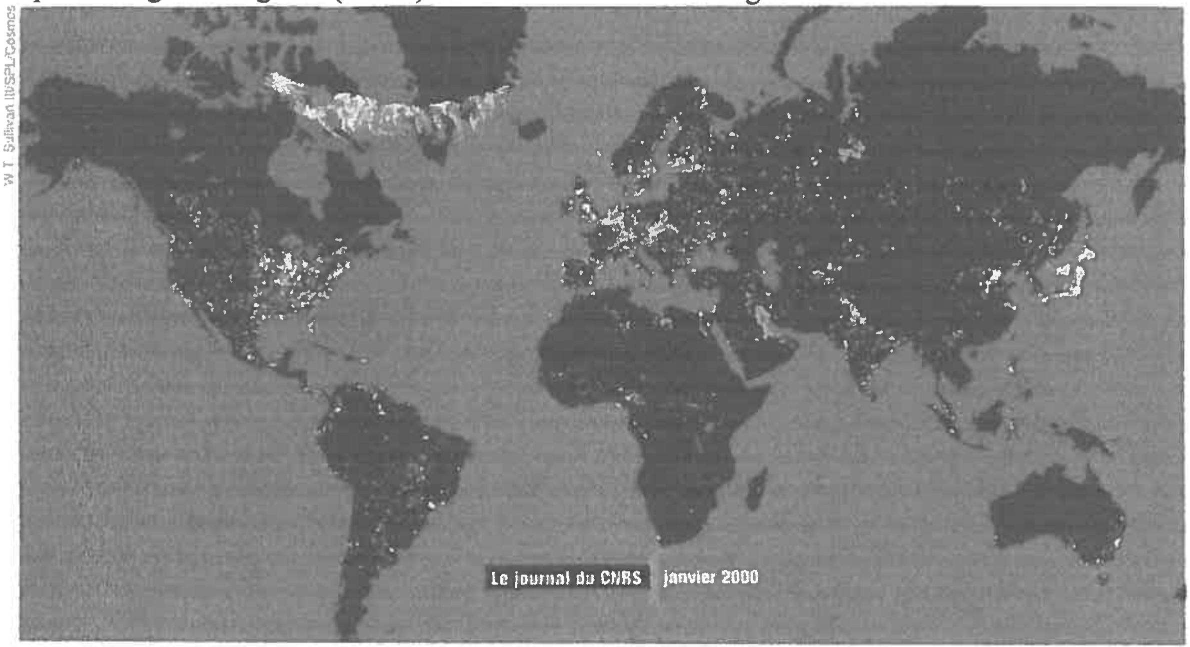


Figure 2.3.3-a : Satellite picture during the night where we can see aurorae on Groenland and Canada.

These fields are "frozen" in the solar wind if the Earth is located on the longitude 60° to the west from the central meridian, the solar magnetic fields are binding because of the solar rotation.

2.3.4 Troposheric rhythms

Strong relationships exist between the solar activity and various cyclic geophysical phenomena mediated by the solar wind. Each phenomena does not repeat in equal intervals and its amplitude is not constant in time.

It is necessary to consider different periods depending on :
- the solar rotation and Earth position and active regions present on the sun
- the existence of stable sectorial structure of the interplanetary magnetic fields

The concerned cycles are :
- 27 days
- 5-6 years
- 11 years
- 22 years
- 80-90 years

Comparing rhythmic solar activity with geophysical processes we must remember that sunspot numbers describe only some manifestations of solar activity and cannot be the universal means of analysing solar/terrestrial relationships both connected with chronospheric feares on the sun.

2.4 Circamensual rhythms (27 days rhythm)

A pronounced tendancy of the recurrence in 27 days correspond to the solar synodal rotation and the stationary sectorial structure of the interplanetary magnetic field produce occurrence of quasi-periodical geomagnetic disturbances with cycles of 6,7 - 9 - 13 - 27 days.

A semi-annual periodicity with equinoctial maxima in the intensity of geomagnetic disturbances is due to angle of 90° between Earth, magnetic axis and the Earth sun line. It favours the occurrence of magnetic storms.

Logunov (1970) has shown that similar periodicities are expected in meteorological and hydrological parameters. Flare type geomagnetic disturbances were connected with the enhancement of the zonal atmospheric circulation while recurrent disturbances were connected with the enhancement of meridional circulation ; these changes of atmospheric circulation occurs 3 days after magnetic perturbation.

Bio-meteorological rhythms

Some stable quasi-periodicities have been observed with a rhythm of 12-15 and 27 days in :

- temperature of Leningrad (Vitels, 1967)
- spectral curve of the planetary circulation variations of 13 days (Monin, 1969)

Biological rhythms

Some stable biological periodicities has been observed in biological system:

- periodicity development of different diseases (Reinman, 1970) of 7, 14, 28 days.
- reject period the 7th day, 14th day, and 21st day after at transplant
- we observe in the myocardium infarct an increase of the coagulating time 14 days after the infarct, then a decrease 28 days after (this observation was done by the author at Foch hospital).

For biological systems external rhythms are in competition with biological intern clocks.

Indeed both, man and woman, would have a coagulating rythm every 28 days in average.

Other rhythms seem to spread over periods of 2583 hours (i.e. 90 days) (urine temperature, organic functions and endocrinic secretions).

2.5 Circannual rhythms

If the existence of annual rhythms of the morbidity and mortality is known since Hippocrates, it hadn't been yet objectified. The organism susceptibility which has stressing agents, is not invariant all along the seasons.

A study on morbidity of Parisian hospitals (1957-1967) and of whole France (1952-1962) due to malignant tumours, brain vascular accidents, and coronarian diseases, has showed a level maximum in February and a minimum in August (figure 2.5-a).

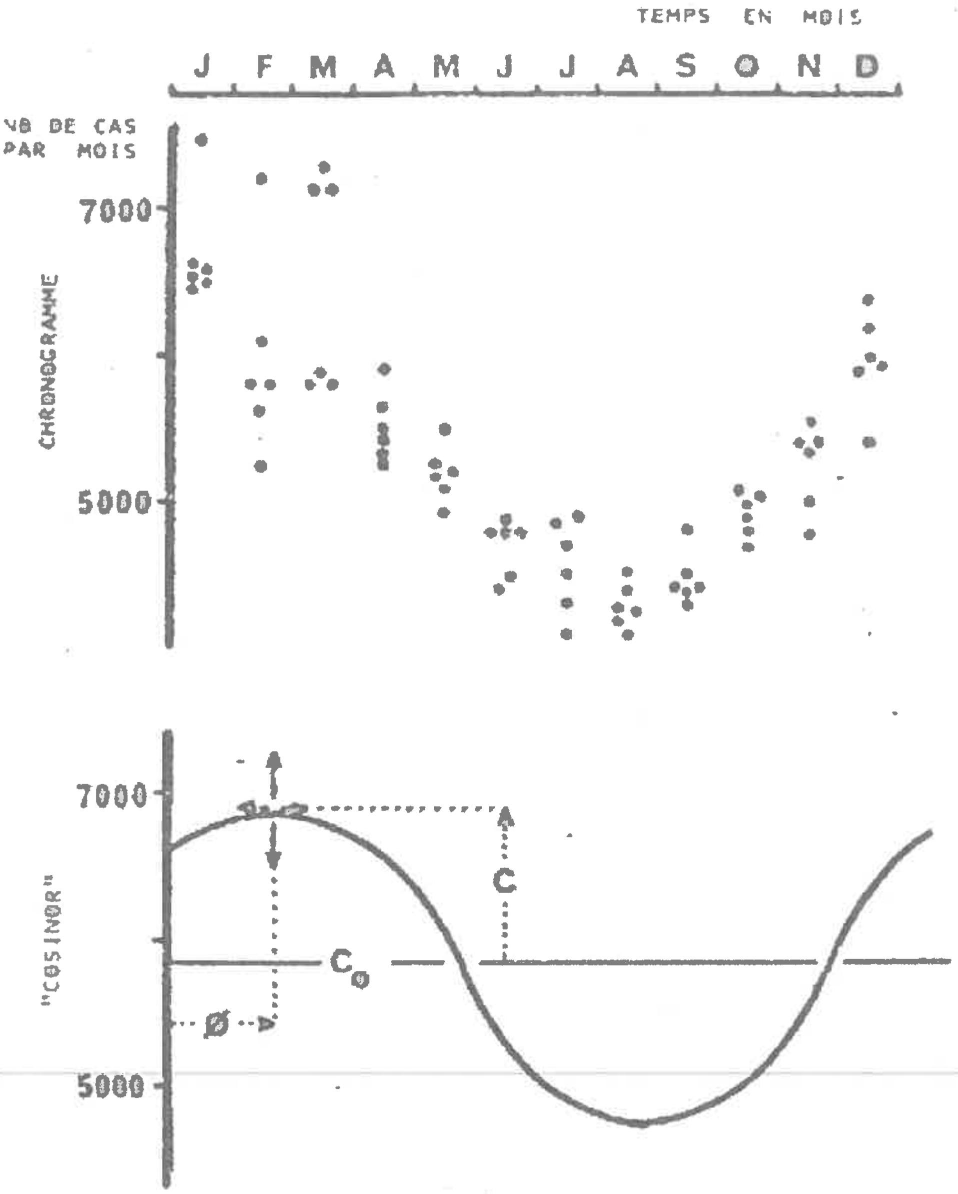


Figure 2.5-a : Rhythms circannual death by cerebro-vascular pathology.

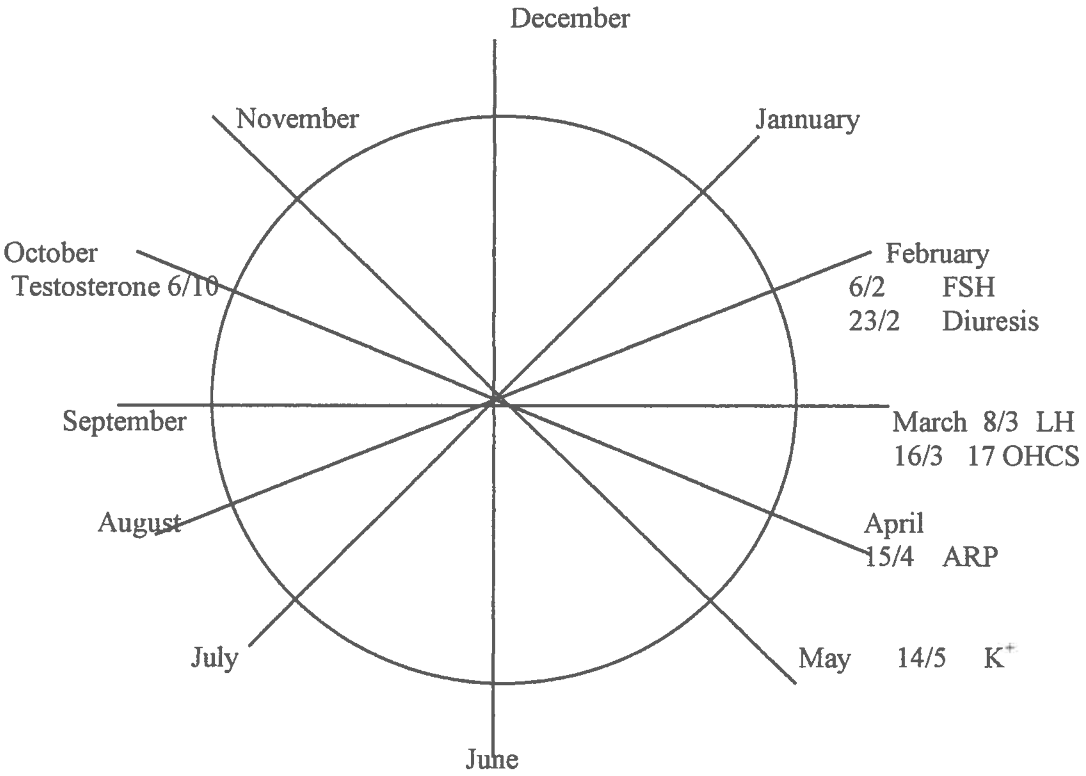
If numerous authors think that this annual susceptibility is an intern mechanism, it would be possible that some external agents like for example cosmic brightness could stimulate or use regulator mechanisms.

Lacagney and Collout observe 5 Parisians aged from 26 to 32 years. The following variables have a very significant urinaries annual rhythm :

	Maxima	Dispersion
17-OHCS	16.03	(01/03 - 31/03)
K^+	14.05	(20/03 - 18/06)
FSH	06.02	(01/12 - 10/04)
LH	08.03	(18/01 - 26/4)*
Testosterone	06.10	(16/07 - 26/12)

ARP (revivo activity)	15.04	(10/12 - 07/06)
Diuresis	23.02	(20/01 - 21/03)

*The hypophysarian secretion is accelerating the growth of the ovarian follicles.



These results reveal an endocrinic aspect of the healthy adult temporal structure and permit to sustain the hypothesis of an endogenous component.

2.6 Seasonal variations

2.6.1 vascular pathologies

Among numerous biologic parameters according to the seasons, the morbidity follows cyclic variations of the environment factors such as :

- temperature
- precipitations
- moisture

We set up the organism resistance to the stress due to the environment, is constant according to Gervais and Reinberg. The biologic rhythms have a proper rhythm genetically inherited.

Through the use of the Cosinor method, seasonal variations of the susceptibility to the stress due to fluctuations of the environment physico-chemic variables, a study made at the Ferdinand Widal hospital in Paris, showed an acrophase on February 22th (variability between 27 January - 17 March) for deaths by brain vascular damages and by coronarian diseases.

The circannual rhythm amplitude is :

- relatively weak : 2,7% concerning malignant tumours death
- 14% for suicides
- 17% for coronarian diseases
- 20% for brain vascular damages
- 23% for other heart diseases

Seasonal rhythms has been observed in Roumania by H.Strauss and al. (1972) in cardio-vascular mortality (brain-vascular accident, myocard infarct and chronic cardio-pulmonary insufficiency). Cardio-vascular death rate are higher in the first semester and lower in June-September period.

Brain-vascular accidents present also a higher frequency in winter and spring and a lower frequency in the months of June to August.

Myocard infarct present a bimodal variation with a spring peak (from March to April) and another with an autumn-winter peak (from October to December) when the cardiac pulmonary conditions present a bimodal variation with an increased incidence in November to February period.

Oscillation of atmospheric pressure during the day of the death occurs in 60% of the cases. Magnetic fields perturbations occur in 72-94% of the brain-vascular accidents and in 100% of the cardio-pulmonary deaths.

2.6.2 Congenital malformations

Also strong evidence for a winter excess was found in cataract, spina bifida, oesophageal atresia, congenital dislocation of the lungs. A summer excess was present in aortic and pulmonary stenosis, partial absence or defeat of limbs (CDH) ; in Japan the observed values were 150 more that could be expected according to the number of total births in the same month.

Various life functions are connected with hormonal system which shows seasonal variations may be related lenght of the daylight. The light dependent hormone may play an important role in the genesis of congenital malformation (provoking a general joint laxity).

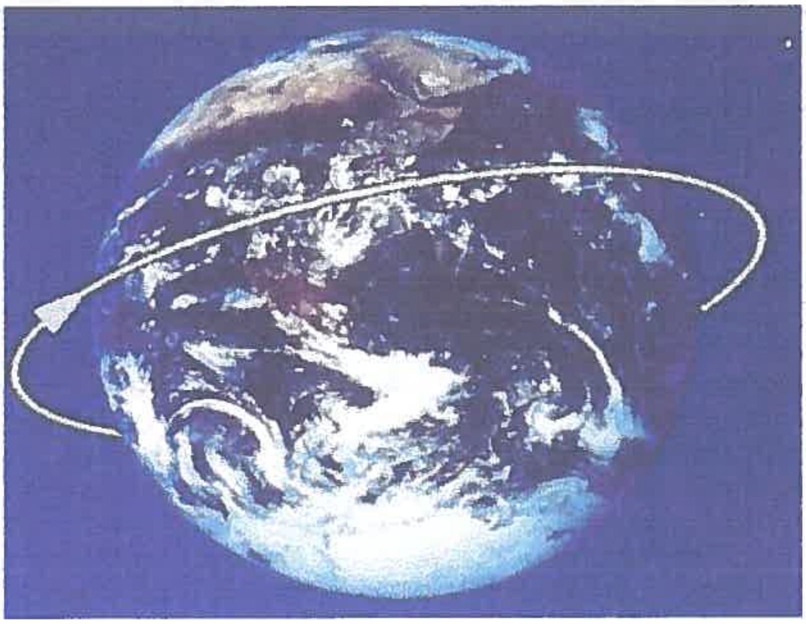
It is conceivable that superposed or a general background, beside infective or toxic agents, endogenous annual rhythms, synchronized by environmental factors (such as light and dark) may play a role in the seasonal variation of congenital malformations.

2.7 Pluriannual rhythms

Sunspot cycles of 11 years have a great influence of the Earth mediated by the solar wind. They can be reconstituted back to before A.D 300 by combining the records of sunspots and observation boreal aurorae (testifying the annual solar wind in the magnetosphere). In the

Fig 2.7.1-a :The biennial oscillator in the equatorial stratospheric wind in relationship with the geomagnetic activity (cf. Shove).

Wind travelling westward in 1883 – …– 1939,2 – 1941,2 – 1943 – 1946,2 – 1948,2 – 1950,1 – 1952,4 – 1954,8 – 1956,9 – 1959,2 – 1960,8 to 1961,2 – 1963,3 – 1966.



Wind travelling eastward in 1947,2 – 1949,2 – 1951,2 – 1953,6 – 1955,9 – 1958,3 – 1960,3 – 1964,5.

2.7.2 Five-six years rhythm

The 5-6 year rhythm observed in geophysical phenomena was also observed in hydrometeorological phenomenons.

- duration of the northern and eastern winds in Greewich
- precipitations in Southport and Bolton
- air pressure at London
- air temperature in Greenwich and in Berlin
- frequency of the cold winters in London
- seismic activity (Sytinsky, 1963)

The main cyclical curve for annual sums of precipitation has two maxima, smaller one being near the sunspot number maxima and larger one being near the minimum (Hellmann, 1906).

Ohl (1972) estimated that the 5-6 year rhythm is connected with sunspot numbers.

2.7.3 Eleven year rhythm

A large observation about 11 year cycle manifestations was done in :

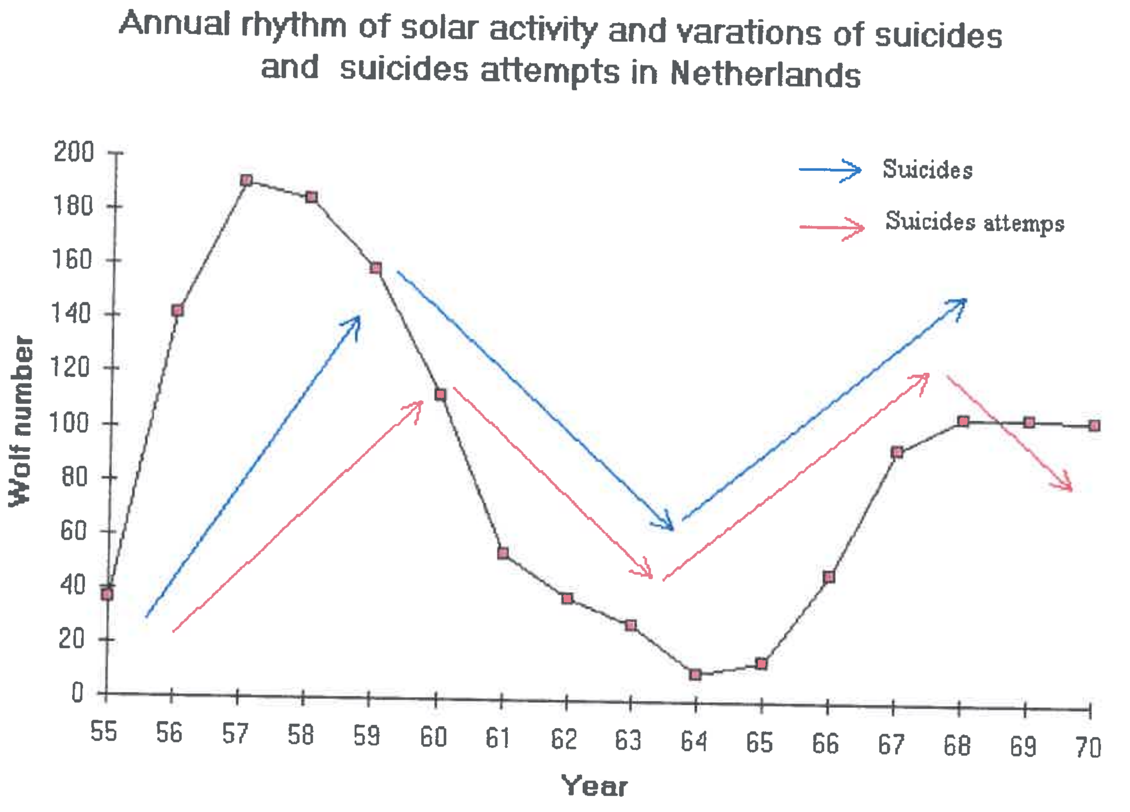
Biometeorological rhythms

- air temperature (Rubinstein, 1966)
- air tempearture in winter (Polozora, 1970)
- run off of Siberian river (Druzhinin, 1966)
- air pressure (Maximov, 1970) near the maxima of sunspot number, anticyclonic processes increase there.
- pressure field beyond the North Pole Circle
- variation in frequency of storms in south-west part of Kara sea (Mozalevskaya, 1970)
- distribution of droughts in Kazakhstan (Baydal, 1969) in sunspot minima droughts were observed, in maxima no one.
- temperature of the Atlantic Ocean waters (Nikolaev, 1970)

Biological rhythms

- Suicides and atemps suicides in Neederland(JANNEKE and col -1972) (figure 2.7.3-a).

Year	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
Wolf number	36	141,7	190,2	184,8	159	112,3	53,9	37,5	27,9	10,2	15,1	47	93,8	105,9	105,4	104,5


Annual rhythm of solar activity and varations of suicides and suicides attempts in Netherlands

2.7.4 Twenty-two year rhythms

The sedimentation rate of the precipitations formed by a chemical reaction involving "healed water" (hydrolysis of and solution of bismuth chlorude)

2.7.5 Eighty-ninety year rhythm

They are well pronounced in climate and air aurorae phenomena, and are observed for :

- severity of winters in Western Europe (measure of the ice cover in Northern part of the Atlantic Ocean and thickness of the Sekwoya's annual rings (Maximov, 1962).
- Winter temperature in Prague (Valnicek, 1965).

This rhythm is may be in relationship with the means duration of the human life.

3-METHODOLOGY

3.1 Linear system : the Cosinor method

The answer in term of frequency of the system can be determined from the transfer function of the system H(p). (Transformed by de Laplace of h(τ)). The answer at the equilibrium state of the system, subject to certain conditions of stability, will be :

$$Y(t) = \int_{0}^{\infty} x(t)\, h(t - \tau) d\tau = a \; || H(jw) || \cos(wt + \phi)$$

where || H(jw) || is the module of H(jw) or gain of the system and ϕ is the argument of the complex number H(jw) obtained by the replacement of p by jw. Both quantities H(jw) and ϕ composing the answer in frequency of the system which can be graphically determined in the phase plan or p.plan, the module and the phase are calculated by measuring the module and the angle of the vectors drawned up from the poles and the zeros of H(p) and having as extremity the corresponding axis point.

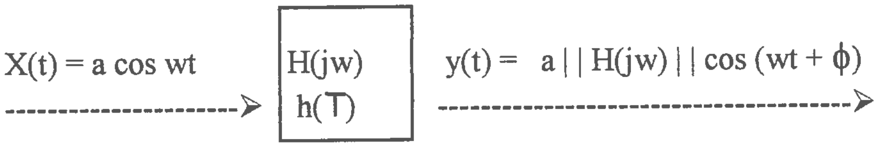


Figure 3-a : Representation of a transfer system and function

We can describe properties of the dynamic system by both characteristics : the amplitude and the phase. (Fig.2.1.1-b)

The study of those linear systems can be realized by the COSINOR method.

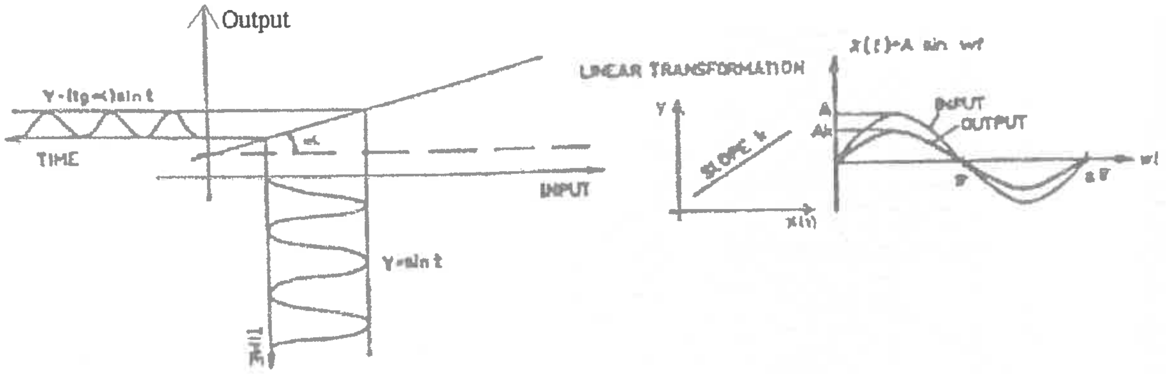


Figure 3.1-a :Sinusoidal incoming signal in a linear system (1)
(Sollberger Biological Rythm Research 1965)

On the other hand, with a non-linear system, the characteristics and the dynamic behaviour vary.

3.1.2 Choice of the model and representation

We planned as study technic, the adjustment of a function Y(t) checking :

$$Y(t) = Y(t + \tau) + \varepsilon(t)$$

The most easier periodic function than we could choose, is certainly a sinusoide of the following type :

$$Y(t) = C \cos(wt + \phi) + \varepsilon(t) \qquad \text{with}$$

$\varepsilon(t)$ = residue at the time t,
C = amplitude,
ω = pulsation which in the circadian rhythms study where T = 24 hours, is equal to $2\pi t / T$
ϕ = dephasing

The previous type y(t) is not easily used for numerical calculation : indeed, the parameter ϕ is not appearing under the linear type.(1)

We will choose the equivalent expression of Y(t) :
such as :

$$Y(t) = a \cos wt + b \sin wt + \varepsilon(t)$$

$$C = a^2 + b^2$$

$$\phi = \text{arctg}\ \frac{b}{a}$$

Data are presenting under the matrix form $[Y]_{ij}$ or :
M is the number of observed series at different periods,
N, the number of observed datas at each serie.

$$[Y]_{ij} = \begin{bmatrix} Y_{11} \ldots Y_{1j} \ldots Y_{1M} \\ Y_{i1} \ldots Y_{ij} \ldots Y_{iM} \\ Y_{N1} \ldots Y_{Nj} \ldots Y_{NM} \end{bmatrix}$$

If data are regularly distributed in time with a time distance(period) between two consecutive dates multiple of 24 hours (the chosen time unity in the circadian rhythm study is the hour), so, we can obtain a_i and b_j thanks to the Fourier analysis.(Equation 3.1-b)

$$a_j^{24} = \sum_{i=1}^{N} Y_{ij} \cos (2\,\pi\, I \blacktriangle_T / 24)$$

$$b_j^{24} = \sum_{i=1}^{N} Y_{ij} \sin (2\pi\, I \blacktriangle_T / 24)$$

Equation 3.1.-b

In the case of data which aren't regularly distributed in time, we'll choose as adjusting method the method of the least squares. We'll look for determine aj and bj such a manner to obtain :

$$Wj = \sum_{i=1}^{N} \left(Y_{ij} - (\, a_j \cos wt_i + b_j \sin wt_i \,)\right)^2 \text{ and be minimum.}$$

Equation 3.1.-c

We can represent each model in a polar plan where we can set the hours of the day.

To each individual, we associate a vector ; of module Cj and of argument ϕj. The circle is graduated from 0 to 24 hours. The whole of individuals M provide M pairs of the amplitude estimated values Cj and of argument ϕj.

$$\left\{ \left(C; , \phi_j \right) , j = 1,M \right\}$$

In right-angled coordinates we will have by setting $x_j = a_j$ and $y_j = b_j$

$$\begin{bmatrix} x_j \\ \\ y_j \end{bmatrix} = \begin{bmatrix} c_j \cos \phi_j \\ \\ c_j \sin \phi_j \end{bmatrix}$$

and to each individual j we will associate a vector Uj (xj , yj).

3.1.3 The adjustment validity and statistic tests

For M series characterized by M vectors Uj (xj , yj), as medium $\overline{x}$ and $\overline{y}$ respective of $\overline{xj}$,$\overline{yj}$.

We will test the hypothesis of the distribution normality of (μ_x , μ_y) representing respective averages of the two-dimensional population from a sample ($\overline{xj}$, $\overline{yj}$) to a risk α.

Then, we determine the trust field of the phase ϕ and the trust interval of the amplitude C by drawing up the mistake ellipse such as :

$$\left[x - \mu_x \; y - \mu_y\right] \begin{bmatrix} 1/S_x^2 & -r/S_x S_y \\ -r/Sx\,Sy & 1/S_y^2 \end{bmatrix} \begin{bmatrix} x - \mu_x \\ y - \mu_y \end{bmatrix} \leq (1 - r^2) \frac{2(M-1)}{M-2} F_2^{(\alpha)}{}_{,M-2}$$

with τ the correlation coefficient
M the number of series
F_2, M-2 the variable of Snedecor to (2, M-2) degrees of freedom for a risk α.

(S_x^2, S_y^2) couple of variances estimating from the the sample σ_x^2, σ_y^2 variances of the population.

(μ_x, μ_y) couple of averages of the population.

We represent the mistake ellipse (Fig.3.1.2-a) in a polar plan with as phase reference $\varphi = 0$ and as sens, the direct sens.

The interval extremities of amplitude trust C are given the ray (beam/radius) intersection with the ellipse middle.
The trust interval of the phase is obtained by drawing both tangential rays to the mistake ellipse.

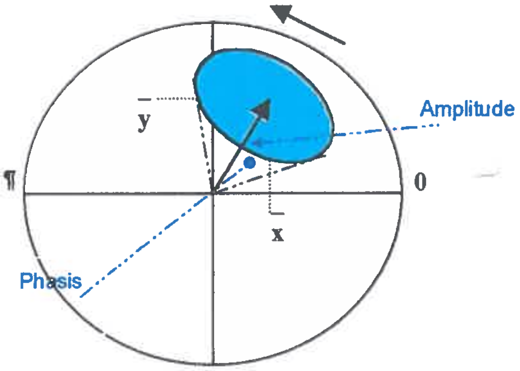


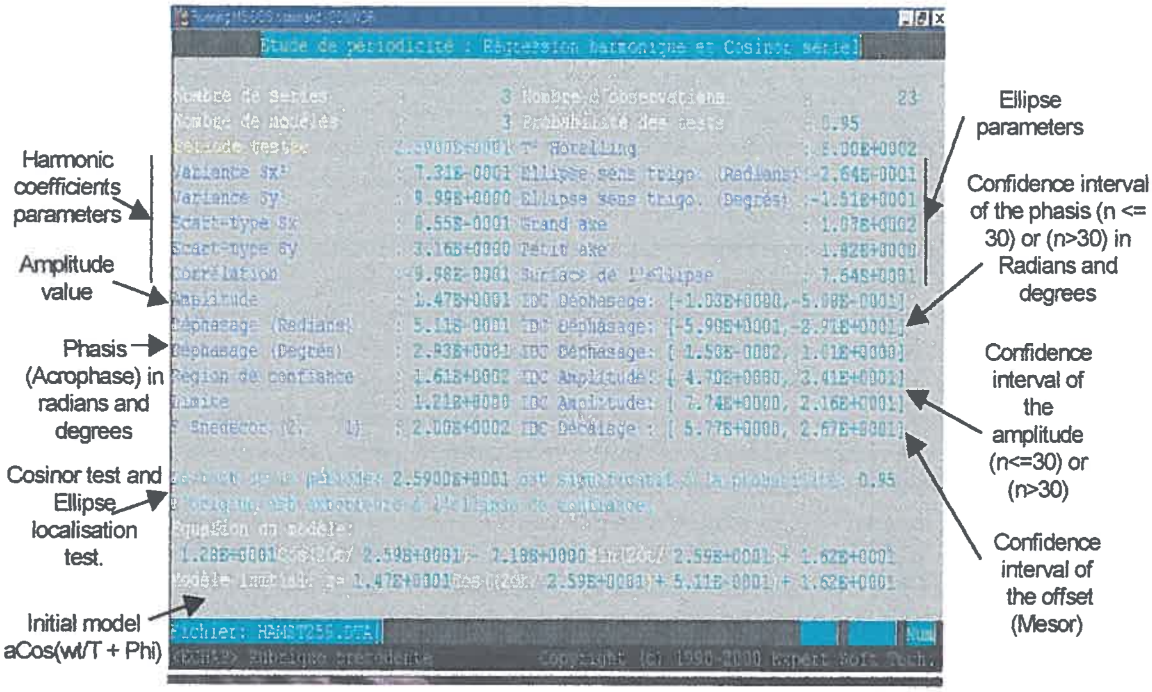
Figure 3.1.3-b : Representation of the error ellipse.

3.1.4 Methodology of the rhythms analysis with the Seriel Cosinor method

Varied methods are used to study or to highlight rhythms like the spectral analysis with or without known period. But the most famous is the Cosinor.
Let us remind that the Cosinor advantage is for one thing to be insensitive to the noise inserted in data. That's what it confers it an important interest with regard to the spectral

methods. The role of this method at the starting is to justify or not the existence of a given data and to calculate its parameters (Amplitude, phase and displacement).

The Seriel Cosinor, aside the aforementioned functions, owns the possibility to detect the rhythmic period, to study that period, to define all its characteristics (figure 3.1.4-a).


```
Étude de périodicité : Régression harmonique et Cosinor sériel
Nombre de séries        :          3 Nombre d'observations        :     23
Nombre de modèles       :          3 Probabilité des tests        : 0.95
Période testée          : 2.5900E+0001 T² Hotelling               : 5.00E+0002
Variance Sx²            : 7.31E-0001 Ellipse sens trigo. (Radians) :-2.64E-0001
Variance Sy²            : 9.99E+0000 Ellipse sens trigo. (Degrés) :-1.51E+0001
Ecart-type Sx           : 8.55E-0001 Grand axe                    : 1.07E+0002
Ecart-type Sy           : 3.16E+0000 Petit axe                    : 1.82E+0000
Corrélation             :-9.98E-0001 Surface de l'ellipse         : 7.64E+0001
Amplitude               : 1.47E+0001 IDC Déphasage: [-1.03E+0000,-5.08E-0001]
Déphasage (Radians)     : 5.11E-0001 IDC Déphasage: [-5.90E+0001,-2.91E+0001]
Déphasage (Degrés)      : 2.93E+0001 IDC Déphasage: [ 1.50E-0002, 1.01E+0000]
Région de confiance     : 1.61E+0002 IDC Amplitude: [ 4.70E+0000, 3.41E+0001]
Limite                  : 1.21E+0000 IDC Amplitude: [ 7.74E+0000, 2.16E+0001]
F Snedecor (2,   1)     : 2.00E+0002 IDC Décalage : [ 5.77E+0000, 2.67E+0001]

[illegible] période 2.5900E+0001 est significatif à la probabilité 0.95
[illegible] extérieure à l'ellipse de confiance
Equation du modèle:
1.28E+0001 Cos(2Pi/ 2.59E+0001) - 7.18E+0000 Sin(2Pi/ 2.59E+0001) + 1.62E+0001
Modèle initial: y= 1.47E+0001 Cos((2Pi/ 2.59E+0001) + 5.11E-0001) + 1.62E+0001
Fichier: HAMST255.DTA
<ECHAP> Rubrique précédente          Copyright (c) 1990-2000 Expert Soft Tech.
```

Figure 3.1.4-a : Seriel Cosinor test and valuation of the parameters related to the detected rhythm. (Activity measured on Hamsters to which a molecule from the anti-depressor family was injected).

The Seriel Cosinor is a "Population" Cosinor (That is to say that it gathers data of several subjects under the series shape, it deduces a global periodic model from models of each serie, etc...) which calculates globally the best sinusoidal model (harmonic regression on Cosinus function) which can go through as better as possible the whole experimental points (figure 3.1.4-b).

Not only applicable to the circadian rhythms (24 + / - 4 h), it permits to modelize as well as the inferior or the superior rhythms (for example Ultradian [(<20h), Dian (24 + / -2h), Infradian (>28h), etc...]. It could as well eliminate models of data series which would have few interests and the inconvenience to distort results (by the use of an adapted test).

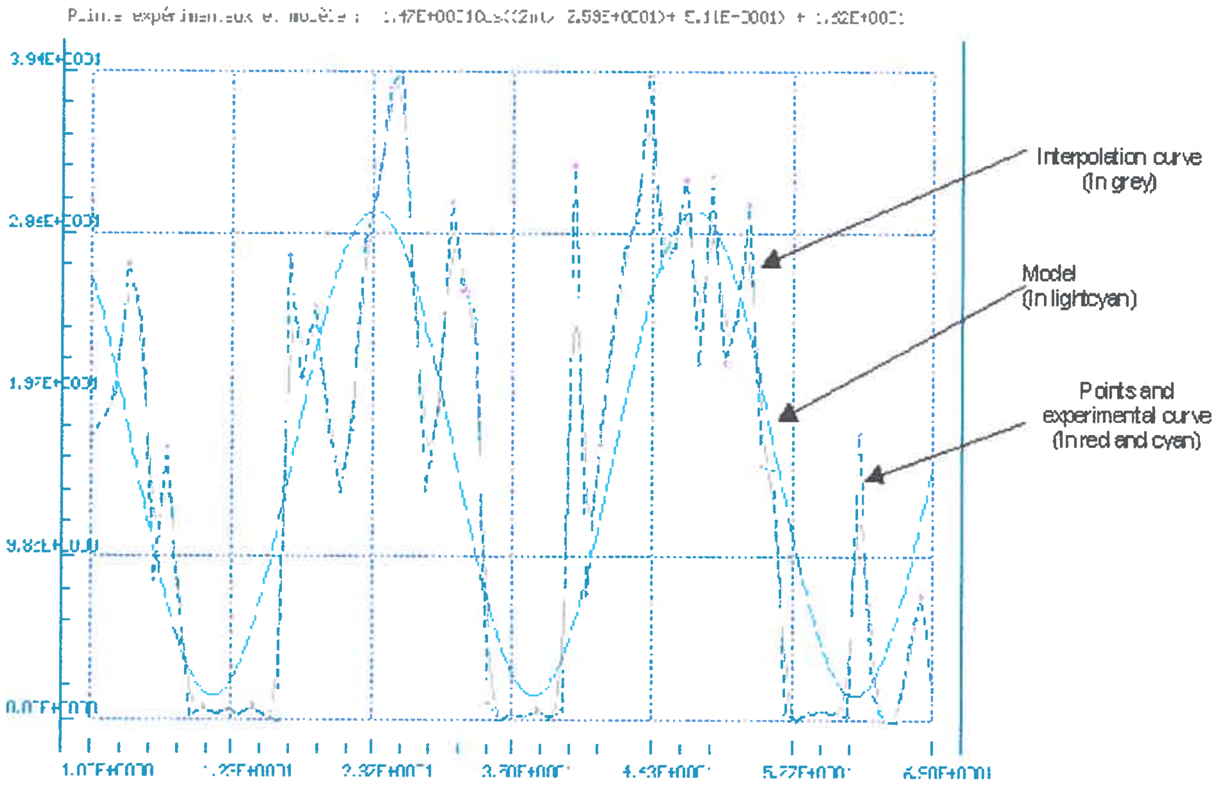


Figure 3.1.4-b : Model, experimental points, interpolation curb. Rhythm of 25,9 hours in a sample of collected data from the study of hamsters activity submitted to an antidepressor molecule. The nycthemeral rhythm is displaced towards the right.

The Seriel Cosinor in its detection mode is based on the hypothesis of the confidence ellipse existence which is not recovering the origin. So, a rhythm is detected (figure 3.1.3-b and figure 3.1.4-c). On consequence the following inequation is verified :

$$\frac{(\mu_x - \bar{x})^2}{\sigma_x^2} - 2r\frac{(\mu_x - \bar{x})(\mu_y - \bar{y})}{\sigma_x \sigma_y} + \frac{(\mu_y - \bar{y})^2}{\sigma_y^2} \leqslant \frac{2(N-1)(1-r^2)}{N(N-2)} F_{2,N-2}(\alpha)$$

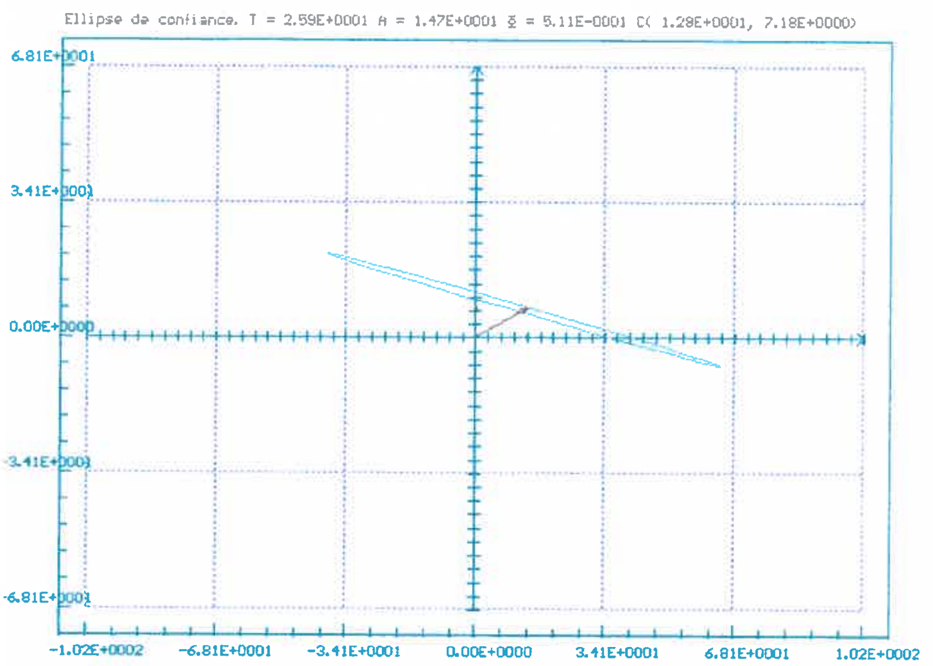


Figure 3.1.4-c : Confidence ellipse to the probability 0.95. Study of the hamster activity submitted to an anti-depressor molecule. Rhythm of 25,9 hours.

We used to consider the classical Cosinor method limited to the mono-rhythmic modelization. The Seriel Cosinor introduces the technic of residues re-injection in order to highlight or not a pluri-rhythmic activity and to calculate the parameters.

The studies and treatments possibilities as a whole gives to the Seriel Cosinor a significant interest in every study in Chronobiometry.

3.1.5 Filtering by transgenerating

Limitations in the use of the Cosinor method

The Cosinor method presents some limitations as underlines it De Prins (1980).(1).

Indeed, the least squares of a function cosinus need that the experimental data would be symetrically distributed. Maxima and minima must be separated by a half-period. If that condition is not encountered, the acrophase estimation can be very far from the minimum. That's why we proposed the transgeneratings susceptible to bring closer to a periodical sinusoidal phenomenon. Indeed, in the Cosinor method, it's very important to test the statistic validity of the individual models and it's difficult to deal with the answers of the living organisms with external synchronizer, non-sinusoidal answers. So that, with the noise inherent in signals we cannot detect an underlying periodical rhythm.

The Cosinor method suggests that the residual mistakes would be :

- normally distributed.(it's necessary to test this hypothesis)
- independent (if this hypothesis is broken trust intervals are subject to important variabilities).

3.1.6 Transitory answers

Biologic oscillators show endogenous rhythms in interaction with rythms of the environment.

An oscillator can be forced (broken) by variations of the environment and it can take a frequency different from the proper frequence. Those frequencies appear in the nycthemeral rhythm and in the homeostat. So that the searcher can be obliged to analyse this phase in which the frequency still changes. He wants then to test the hypothesis of the period change.

So that, the use of transgenerating allows to detect the proper period by the means of the filtering of the initial signal. An appropriate transformation in the limits of validity previously fixed, associated to a sweeping of frequency, can reveal a proper cycle which was up there invisible through the Cosinor test.(figure 3.1.6-a).

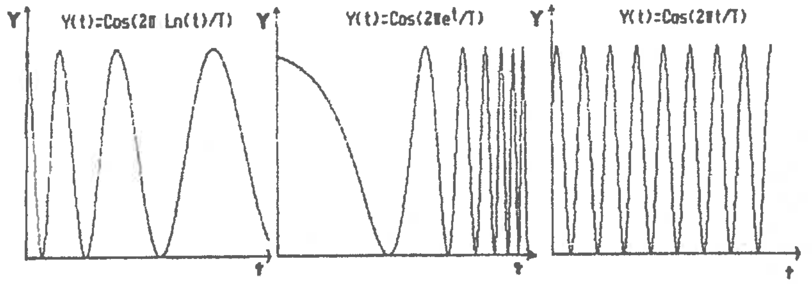


Figure 3.1.6-a :Transitory answers of the biologic system, Use of single transgeneratings on the times axis

A logarithmic transformation type (figure3.1.6-a) from a non-periodic signal (figure 3.1.6-a) allows to obtain a periodical signal to be disclosed by the test of the Cosinor.

As well an exponential transformation (figure 3.1.6-a) allows from a non-periodical signal (figure 3.1.6-a) to detect a periodical cycle.

In general, biological oscillators accept the forced frequency only if it is not much different from their standard frequency.

In case of non-linear system, it can occur a change in the harmonics or the sub-harmonics of the incoming frequency.

3.1.7 Research of the proper period

As much of the biological systems have non-linear answers and that internal biologic oscillators are forced by the environment, we often observe an answer of the system at a different frequency from this of the synchronizer. So that the realized Cosinor 1 (1) programme is looking for this proper frequency in a frequency area that the scientific worker have determined.

3.1.8 Models with several periods and residues analysis

The study of proper rythms showed for example that the woman oestrogens concentration during the labour offers a non-linear answer with periods of 24, 16, or 12 hours. For some subjects the acrophase is situated 4 hours after the beginning of the dinner and four hours after the lunch. This example shows that is necessary to study periods different from that of 24 hours called "ultradians".

One has to quote that the hypothesis to check is the existence of a periodicity in the data, that doesn't absolutely give an idea (preconceive) of the type of the function representing these variations. If the variations are not represented by a sinusoide, we can deal the datas under the form of a serie of trigonometric functions of superior frequencies to the principal frequency (Fourier's decomposition).

It exists T such as : $y(t) = y(t - \tau)$

So $$Y(t) = C_1 \cos(\omega_1 t + \phi_1) + C_2 \cos(\omega_2 t + \phi_2) + C_3 \cos(\omega_3 + \phi_3) \ldots$$

With $$\omega_1 = \frac{2\pi}{T} \qquad \omega_2 = \frac{2\pi}{2T} \qquad \omega_3 = \frac{2\pi}{3T}$$

The successive treatement of residues by the Cosinor method allows to determine the other characteristic frequencies and so on to come back to an analysis of the whole periods (method of residues reinjection).

3.1.9 Spectral analysis of data non-equally distributed in time

The advantage of the Cosinor method upon the spectral analysis method is that isn't necessary to have data equally distributed in time. Indeed, it is difficult to plan making measures in samples form, on individuals in precise and regular time intervals (sampling during the sleep can affect vital biologic cycles). On the other hand, it is difficult to fix exactly an experimental protocol of measures when it deals with studying natural phenomenons occuring independently of the work searcher. It's the case of measures of volcanic eruption cycles. The measures quality is often dependent of the time ; The phenomenon amplitude in the time and above all the physical reality of this last can blurt out the work searcher (here we will be able to say that the phenomenon is fixing experimental conditions of measures and not the work searcher, from which the difficulty to make measures at regular interval time during a natural phenomenon trigger from which we look for determining the periodicity).

In the spectral analysis, powerful spectrums are obtained, by the Fourier transformation of the function of self-correlation of the incoming and the coming out, and of the function of self-correlation between the incoming and the coming out.

In the way to estimate the function of self-correlation of the data non-equally distributed in time, a number 1 of intervals or categories of width r chosen such as $1\ r = \tau$. (1).

The τ th category $C\tau$ is centred (adjusted) on the time τr and fits with the interval :

$$\left[\left(\tau - \frac{1}{2}\right) r; \left(\tau + \frac{1}{2}\right) r\right]$$

Equation 3.1.9-a

The covariance is estimated by $D_o = \frac{1}{N} \sum_{i=1}^{N} Y_i^2$

$$D_\tau = \frac{1}{n_\tau} \sum_{i=1}^{N} \sum_{j=i+1}^{N} Y_i Y_j [(t_i - t_j) \in C_\tau] \text{ for } 1 < \tau < l$$

N is the number of products

Yj Yj such as (ti - tj) owns to the category Cτ;

$S_i\ (t_i - t_j) \in C_\tau = A$

I [A] is the indicator of the event A: I [A]=0 if A is not realized, I[A]=1 if A is realized.

We obtain a cloud of points permitting the calculation of averages of categories for a first estimation of the covariance (figure 3.1.9-b)

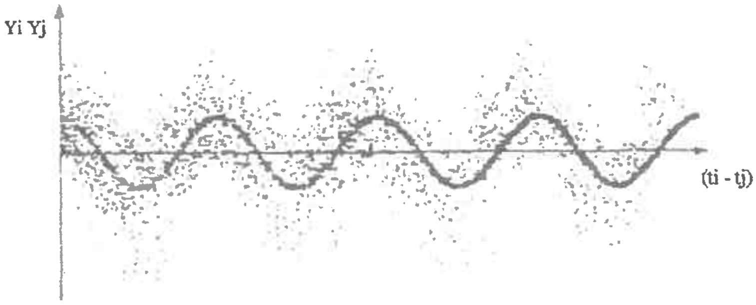


Figure 3.1.9-b : Experimental curve through a cloud of points.

The choice of l has to be such as each category contains a reasonable number of points.

The sequence of self-variance is obtained by balancing results with a triangular function (equation 3.1.9-c).

$$Y_\tau = \frac{D_\tau (T - Tr)}{D_0 T}$$

Equation 3.1.9-c

3.1.10 The Cosinor method criticism

So, in conclusion, the Cosinor method consists in the data adjustment a cosinusoidale function through the method of least squares of imposed period the provided method.

Three parameters :

- the mesor (the constant)
- the amplitude
- the acrophase (angular phase of the maxima of the adjusted cosinusoide ; confidence intervals : ellipse surrounding or not the origin) allows to decide about the presence or not of significative rhythm for a given period.

But the algorhythm applies on the fact that the observed values are the results of a cosinusoidal phenomenon and full of independent mistakes distributed according to a standard law. The more often the rhythm shape has at the beginning a temporal variation, then it is slower.

The acrophase can be very far from the maximum of the studied rhythm without that the confidence interval reveals it.
In order to prevent these inconvenients we can make some transgenerations upon the temporal variations.

3.2 Non-linear system : Determination of the third order moment and estimation of the Volterra kernels

The biological systems having a multiplicity of rhythmic environmental factor acting on its. It is necessary in order to understand the influence of outer rhythms to consider no linear response.

We offer our services to present a statistical method based on the study of the non-linear systems characterised by series of Volterra, whose the aim consists in the estimation of the Volterra Nucleuses, by the intermediary of the calculation of the cross correlation functions.

In a first part, we explain on the one hand the essential properties linked to the junctional representation of the non-linear systems, by series of Volterra, on the other hand, the proposed statistical method.

In the second part, we apply this method to the identification of the sun spots generation process.

3.2.1- Identification of the non-linear systems by the study of the Volterra functionals

Do consider a process to identify represented as follow : (figure 3.2.1-a)

Figure 3.2.1-a

- u (t) ∈ u, u representing a set of input data classes.
- y (t) : output of the system.
- H : input functional / output of the system.

The process owns the three following properties :

- P1 : it is continuous
- P2 : it is stationnary
- P3 : it is non-linear

Moreover, we don't know, a priori, the structure of the system. Then, a possible means to identify this process consists in the representation in series of Volterra functional of the system input.

3.2.2 - Decomposition in series of Volterra of the impulsional response of a non-linear system

Let be the functional of order K : $V_k\{g_k, u(t)\}$ (if $K > 1$ the functional is non-linear) regular and homogeneous, it admits a complete representation of the form. (1)

$$(1) \qquad V_k\{g_k, u(t)\} = \underbrace{\int_{\tau o}^{t}\int_{\tau o}^{t} \cdots\cdots\cdots \int_{\tau o}^{t}}_{K} g_k(t, t_1 \ldots\ldots t_l) \prod_{j=1}^{k} u(t_j)\, dt$$

We shall say that $V_k(g_k, u(t))$ is :

- stationnary if $g_k(t, t_1, \ldots, t_k)$ depends only of the differences t.
$t_i = t - \tau_j$
- realizable and of Volterra type if the order nucleus K of the functional verifies:

$$V_l \in (1, k),\ t_l > t \Rightarrow g_k(t, t_l \ldots\ldots t_k) = 0$$

Then, we'll consider only stationnary functionals, realizable and of Volterra type than we'll write on the form (2) :

$$V_k\{u(t)\} = \frac{1}{k1} \underbrace{\int_{0}^{t}\int_{0}^{t} \cdots\cdots\cdots \int_{0}^{t}}_{k} h_k(\tau_1, \tau_2 \ldots\ldots \tau_k) \prod_{i=1} u(t - \tau_i)\, d\tau_i$$

$$g_k(t, t_1, \ldots\ldots, t_k) = h_k(t - t_1, \ldots\ldots, t - t_k) = h_k(\tau_1 \ldots\ldots \tau_k)$$

- $h_k(\tau, \ldots\ldots, \tau_k)$ is the Volterra nucleus of order K characterizing the impulsional answer odd order K of the system.

From these fews definitions, we can then define a series of Volterra. We call series of Volterra an expression of the form (3)

$$y(t) = h_0 + \sum_{k=1}^{+\infty} V_k\{u(t)\}$$

We say from a theorem due to Frechet that all continuous functional $H(u(t))$ can be approached by a polynomial of functionals of Volterra in the form :

$$H(u(t)) \sim \sum_{k=1}^{N} V_k\{u(t)\}$$

Then, the system will be completely determinated by the knowledge of the nucleuses. $(H_k)_{1<k<N}$

3.2.2.1 Statistical approach method of the nucleuses of Volterra

The work of Y.W. LEE and M. SCHETZEN based upon the theory of WIENER concerning the non-linear systems, have shown that the nucleuses were very linked to the functions of cross correlation of order K between $y(t)$ and $u(t-T1)$......., $u(t-Tk)$.

In other words, this function of cross correlation can give a criterion of relative importance of this (h_k) at the time of an estimation of $y(t)$.

Then, we propose to establish a statistical method allowing the estimation of $y(t)$ from :

- N_y value of $y(t)$
- N_u value of $u(t)$ $(Ny < Nu)$

The adapted process is the following one :

- 1) To fix the degree of non-linearity N corresponding to :

$$H(u(t)) \sim \sum_{k=1}^{N} V_k\{u(t)\}$$

-2) To calculate the functions of cross correlation noted :

$$\phi^1_{yu}(\tau_1), \phi^2_{yu}(\tau_1, \tau_2), \ldots\ldots\ldots, \phi^N_{yu}(\tau_1, \tau_2, \ldots\ldots\ldots\ldots \tau_N)$$

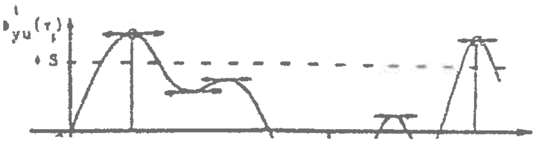
$\phi^1_{yu}(\tau_1, \tau_2, \ldots\ldots\ldots\ldots \tau_1)$ showing the function of cross correlation of the order 1 between : $y(t)$ et $u(t-t_1)$, ..., $u(t-t_i)$

- 3) To select a certain number of vector :

$$u(t-\tau_1), u(t-\tau_1), u(t-\tau_2)\ldots\ldots\ldots\ldots\ldots\ldots\ldots \prod_{i=1}^{K} u(t-\tau_1) \text{ corresponding to the}$$

extrema of functions.

$\phi\ yu(\tau1, \tau2\ldots\ldots\ldots\tau1)$ and to exceed a certain threshold noted S. (for example : to the



order 1, Figure 3.2.2-a). We'll note (s1) 1 < i < N the set of the i uplet selected. Then we possess K vectors of dimension Ny.3.2.2-a

0 : selected extrema

Figure 3.2.2-a.

- 4) We then execute a regression by steps between the vector y (the dependent variable) and these K selected vectors (the independant variables).

What leads us to the following estimation :

$$y(t) = \sum_{\tau_1 \in S_1} [a(\tau_1)\, u(t-\tau_1)] + \sum_{(\tau_1, \tau_2) \in S_2} [a(\tau_1, \tau_2)\, u(t-\tau_1)\, u(t-\tau_2)] + \ldots\ldots\ldots\ldots + \sum_{(\tau 1 \ldots\ldots \tau N) \in S_N} [a(\tau_1 \ldots\ldots \tau_N) \prod_{j=1}^{N} u(t - T_j)]$$

and also (5) :

(5)

$$y(t) = \sum_{i=1}^{N} \left(\sum_{(\tau 1 \ldots \tau i) \in S1} \left[a(\tau_1 \ldots\ldots \tau_i) \prod_{j=1}^{i} u(t - \tau_j) \right] \right)$$

3.2.2.2 Adaptation of the theory of Volterra to the multivariable non-linear systems

In the context of a non-linear system with n inputs , represented on the figure 3.2.2-b, verifying the properties P1, P2, P3 (cf. 1)

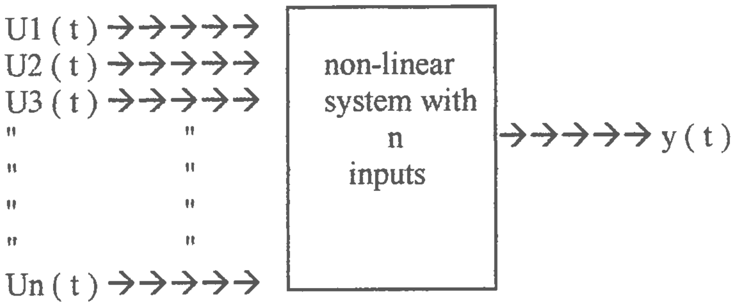


Figure 3.2.2-b

The expression (3) becomes :

$$(6) \qquad y(t) = \sum_{k=1}^{n} \frac{1}{k\,i} \sum_{j_i=1}^{n} \sum_{j_1=}^{n} \sum_{j_k=1}^{n} \cdots \cdots \int_{0}^{+\infty}\int_{0}^{+\infty}\int_{0}^{+\infty} a_k^{\,j_1 \cdots\cdots j_k}(\tau_1 \cdots\cdots \tau_k) \prod_{i=1}^{k} u_{j1}(t-\tau_j)$$

- n, being the degree of non-linearity of the system.

The statistical methods explained, are transposed easily to the multivariable case, but this time in calculating all the functions of cross correlation of the order K noted :

$$\left(\phi\, y u_{j1}\, u_{j2} \cdots\cdots u_{jk}\,(\tau_1 \ldots \tau_k)\right) \qquad \begin{array}{l} 1 \leq i \leq k \\ 1 \leq j_i \leq n \end{array}$$

For K varying from 1 to N.

Afterwards, the process stays unchanged and tge expression (5) becomes :

$$(7) \qquad y(t) = \sum_{j=1}^{n} \sum_{\tau_1 \, E \, S_1 j_1}^{j_1} a_1\,(T_1)\, u\, j_1\,(t-\tau_1)$$

$$+ \sum_{j_1=1}^{n} \sum_{j_2=j_1}^{n} \sum_{(\tau_1,\tau_2) \in S_2 j_1 j_2}^{j_1 j_2} a^{j_1 j_k}\,(\tau_1,\tau_2) \prod_{i=1} u_{ji}\,(t-\tau_1) + \cdots\cdots$$

or else :

$$(8) \qquad y(t) = \sum_{k=1}^{N} \left[\sum_{j_1=1}^{n} \sum_{j_2=j_1}^{n} \cdots\cdots \right.$$

$$\left. \cdots\cdots \sum_{j_k=j_k-1}^{n} \left\{ \sum_{(\tau_1 \ldots \tau_k) \in S_{j_1 k \ldots j^I_k}}^{j_1 \ldots j_k} a_k (\tau_1 \ldots \tau_k) \prod_{i=1}^{k} u_{j_1}(t-\tau_1) \right\} \right]$$

3.2.3 Application to the identification of the solar activity

This second part will be dedicated to the research of a process representation pattern of the solar tasks generation. We offer our services to use, at this effect, the method developed in the first part.

3.2.3.1 Presentation of the solar activity : the number of wolf.

We can characterize the solar activity by : the number of wolf, noted W, and defined by (9) : $W = k(10g + f)$.

Where : k is the factor of normalization
g is the number of the groups of spots
f is the total number of the spots

We possess W month after month from 1932 to 1977.

Let be Nw values ($Nw = 12 \times 46 = 552$).
The number of wolf is reprented on the fig.1.
The solar tasks, as the eruptions on the surface that are associated to them, are supposed, in a first time, due to the deformation of the exterior plasma of the sun.

In a second time, this phenomenon is considered as similar to a process of solar tide. The gravitational sources are, then, the planets of the solar system.
The generating strengthes of tide are of this form : (10)
F = G x M / R ^ 3

Where : M is the mass of the considered planet
G is a constant
R is the distance sun / planet

3.2.3.2 Definition of the inputs of the system

The correlation studies have proved that the optimal function characterizing the influence of a planet on W (t) was given by (11) :

$$(11) \quad X_l(t) = \frac{M_l}{2} \cos(e_l(t))$$

R i

$$(12)\ R_1(t) = \frac{a_1(1 - a_1^2)}{1 - a_1 \cos(v_1(t))}$$

With M1 : Mass of the planet 1
R1 (t) : Distance from the planet i to the sun at the time t
ϕ i (t) : Heliocentrical longitude put back to the elliptic at the time t.

A1 : half great axis of the ellipsis followed by the planet i
e i : eccentricity of the ellipsis followed by the planet i
v i (t) : true anormaly at the time t for the planet i

Considering the negligible aspect of the masses of the asteroids, satellites, comets and of Pluto, compared to these of the eight other planets of the solar system, we are limited volontarily to consider only these last ones as inputs of our system. We possess the values of (Xi) 1 <= i <= 8 month after month from 1901 to 1977, that is Wx values.

3.2.4 Application of the method of identification

The process of generation of the sun spots, then, will be studied from a point of view system as shows it the figure3.2.4-a, a system with eight inputs and one input.

The process represented on the figure 3.2.4-a has been studied for a degree of non-linearity N=2
otherwise, we'll suppose as representative of the process the expression (13).

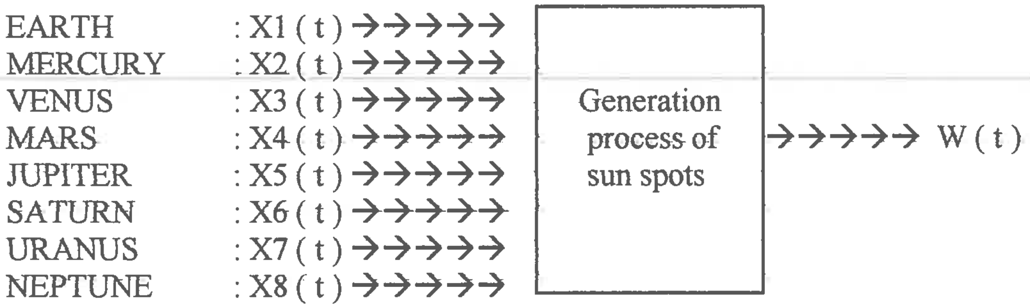


Figure 3.2.4-a : Outline of inputs / outputs of the system

(13)

$$W(t) = W_1(t) + W_2(t)$$

or :

$$W_1(t) = \sum_{j_1 = 1}^{a} \int_0^{+\infty} a_1^{j_1}(\tau_1)\, X_{j_1}(t - \tau_1)\, d\tau_1$$

$$W_1(t)=\sum_{j_1=1}^{a}\quad\sum_{j_2=j}^{a}\int_{0}^{+\infty}\int_{0}^{+\infty}a_1^{j_1 j_2}(\tau_1,\tau_2)\,Xj_1(t-\tau_1)\,Xj_2(t-\tau_2)\,d\tau_1\,d\tau_2$$

What leads us to the determination of the eights moments of the second order (functions of cross correlation of the first order) given by (14)

(14)

$$\phi^1_{Wxj_1}(\tau_1)=\frac{\sum_{t=1}\{W^1\ (t)^1-Xj_1(t-\tau_1)\}}{\sqrt{\left(\sum_{t=1}W^1\ (t)^2\right)\left(\sum_{t=1}Xj_1(t-\tau_1)^2\right)}}$$

which $W^1(t)=W(t)-\frac{1}{552}\left[\sum_{t=1}^{\infty}W(t)\right]$

$$Xj_1(t-\tau_1)=Xj_1(t-\tau_1)-\frac{1}{552}\left[\sum_{t=1}^{\infty}Xj_1(t-\tau_1)\right]$$

$t_0=t$ corresponds to January 1932
$t=1$

j1 varying from 1 to 8 for the eight planets

We'll find the representation of $(\phi\ wxj_1)\quad 1<j_1<8$

(fig. 12, 13, 14, 15, 16, 17, 18, 19)

Ti varies from 0 to 372 (the maximum interval corresponding to January 1901).

Of the thirty six momoents of the third order (functions of intercorrelation of the second order given by (15) :

(15) :

$$O^2 \; X_{j1}\, Xj_2{}^{(\tau 1,\, \tau 2)} \quad \frac{\sum\limits_{t=1}^{552} \left(W^1(t) - Xj_1(t-\tau_1) - Xj_2(t-\tau_2) \right)}{\sqrt{\left(\sum\limits_{t=1}^{552} W \; (t)^2\right)\left(\sum\limits_{t=1}^{552} Xj_1(t-\tau_1)^2\right)\left(\sum\limits_{t=1}^{552} Xj_2(t-\tau_2)^2\right)}}$$

T_1 and T_2 varying from 0 to 372, after a selection of the intervals t1, giving us the sets S1^ j1 and s2 ^(j1 x j2) (cf. 1.3). J1 varying from 1 to 8, j2 varying from j to 8, the regression by stages leads us then, to the following estimation of the number of wolf.

$$W(t) = C + \sum_{j=1} u_{1j}(t) + \sum_{j=1} u_{2j}(t)$$

with C = 92.36719

$u_{1\,1}(t) = -\,4{,}66119.\ X_s(t-168)$
$u_{1\,2}(t) = 16{,}86636.\ X_s(t-239)$
$u_{1\,3}(t) = 206{,}39165.\ X_6(t-210)$
$u_{1\,4}(t) = -\,16185{,}33594.\ X_7(t-336)$
$u_{2\,1}(t) = 356{,}13159.\ X_s(t-15).\ X_s(-200)$
$u_{2\,2}(t) = -\,251{,}\ 02371.\ X_s(t-165).\ X_s(t-200)$
$u_{2\,3}(t) = 342{,}21118.\ X_s(t-225).\ X_s(t-200)$
$u_{2\,4}(t) = 3896{,}19580.\ X_s(t-15).\ X_7(t-360)$
$u_{2\,5}(t) = -\,10593{,}48438.\ X_s(t-135).\ X_7(t)$
$u_{2\,6}(t) = -\,13012.18750\ X_s(t-195).\ X_7(t-30)$
$u_{2\,7}(t) = -\,3928{,}\ 45874.\ X_s(t-285).\ X_7(t)$
$u_{2\,8}(t) = -\,19254{,}\ 16016.\ X_s(t-360).\ X_7(t)$
$u_{2\,9}(t) = -\,74190{,}75.\ X_s(t).\ X_7(t-270)$

(The time is discretizided in months, the origin of the times being taken in January 1932).

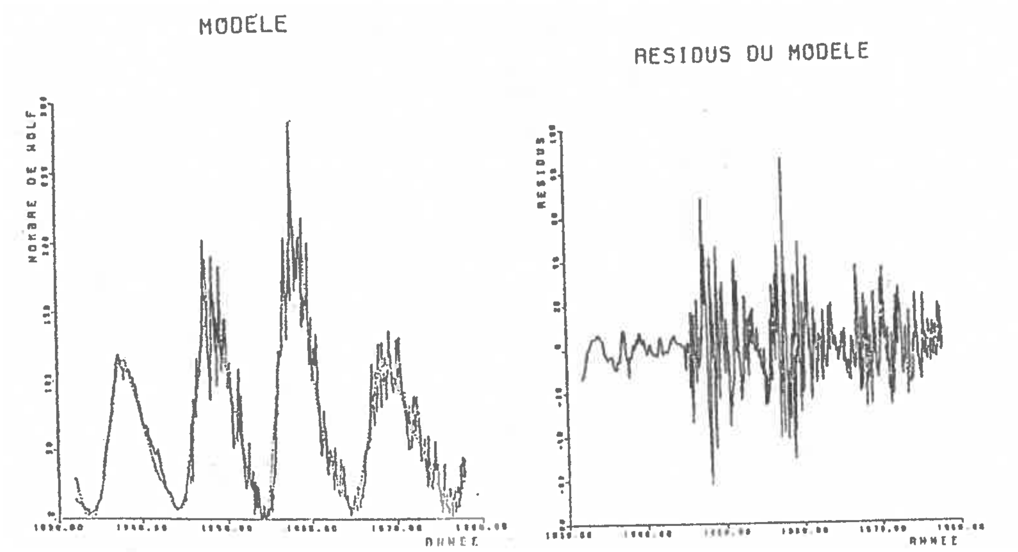


Figure 3.2.4-a and b: The first represent the observed solar activity process and the obtained identification the result are very close with Wolf number rhythms, and the second represent the residue which are due to the small planet not taken in account.

CONCLUSION

For the first time an attempt of non-linear identification of the solar activity is taken up by the means of Volterra nucleuses, the quality of the obtained results seems to justify this attempt and the use of the statistical method planned. If this pattern constitutes a right representation of the process for the low frequencies, we can yet observe its imprecision for the high frequencies. That is due to the lack of the four planets which are the nearest to the sun (Mercury, Venus, Earth, Mars). Thus, we can think that, from one part their introduction, justified by the aspect of the residues (fig.3.2.4-b) and from the other part the increase of the number of data could improve the pattern.

This type of non-linear analysis can be planned between the solar activity such as it appears in the magnetosphere, the biosphere and in the high strata of the atmosphere of Earth and all the terrestrial activity (climatic, ecologic, biologic).

The investigation of numerous rhythms in Earth's atmosphere and hydrosphere and the proof of their solar origin have a great importance of long biological rhythms and a great amount of proofs show that the living organisms pass "compulsorily" by the solar activity.

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