2500 years from dendrochronology back to ancient French human biotopes. Trees studied: low altitude oaks

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Introduction

We propose an experimental method, using curvilinear regressions, called corridor method, for dating and building a global useful signal based on oak ring widths in northern and eastern France. The resulting signal seems to be more useful than others to progress in the domains of ancient climate and ancient environments: dendrodating, dendroclimatology, dendroecology and, of course, human history (Lambert, 2002, Houbrechts and Lambert, 2004, Durost, 2005). However, we were lead to adapt or reconsider several basic mathematical functions, meteorological indexes or common dendrochronological definitions.
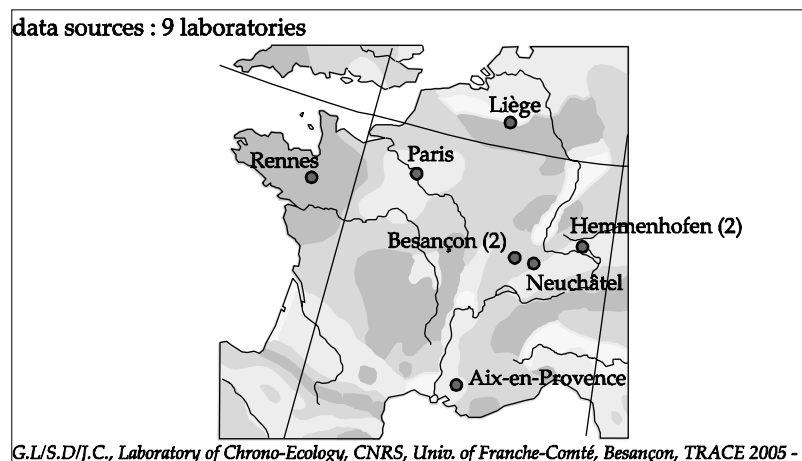
Figure 1: Contributing laboratories. The map gives a first idea of the concerned area.

We are currently working towards the publication of a large Data Base (web-DB). A first element of this DB can be consulted on the website of the ChronoEcology laboratory (French keywords: chrono-Ecologie, dendrochronologie). A discussion has opened about the participation of private contributors to such a public DB. The private contributors to this note agreed to show a part of their data without rights (money) and to justify explicitly their own dating procedures.

Data sources and dating method

Data source

A set of 142 synchronized historical site oak chronologies gave information about the last 1000 years. Another group of 74 site chronologies related to the late prehistoric and roman

periods. The studied area which lies within the points 51°N-3°E, 50°N-7°E, 45°N-6°E, 45°N-0°E corresponds to low altitude countries, under 500m, and covers a global area of about 300 000 km2. 2500 years of chronologies were rebuilt with 500 missing years from the early medieval period. The oldest ring dates back to 546 BC, the latest ends the system at 1995 AD. The missing years are precisely between 194 AD and 671 AD. We will show how the resulting signal, obtained by the corridor method, is interesting for engaging climatologic researches on large areas. The material comes from 9 laboratories based in France, Belgium, Switzerland and Germany (Fig. 1 and acknowledgments). Samples come from living trees, old buildings and archaeological excavations. About 5000 trees (4.781) were selected from an original set of 10000 dated oaks. The average age of samples is about 90 years. The average depth of the resulting chronology is around 80 rings by year. The main prehistoric and roman sites, which provided more than 50 samples, are Tours (F-37), La-Pacaudière (F-42), Rouen (F-76), Brognard (F-25) (Durost, 2005). The most interesting medieval and modern sites are cathedrals of Paris (F-75), Beauvais (F-60), Amiens (F-80), Auxerre (F-89), Laon (F-02), Poitiers (F-88), abbay of Fontevraud (F-49), Landevennec (F-29), towns of Liège (B), Autun (F-71), Cluny (F-71) (Lambert, 2002, Houbrechts and Lambert, 2004). A site chronology was first built for each site for a given period. In a second phase, the signals of nearby locations were grouped to create coherent local chronologies.

The properties of the two resulting data basis are listed below.

Reference system

Part 1: historic periods

    Name: HistoricOaks-20050126

    Period: from 672 AD to   1995 AD; duration: 1324 years

    Location: North of France, South of Belgium, West Switzerland

    Source: 9 laboratories; woods: several materials

    Last version from: Laboratory of Chrono-Ecology (LCE-CNRS)

    Registration: 26 January 2005 by Georges Lambert (GL)

    Components: 142 chronologies; 2529 samples.

Part 2: prehistoric and roman periods

    Name: ClassicOaks-20050101

    Period: from -546 (BC) to 193 AD; duration: 739 years

    Location: North of France, West Switzerland

    Source: 7 laboratories: woods: archaeological excavations

    Last version from: Laboratory of Chrono-Ecology (LCE-CNRS)

    Registration: 01 January 2005 by Sébastien Durost (SD)

    Components: 74 chronologies; 1252 samples.

Method: computing the corridor index

The raw data calibration by the corridor method is obtained after three steps (Fig. 2). The first step computes a triple polynomial regression, which draws for each tree a curving corridor

which follows the main movements of the growth. The first regression of computing data gives the trend of each series. The polynomial degree of the regression is chosen either by the operator or by the computer. The same degree is used for computing a regression with the lowest data (under the trend) and thus we draw the "floor" of the corridor. The last regression repeats the same operation with the highest data, which stands up the trend, and draws the "ceiling" of the corridor.

The second step modifies the corridor to give it the shape of a rectangle and at the same time, each point of the data series moves to keep its relative position between the top and the bottom of the corridor (morphing). Usually, choosing lower degrees for the polynomials is the best solution. Degrees between 3 and 6 are generally chosen. The computer program proposes to take degree 3 as default option. This degree 3 is a good tool for erasing the senility effect. However we must search for sufficient stability of the global signal in order to later apply calculations as the correlation coefficient (for instance). Therefore, the user is often led to raise the starting degree. However, we must be careful not to suppress all movements from the series: a minimum flexibility is necessary in order to get interesting information from the resulting calibrated series.
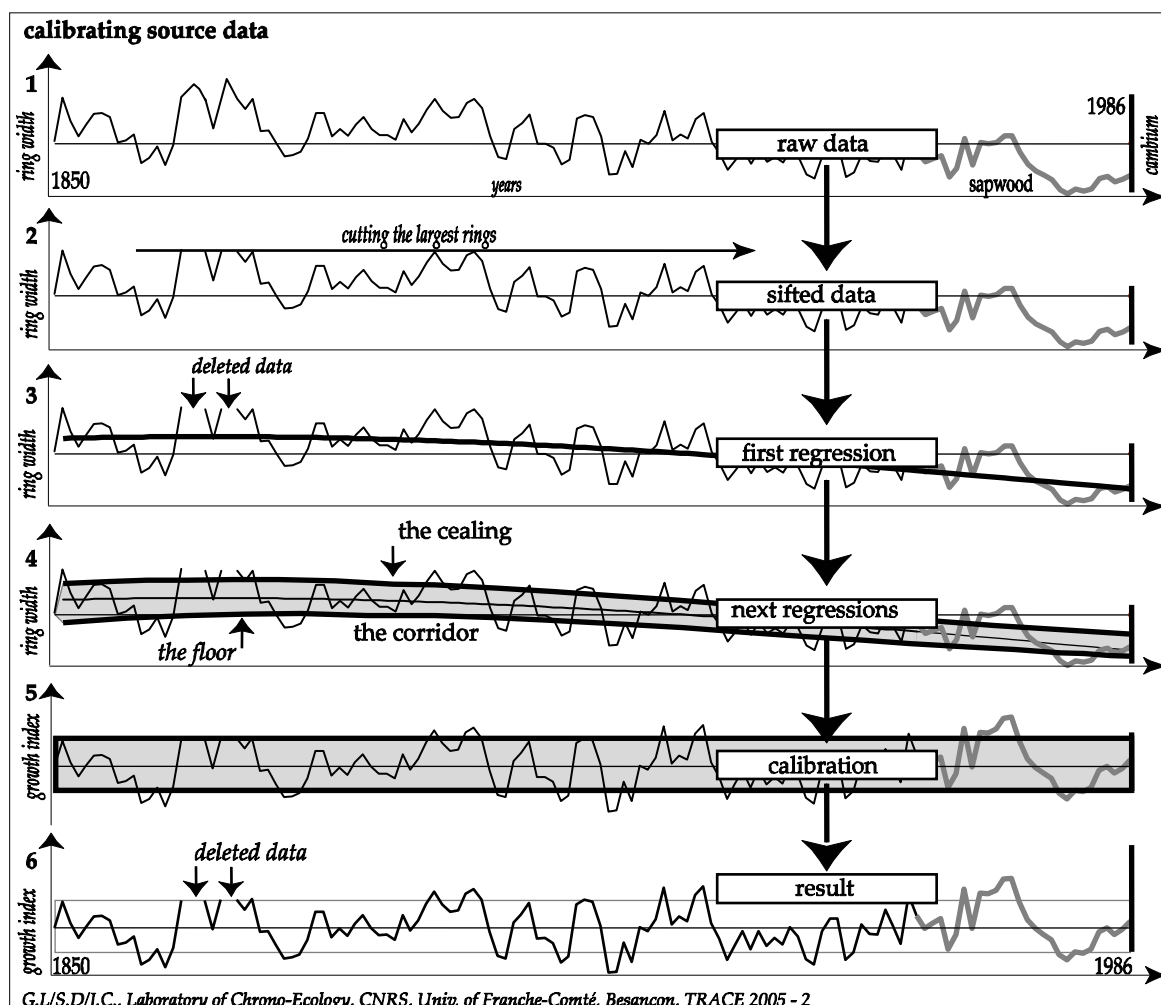

Figure 2: Dendrochronological data calibration by the corridor method using polynomial regressions

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The third step is the computing of the dendrochronological average from a set of several individual calibrated series. A useful property of the resulting series is that it is comparable with other source series, which are not (or not yet) calibrated. In theory, this calibration authorizes mixing both raw data (if it is regular enough or does not show too much noise) with other indexed series to build experimental local averages. The global signal obtained is stable enough to allow a wide range of computations.

Consequences for dating

Significant changes were made compared to previous chronological propositions. About 40% of the original series was discarded because the dating could not be verified by the new calculations. Many of these series are too short or have problematical noise. A great part of this discarded series was probably correctly dated but we could not confirm the date through the mentioned method above.

The re-update was made in each local group. Some dates were changed. A new chronology is accepted as a new component of the system if it yields a set of pertinent correlations with the previously integrated items. Figure 3 shows correlations between a new eligible item and a potentially contemporary series, which has already been dated (chronology Cluny-GL51: Cluny is a well known medieval site in Burgundy; GL=operator's identifier; 51=version or number); the best correlations are grouped in the left part of the fan. Then, the set of resulting chronologies shows best correlations between contemporary sites, as the old data bank did.

The correlating system becomes coherent on a large geographical scale. Very good correlations through wide areas can be exhibited whatever the period (Fig. 3).The accuracy of a group of chronologies of a given century is expressed, through another method, by a symmetric matrix, which shows the correlations between all components.

Correlation control before including a new chronology into the reference system

example :

candidate : chronology #51 of Cluny *(3 monuments:14, Republic road + Belfry + ENSAM)*
chronologies 1 to 19 are already included (and dated) in the reference system
period : 1581 - 1761

prob = 1 (100%)
prob = 0.99995
prob = 0.9999
prob = 0.9995
prob = 0.999

probability / security

number of samples

Cluny-GL51 : last ring = 1761 AD

a : sorted correlating fan :
Highest correlations with : 1: Dijon.Refg-LCE07a, 2: Nolay.Halles-10b, 3: Autun.EvD-GL04 4: Orgelet.Fut-GL04b+c,
5: Neuchatel.StHo-GL11, 6: DelleFeltin-GL02, 7: Compiegne-YT01,
8: Poitiers.ca-CE50b, 9: Bes.Citad-GL13
good correlations with: 10: Nuits.Meo-GL11, 11: Pointre.Sg-GL13, 12: Paris.ND-GL250, 13: Rouen.ca-LCE11
admissible correlations with: 14: Laon.PEpisc-PHs8, 15: Gray.GAnc-GL13 , 16: Presilly.FCh-GL07, 17: Montaigu-GL08
18: Trier/b-Hollstein1964, 19: Fontevrd-LCE103

300km

Cluny-GL51

computing period: 1581 to 1761

computing period: XIII-XX : total lengths

b : concerned area :
Correlations between the Cluny chronology and
the dated sites previously placed in the
reference DB

c : resulting correlated network
Correlations between all the chronologies linked to
Cluny - chronology #51

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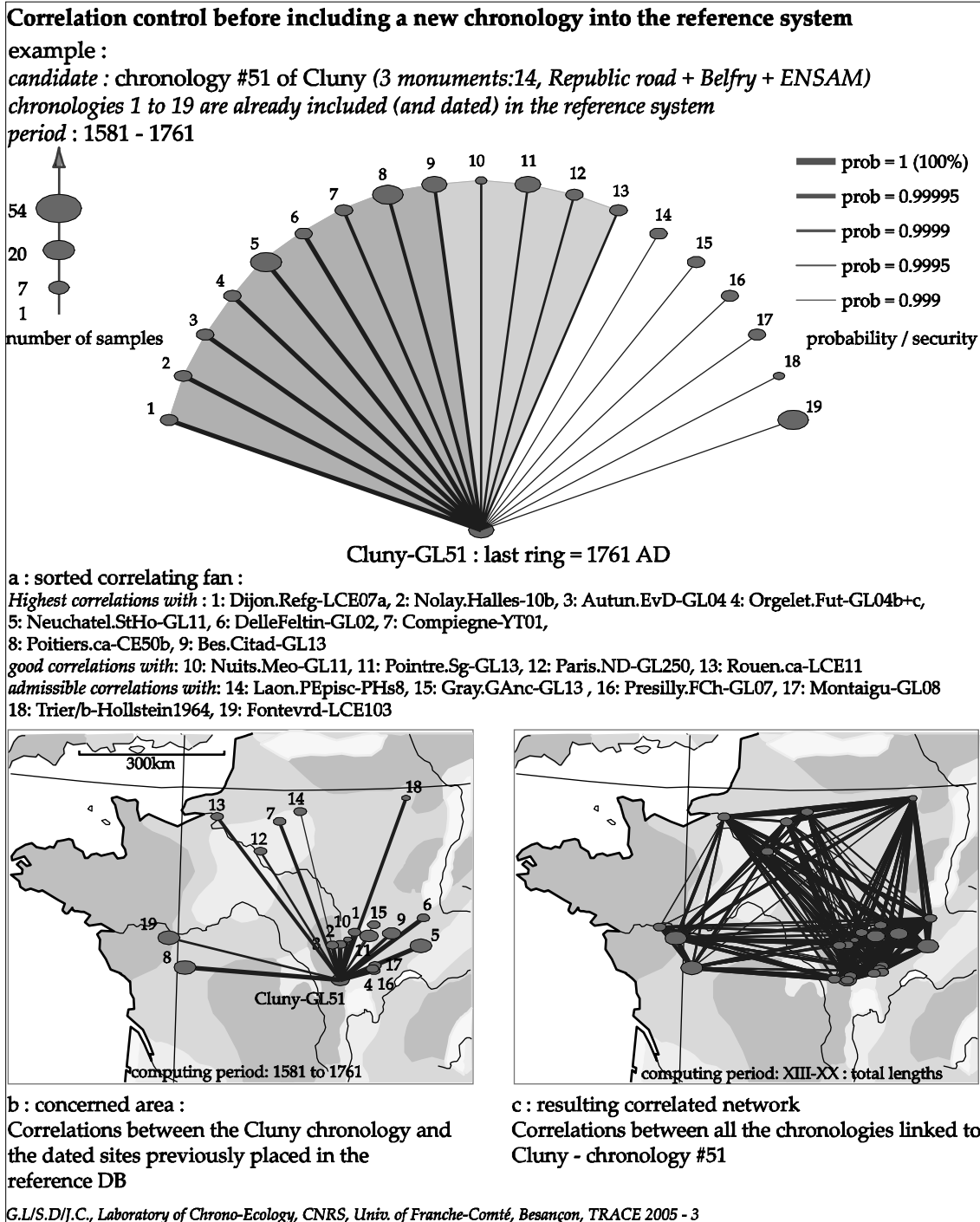
*Figure 3: The new site chronology Cluny, version 51 –built or (re)built by GL - has to demonstrate his
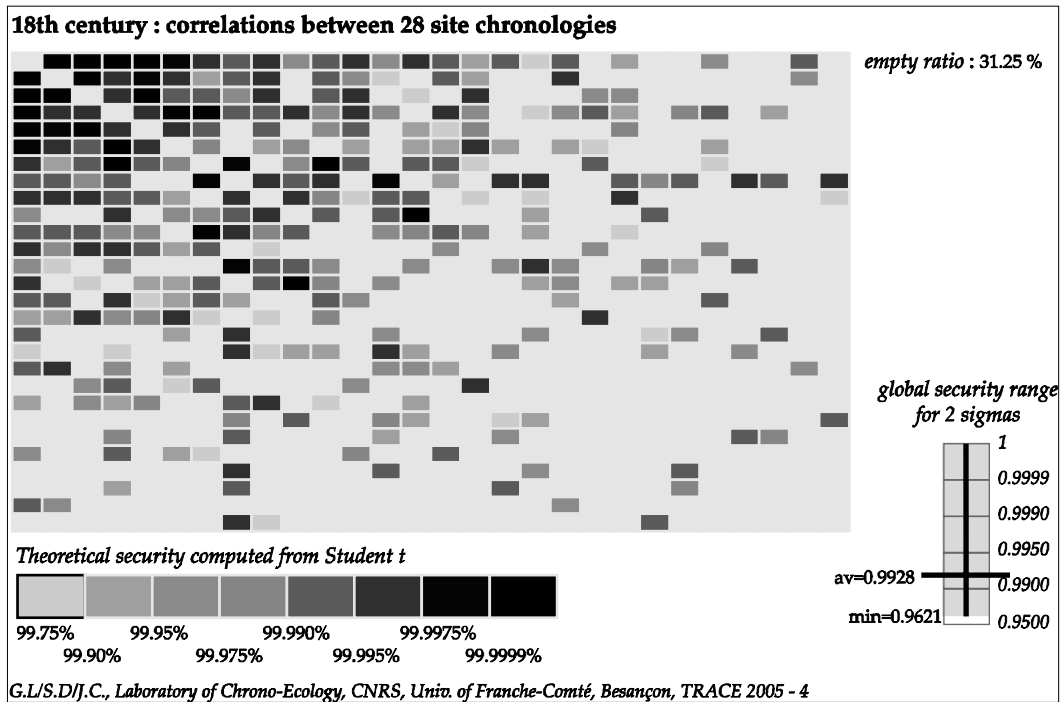ability to be accepted in the existing reference system.*

Figure 4: Matrix of inter-correlations between the site chronologies which pass through the 18th century.

The Student t is the used value for building the matrix. As for the fan graphic, the minimum shown t value corresponds to the theoretical risk 0.999. The best coefficients give a dark box in the figure (Fig. 4) and the lowest give a light box.
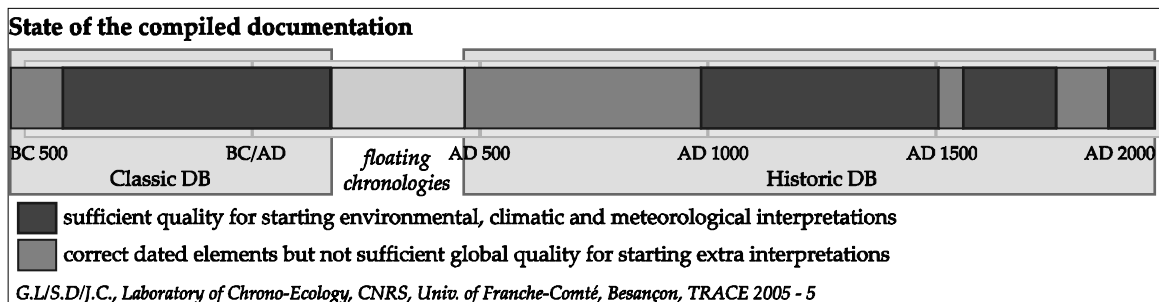

Figure 5: Prehistoric et historic bar of subjective credibility of the reference system Hist20050126

Finally, thousands of wood chronologies were connected for a 2500 years period except for the late Roman and Merovingian times for which we got some chronologies, still floating though. The credibility of the resulting system is summarized in the next figure (Fig. 5).

Climatic signification of the resulting signal

Aim

The goal was to find a method to build multi-proxy charts or matrices through time for trying meteorological or climatic reconstructions with the growth index discussed above. Therefore, we had to find a method which allowed the association of dendrochronological data,

meteorological data and, later, other information such as historical precisions for example. The necessary starting condition was to find enough sites or better, sectors - which group several sites - for a sufficiently long period (minimum 500 years) and for each sector to be able to build comparable data. It is very rare to find long ring chronologies and long enough meteorological records for the same location. The dendrochronological information in particular is spread over a large area but the internal structure of this area changes with time: buildings or sites used several times rarely give data over a long time and none of them give information for the whole of the period in question. Precise maps of known areas change from a century to another. As a result, site chronologies are not adequate to work from with such a process. We were therefore led to consider theoretical spaces, which yield dendrochronological and meteorologicalrecords. The previous discussion showed that the dendrochronological growth index is stable information through a relatively large area around a given point, so it authorizes us to try to create regrouping sectors. Starting from phytoclimatic studies (Choisnel et Payen 1989, Emberger 1930), we divided the French territory into 42 "natural" sectors and built an elementary geographical model. Our research sector encompassed about 30 of these sectors. In a second step, we built a new dendrochronological average chronology for each sector, which is a chronology that summarizes all the data of the sector. In a third step, a global regional chronology was built from the sector chronologies – not from the original samples. This regional chronology will provide some parameters for the following computing. Meanwhile, we collected as much meteorological data as we could from the stations which are - or were - located in the sector. After applying the dendrochronological methods, we summarized and averaged it to get a global yearly data for the sector: temperatures, precipitations and climatic indexes. This step in the collection of the meteorological data from a lot of little temporary old stations put to us the questions of data choice (not all compiled data is reliable) and of missing data reconstruction. Here we will ignore this point as it requires a long explanation. This way, we will be able to collect dendrochronological and meteorological data to build mixed charts for each sector and a global chart for a global zone: the North and East of France. In such a situation, the use of the response function poses a lot of questions. Before introducing these computations, we made a survey of the potential information located in the dendrochronological calibrated signal, compared with the meteorological information of the sector. Below are our findings for one of these sectors.

Tree ring and meteorology in middle Saône basin
We chose the middle Saône basin as the experimental sector and the 20th century as the experimental period. Six meteorological stations of the sector were selected:
1. Chalon-sur-Saône (F-71),
2. Bourg-en-Bresse (F-01),
3. Dijon (F-21),
4. Dole (F-39),
5. Lons-le-Saunier (F-39),
6. Besancon (F-25).

This way a coherent area of about 90 000 Km^2 was delimited. The last 120 meteorological years were re-built and we kept the synthetic trimester data of rains and temperatures. Thus, for precipitations and temperatures, we got respectively 4 annual series, one per season in which the autumn of the previous year is taken as the start of the concerned year (biological year: In the charts the autumn of the year 1900 i.e. is the period October-December 1899). A yearly meteorological index (ED7) derived from the bio-climatic index of Emberger (Emberger 1930, Lacoste and Salanon 1999) was added as a ninth climatic vector. This index expresses the notion of dryness and includes somehow the tree adaptation capacity through the winter. And, in order to introduce a meteorological index that does not include a division we tested an index, called GL2, which simply adds autumn temperature average, winter temperature average, spring precipitations and summer precipitations, after having made an elementary reduction. This index expresses the most part of the atmospheric energy usable by the tree during the biological year.

The ED7 and GL2 indexes are computed as follows,

ED7 = k* ln(som.p)/(som.t -win.t)*(som.t +win.t).

GL2 = red. aut.t +red.win.t +red.spr.p+red.som.p

with:

ln = natural logarithm;

for the global period (1879-1993):

per.aut.t = average of autumn temperatures

per.win.t = average of winter temperatures

per.spr.p = average of spring precipitations

per.som.t = average of summer temperatures

for each year:

aut.p = autumn precipitation average (previous year),

win.p = winter precipitation average,

spr.p = spring precipitation average,

som.t = summer temperature average,

aut.t. = autumn temperature average,

win.t = winter temperature average,

spr.t. = spring temperature average,

som.t = summer temperature average,

k = arbitrary factor for convenience (here k=100),

and

red. aut.t = aut.t / per.aut.t (previous year),

red.win.t = win.t / per.win.t,

red.spr.p = spr.t / per.sprt.t,

red.som.p = som.t / per.som.t

The middle Saône basin (sectors 18 and 25: between 47.50N-5E, 47.40N-6.50E, 46N-5E, 46N-4.40E) lays under low altitudes (under 500 m) seven dendrochronological stations were selected:

1. Area of Luxeuil (F-70),
2. Chaux forest, between Dole and Besancon (F-39),
3. Oussières, old trees (F-39),
4. Several points in the West-Jura, in the South of Lons-le-Saunier, called "Petite Montagne" (little mountain, F-39),
5. Citeaux, forest in the South of Dijon (F-21),
6. La Ferté, forest in the South of Chalon-sur-Saône (F-71),
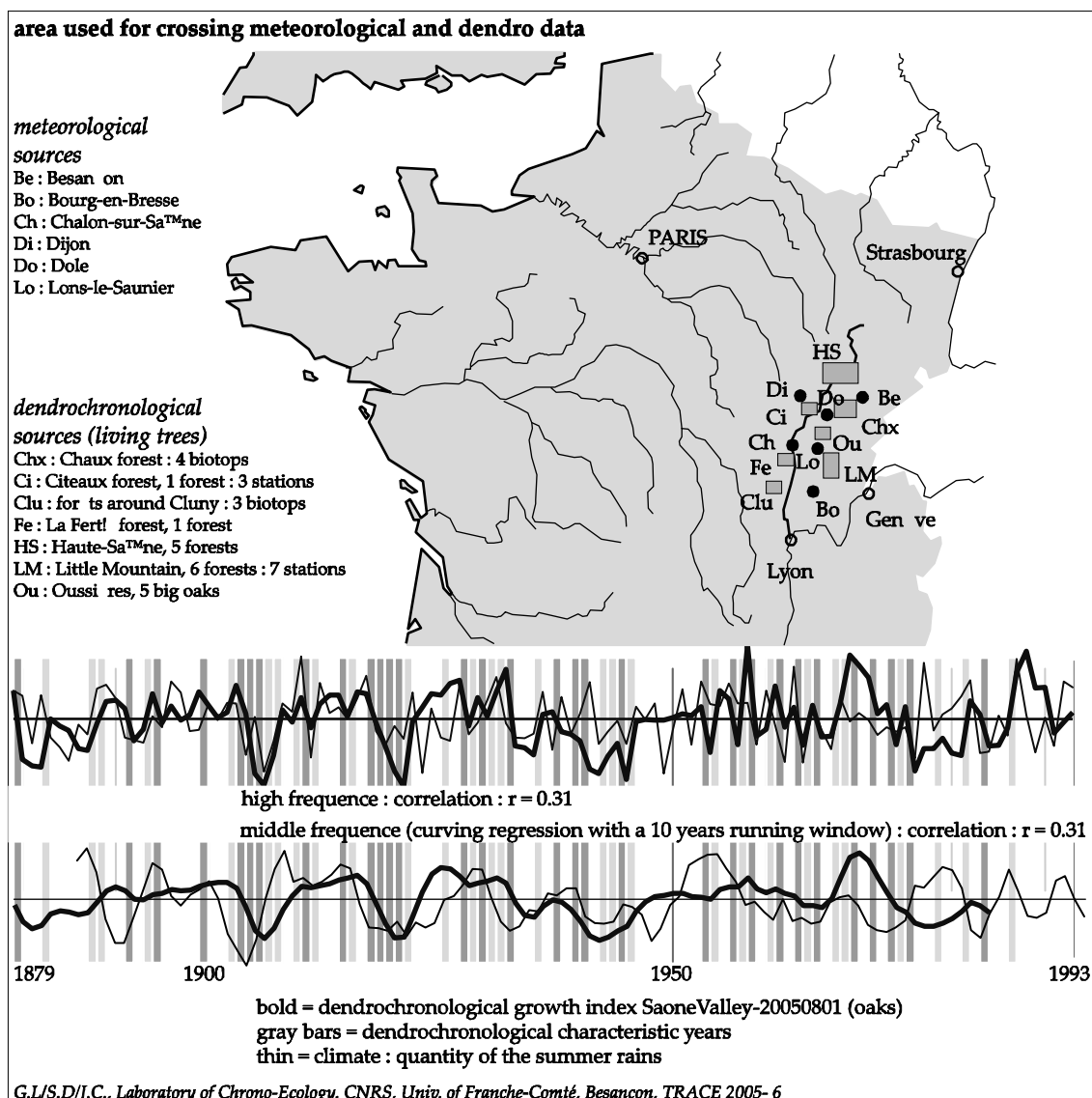7. Forests in the neighboring of Cluny (F-71).

area used for crossing meteorological and dendro data

meteorological sources
Be : Besançon
Bo : Bourg-en-Bresse
Ch : Chalon-sur-Saône
Di : Dijon
Do : Dole
Lo : Lons-le-Saunier

dendrochronological sources (living trees)
Chx : Chaux forest : 4 biotops
Ci : Citeaux forest, 1 forest : 3 stations
Clu : forêts around Cluny : 3 biotops
Fe : La Ferté forest, 1 forest
HS : Haute-Saône, 5 forests
LM : Little Mountain, 6 forests : 7 stations
Ou : Oussières, 5 big oaks

high frequence : correlation : r = 0.31
middle frequence (curving regression with a 10 years running window) : correlation : r = 0.31

1879   1900   1950   1993

bold = dendrochronological growth index SaoneValley-20050801 (oaks)
gray bars = dendrochronological characteristic years
thin = climate : quantity of the summer rains

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Figure 6: Dendrochronological signal and meteorology in the middle Saone Valley.

The "middle Saône-Valley" room, which represents about 20% of northern France (as defined above), is considered as a representative container of the global climatic energy on which the 300 living trees of the corpus depended (Fig. 6).

The resulting chronology is called SaoneValley20050801 (version of 08 August 2005, abbreviated below as SVoaks). Computations were drawn for the period 1879 AD - 1993. The correlations (r) between the oak chronology and the fifth meteorological data are summarized with a few numbers:

1879-1993:
    r (SVoaks, automn prec) = 0,01
    r (SVoaks, winter prec) = 0,06
    r (SVoaks, spring prec) = 0,17
    r (SVoaks, summer prec) = 0,31
    r (SVoaks, automn temper) = 0,09
    r (SVoaks, winter temper) = 0,1
    r (SVoaks, spring temper) = 0,16
    r (SVoaks, summer temper) = 0,13

Such results are not satisfactory. Only one correct correlation is given with the summer precipitations. We had hoped to find better correlations, especially with the climatic factors from spring and summer. A lot of other computations show that in this sector and for this period there are no direct correlations between spring and summer temperatures and the global growth of the oak. However, the indexes as ED7 and GL2 deliver better results:

1879-1993:
    r (SVoaks, ED7) = 0.37
    r (SVoaks, GL2) = 0.36

Combinations between factors give better results than direct correlations. At this point, we wanted to know what happens for typical years known for notable events like a hard winter or severe summer dryness. To choose the potentially most symptomatic years, we did not consider meteorological facts,- which are too diversified to allow an easy choosing procedure, but we looked at a dendrochonological indicator: the event year which carries a positive or a negative sign.

Event or signed years
The notion of dendrochronological event years or positive or negative signed years comes from old German researches (*Huber and Giertz-Siebenlist, 1969*) and is frequently used as an auxiliary of the dating procedures. An event year is defined, in a lot of woods - here, in a lot of site chronologies - by the common sign of growth difference (positive or negative) between the studied year and the previous one. If the minimum growth of 75% of a group of trees falls

between the years y-1 and y, B. Huber marked the year y as a characteristically negative year (a negative signed year) and, symmetrically, if the growth gets up in a minimum of 75% of the trees between the years w-1 and w, then year w is a positive characteristic year (a positive signed year). As other authors who tried to put the arbitrary floor of 75% in a probability evaluation (*Schweingruber and coll. 1990*), we used the probability notion to compute an event index, but starting from a floor of 70%. And, other change of usual, the synthetic chronology SVOaks was built with site chronologies as individuals (not with the tree chronologies). The Saône Valley chronology, calibrated by the corridor method, showed 62 event years in the period 1879AD-1993 (54%) in which we saw the known dry summers of 1904, 1911, 1959, 1976 (Fig. 6). The correlations computed with the meteorological data, only for the event years, gave the following results:

r (SVoaks, autumn prec) = -0,08
r (SVoaks, winter prec) = 0,21
r (SVoaks, spring prec) = 0,21
r (SVoaks, summer prec) = 0,43
r (SVoaks, autumn temper) = 0,13
r (SVoaks, winter temper) = 0,12
r (SVoaks, spring temper) = -0,32
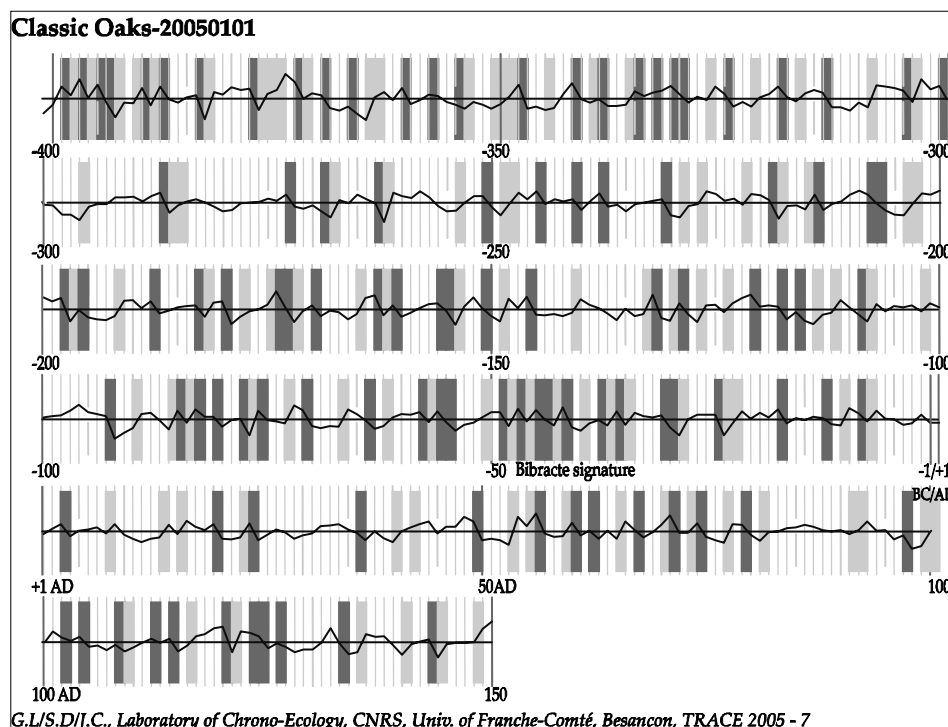r (SVoaks, summer temper) = -0,21

Figure 7: Event years of the classic period (400 BC – 150 AD) in northern France

The precipitations of the current year work as a positive factor of the tree ring growth. Instead we are led to consider a signed narrow ring as a sign of a potential dryness. There is but a

question about the negative correlations given by the spring and summer temperatures. Of course summer temperatures which are too high probably indicate dryness and in this case, a negative correlation between ring width and temperature is understandable; but according to the previous computations carried out on the whole period, it seems that in this sector of the Saône Valley the spring and summer temperatures do not influence directly the making of the current tree ring. The next correlations with indexes ED7 and GL2 show that we can be more optimistic. The correlations between tree growth and the combined meteorological indexes ED7 and GL2 clearly show that working with combined meteorological factors is better and the relationships between the ring growth and the immediate meteorology work efficiently:

62 event years between 1879 and 1993 give:

    r (SVoaks, ED7) = 0.46
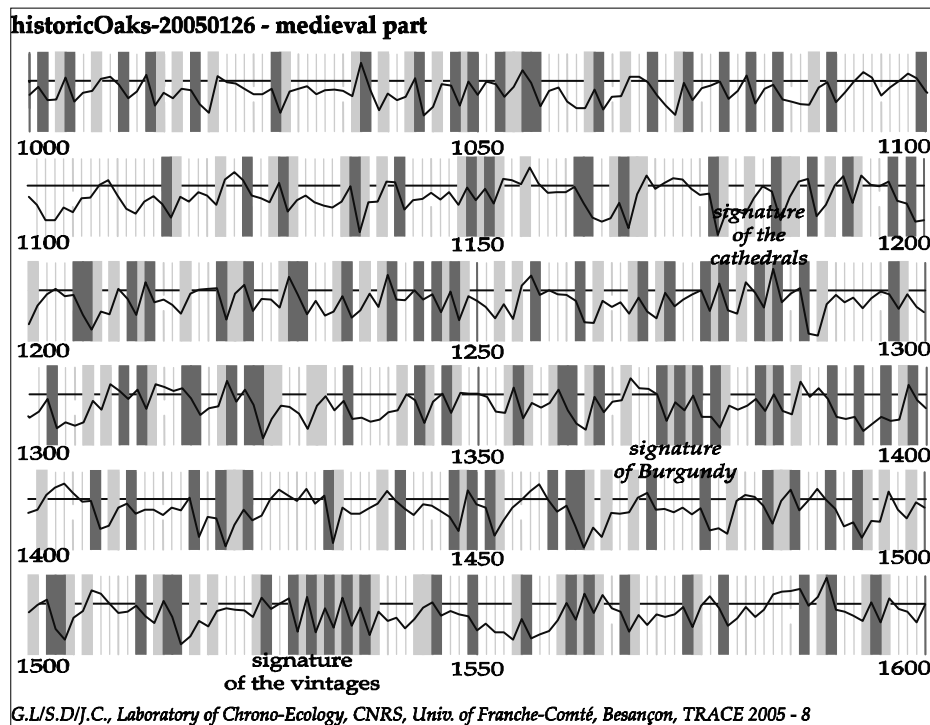
    r (SVoaks, GL2) = 0.47

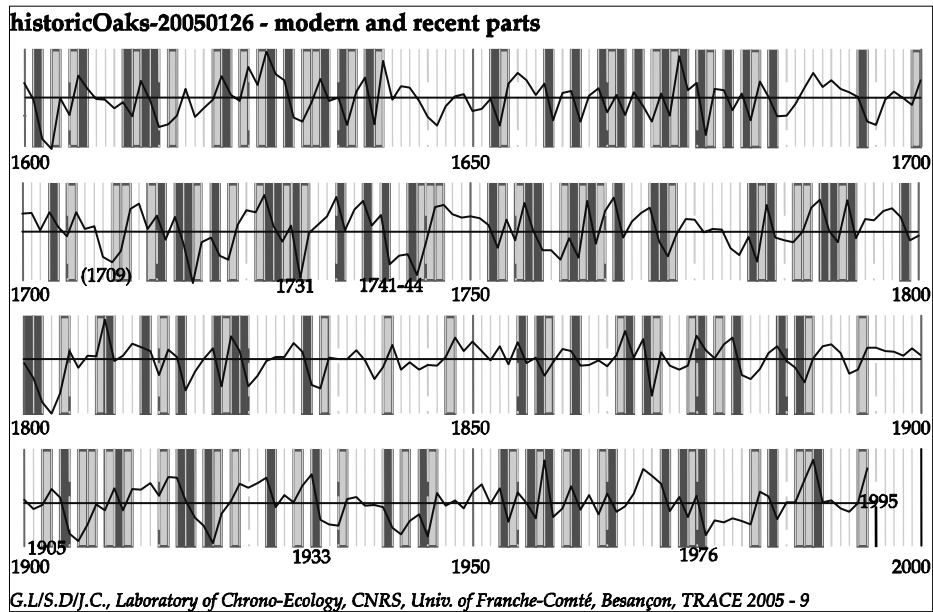*Figure 8: Event years of the late medieval period in northern France.*

Figure 9: Event years of the modern and contemporary periods in northern France

Such good correlations encouraged us to look at the situation in other countries. In the direction of the historians, we note that most of the negative signed years (narrow ring) indicate, more or less, dryness. Negative event years highlight bad vegetal production, potentially bad harvests. This may be related to potential nutritional and social human problems. On the other hand, a global narrow ring is a possible indicator of good vintages in the northern half of France (Fig. 7, 8 and 9).

Then, for each event year, we thought about a mapping of the phenomenon. But, we had first to find a method for modeling the tree response of event years like 1904, 1911, 1959, 1976, etc.
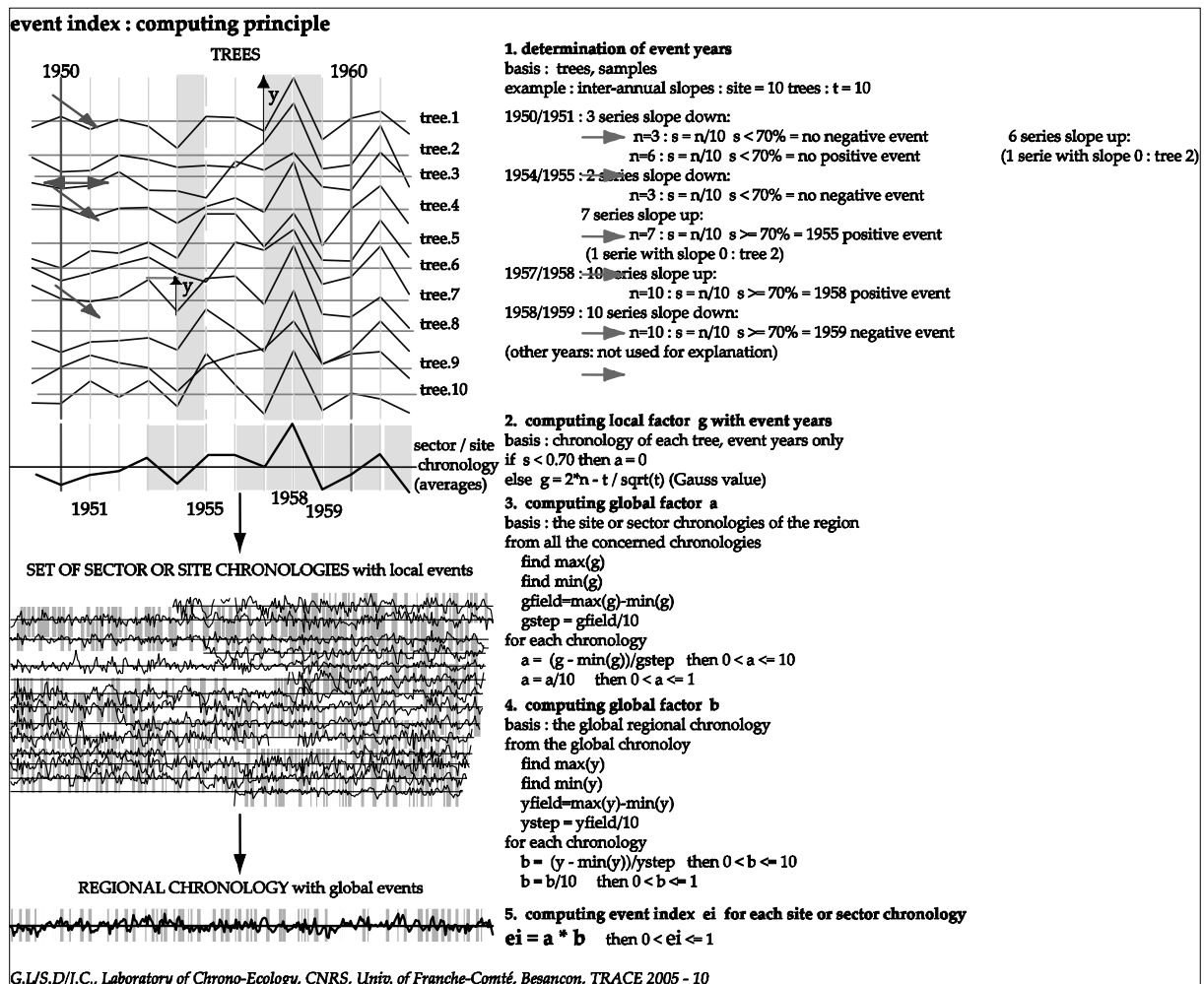
Fig. 10: Event index computing

Maps for prognostics back in the history: mapping the event years

We then looked at what happens over a large area with the event years. The starting model included 30 forests, more than 500 trees spread over 300 000 km2 and the application field was the data basis HistOaks20050126 and ClassicOaks20050101. In order to be concise, we will only consider small rings.

Process

The trees of each site did not all respond in exactly the same way to hydric stress. For each year, the response of each region was evaluated according to the average size of the ring width and to the percentage of sensitive trees which show a typical narrow ring. All other trees were ignored. An index of this type of response was computed, associating both points of view. For the whole region, ring widths of the event years were divided into 10 classes (factor b); for each sector the Gauss value provided by the significant part of the trees contributing to the signature were also divided into 10 classes (factor a). The product of both results, $ei = a*b/100$, gives a number between 0 and 1 (Fig. 10). It is used as a percentage or a precise colour (or a shade of gray) for representing on a map the response degree of a sector. Here 0 is white (no tree response, neutral situation) and 1 totally black (best

sensitivity: sector with the narrowest rings). Four years (1959 (AD), 1976, 1928 and 1952) known for their summer hydric deficit and which give a very narrow ring on oak trees are shown (Fig. 9). The resulting maps are quite different from each other. Each year gives a typical image. Such an image is the result of global meteorological conditions which were interpreted by the trees over a 500 km area.
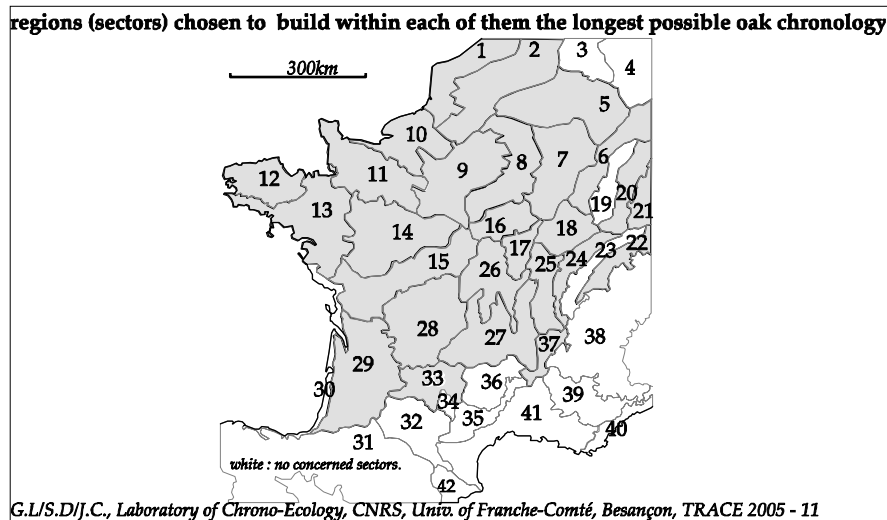

Figure 11: Initial territorial partition, potential stable biotopes

We think that a precise map could describe a global precise meteorological situation. The more extreme the meteorological conditions are - especially during spring and summer -, the stronger the relationship between them and map types are. Our goal is to classify these maps and to try and compare them over the time. Recent well known mapped situations could be used to explain historic or prehistoric years which are represented by the same type of map. Thus, for example, the 15th century is globally a bad century for trees - and harvests – (Fig .8) and the exact opposite situation seems to characterize the first century before Christ (Fig. 7). The necessary condition is being to have got over the time dendrochronological information in comparable geographical sectors.

Taking phytogeographical studies as a basis, we divided the French territory into 42 areas. Each area represents a balance between several environmental parameters: latitude, altitude, distance from the ocean and geological ground. All the trees and woods of all the periods of each area were collected to build a regional chronology. 27 sector chronologies were re-built: zones 1-2, 5-18, 20-22, 24-29, 33 and 37. The Saône Valley region, which we previously discussed, groups sectors 18 and 25 (Fig. 11). As explained above, the event index values were computed and recorded in a 27-column chart. The year 1026 AD was taken as the starting point, the year 1995 as the ending point (970 years). Note however that not all chronologies are complete for the whole period and this work is a first draft.

First results

The chart was sorted according to the average value index of each year. Then the most typical 80 years were returned ahead in the chart and led to a factor analysis. To solve the

problem created by the missing data (no event years), a special linear distance was chosen instead of the classic Correlation coefficient r. The plot obtained shows a central group surrounded by scattered points (Fig.12).
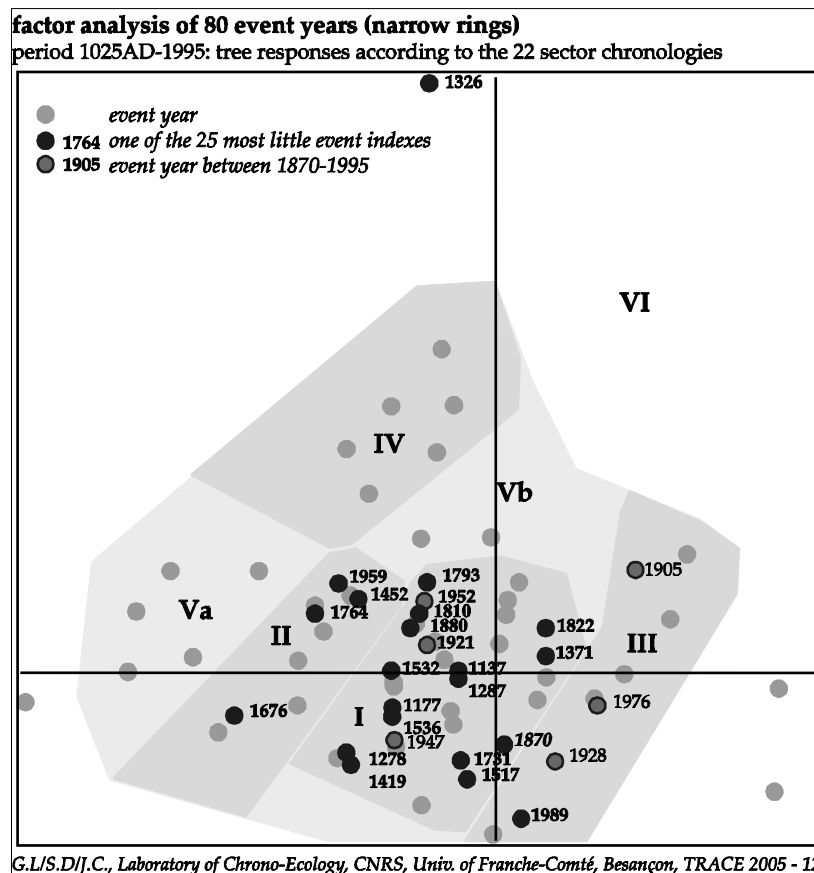

Figure 12: Factor analysis of 80 historical event years

20th century years fill the right part of the scatter plot. This is probably a wrong effect due to the set of living trees, which is making the best network of the basis. Nevertheless the points scattering shows definite evidence of the quality of the stress changes with the sector and the year. In fact, the most marked years (by the narrowest rings) tend to regroup around the center of the graph. Generally they are the warmest and driest years of the period. The right of the graph probably indicates the warm section and the left section indicates the colder part but still dry enough. We defined six temporary areas of sensibility within the plot. The maps, drawn from samples of zones I, II and III, show the diversity of the tree responses through the landscape. Such responses are possibly representative of cyclic or repeated climatic conditions. Zones IV to VI relate to more special or individual years and especially some parts of the original chart, which does not contain enough data.

The year 1976, marked by a strong spring-summer warm dryness, yielded laboriously a very narrow ring in all the territory. But the dryness of 1959 did not hit with the same strength the rings in the eastern part of the country. It looks as though the plain between Bordeaux and Paris recorded the worst climatic impacts. 1952 gives another view in which western countries clearly escaped the stress. Then, each map is linked to a particular meteorological

situation (Fig. 13), in which the dominant position of clouds and dominant direction of the winds work efficiently or not. We think that some types of map suggest the main direction of the winds in summer and then the positions of the anticyclones of the northern hemisphere around the Greenwich line. We will explain this later in another paper.
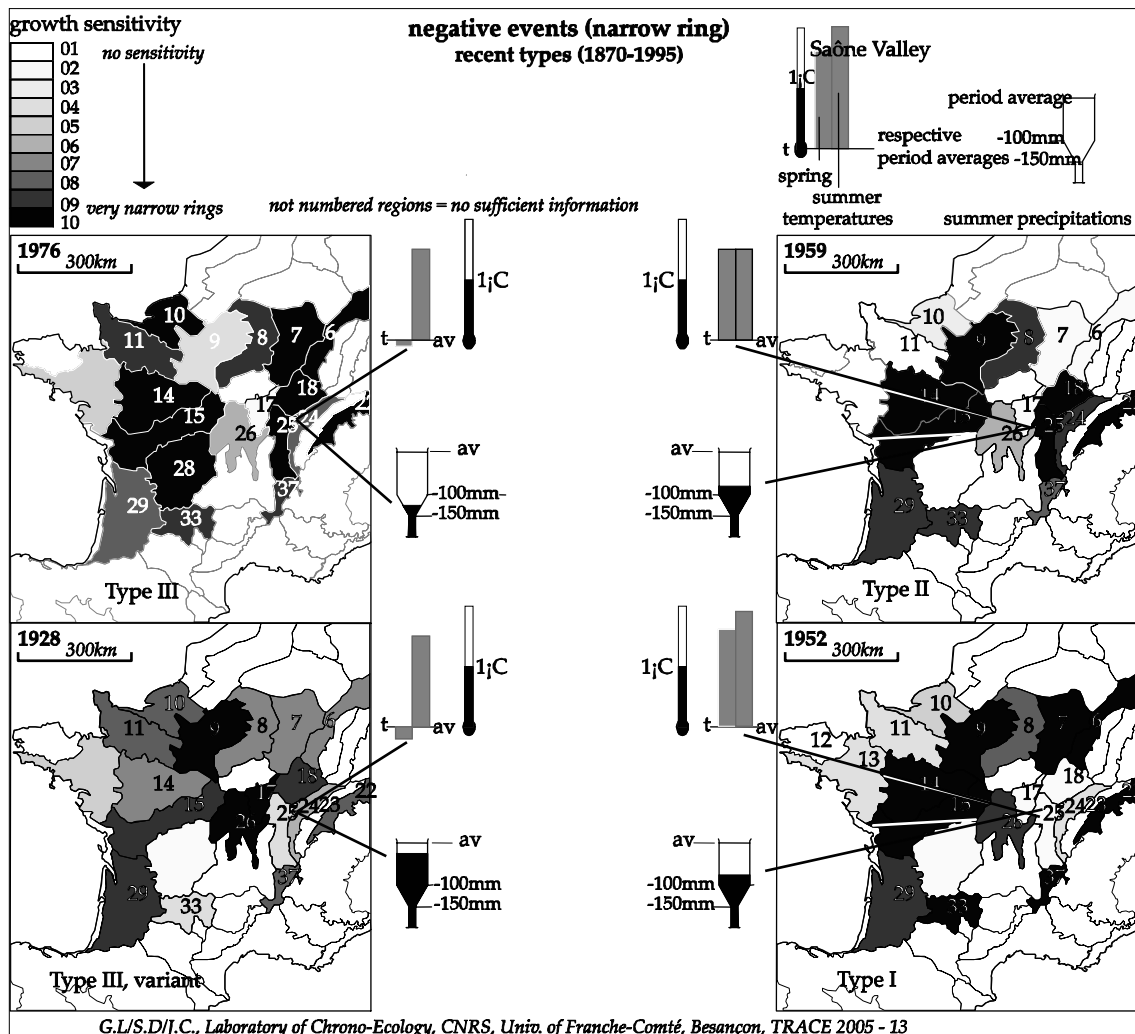

Figure 13: Narrow oak rings and dryness in France in the last century.

Conclusion: sensitive years

At this point, we are not able to lead the demonstration at this end because we did not get enough woods: treating 2500 years in such a small area as northern France would require about 10000 trees correctly chosen. Except for short periods (late roman /early medieval) they are in the backgrounds of our laboratories! We can however put forward a hypothesis about the weather of some past years, which concerned the life of the most important sites we had to study. The last figures (Fig. 14 and 15) show, firstly, noteworthy historic (event) years and secondly, other event prehistoric years about which we only know the figure. It is more difficult at this point and stage of this research, which requires lengthy controls of a lot of small sites, to draw complete maps of the historical period. Nevertheless we produced some maps, which suggest dendrochronological situations that would be workable. The year 1137, well known for its very narrow ring (sometimes invisible on the samples!) tends to

show a comparable situation to 1976. Potentially, the same climatic situation could be applied to year 1676. The meteorology of the summer of that year is described in ancient texts as exceptionally hot and dry. Year 1419 shows a situation similar to 1959. As a paradox, data from the late prehistory (late Gallic and early roman period) gives more results. Numerous excavations about this period delivered a lot of woods which were recently re-studied (Durost 2005). Samples of maps show the dendrochronological potential of these periods: The year 76 before Christ is probably the driest one in the Gallic period (as1976).
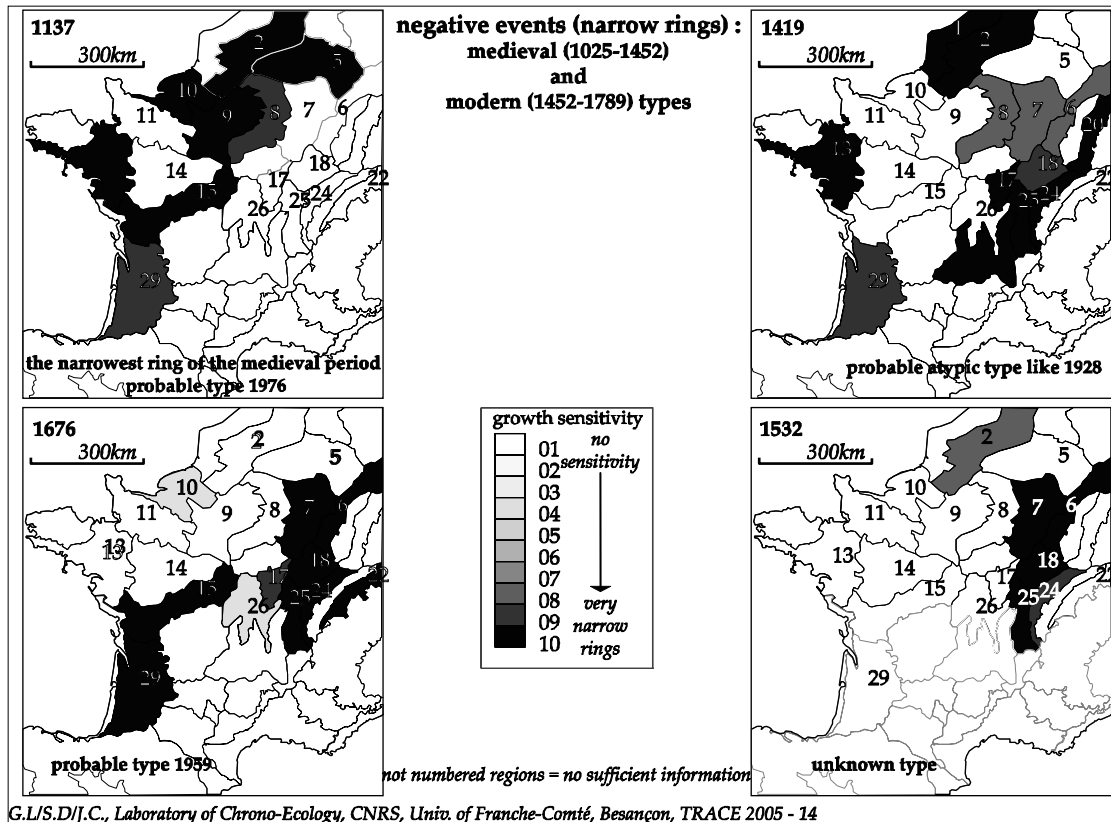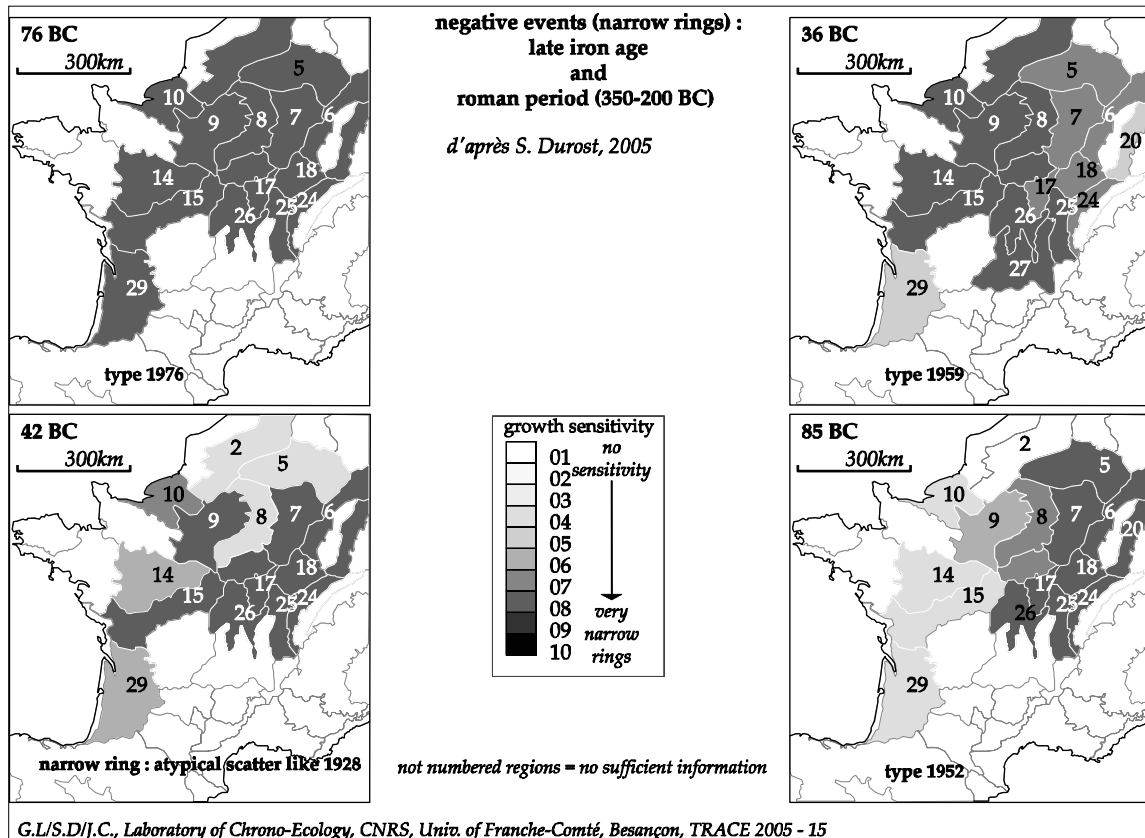

Figure 14: Medieval and modern narrow rings

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Figure 15: Late prehistoric narrow rings

But a suite of such years has been noted during the 300-year period before Christ and the whole of Gaul, which stretched under temperate climate. This leads us in two directions: firstly, that the human impact on trees, even on trees located in neighboring areas of human societies and used by men, is less than we thought – this is a subject for researches in archaeology - and, secondly, that the global climatic factors worked differently compared to the 20th century.

We give at the end a summary of years, which could be discussed with Historians (Fig. 16).
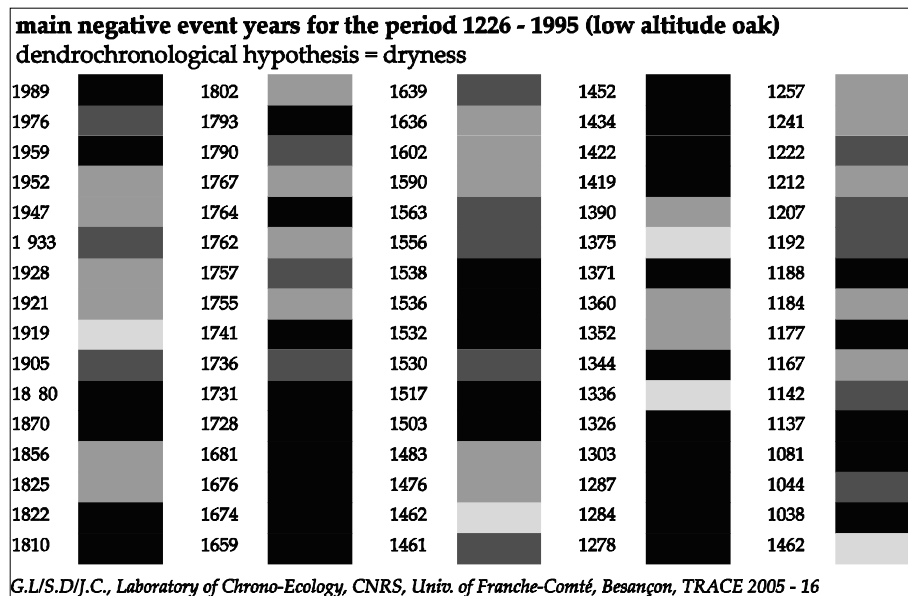
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main negative event years for the period 1226 - 1995 (low altitude oak)
dendrochronological hypothesis = dryness

1989	1802	1639	1452	1257
1976	1793	1636	1434	1241
1959	1790	1602	1422	1222
1952	1767	1590	1419	1212
1947	1764	1563	1390	1207
1 933	1762	1556	1375	1192
1928	1757	1538	1371	1188
1921	1755	1536	1360	1184
1919	1741	1532	1352	1177
1905	1736	1530	1344	1167
18 80	1731	1517	1336	1142
1870	1728	1503	1326	1137
1856	1681	1483	1303	1081
1825	1676	1476	1287	1044
1822	1674	1462	1284	1038
1810	1659	1461	1278	1462

G.L/S.D/J.C., Laboratory of Chrono-Ecology, CNRS, Univ. of Franche-Comté, Besançon, TRACE 2005 - 16

Figure 16: Ancient negative event years: dark = probable hard summer dryness; grays : opened hypothesis for discussion.

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