Session h1

TIMING AND NATURE OF VEGETATION RESPONSE TO ABRUPT CLIMATE CHANGES

Rapid and widespread vegetation responses to late-glacial climate change in the North Atlantic region

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The degree to which plant-taxon distributions are in equilibrium or disequilibrium with climate is both spatially and temporally scale-dependent. The central measure of temporal scale-dependence is the time lag between climatic change and vegetational response, defined here as the time elapsed between the initiation of a climatic event and the first measurable vegetational response. Although models of forest-stand dynamics predict that such time lags should be on the order of several hundred years, there has been little empirical corroboration of these estimates. This paper presents a meta-analysis of 11 lakes from eastern North America and Europe with highly resolved and well-dated fossil pollen records and independent paleoclimatic proxies spanning the last deglaciation. Cross-correlation analyses indicate that vegetational response times are consistently of <200 yr and often <100 yr. These findings confirm the observations made at individual sites and demonstrate that rapid vegetation responses to abrupt climate change is a general phenomenon not limited to individual sites or regions. No significant difference was observed between sites in eastern North America and Europe, despite differences in floristic composition and topographic relief. These results uphold the general consensus that vegetation is in dynamic equilibrium with climate at millennial and longer timescales, allowing the use of fossil pollen records as paleoclimatic proxies. Moreover, these results are consistent with reports that plant distributions are already shifting in response to recent climate change, and suggest that these responses will persist for the next several centuries.

Rapid vegetation response to Holocene climate changes

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Traditionally, pollen analysis has evidenced major vegetation response to high-amplitude climate change at the Glacial-Interglacial scale. However, several phases of climate change have been evidenced in ice-cores and especially in the marine record. Vegetation reacts dynamically to changing climate, especially at the range limits of plant species. Given a suitable environmental archive with high chronological resolution past vegetation change in response to climate may be traced in the pollen record. Based on examples from Central Europe and North America the response of late-glacial and Holocene vegetation to climate changes of different amplitudes and duration is discussed. We emphasize high-resolution pollen analyses to detect Holocene vegetation response to climate change and stress the use of independent climate proxies to assess vegetation response.

In a first example we focus on the effect of the climate cooling of the Younger Dryas (ca. 12,600 to 11,500 cal. BP) and the subsequent warming on late-glacial birch-pine woodland at Gerzensee, a small lake at the northern border of the Alps. The bulk sediment oxygen isotope data, which matches the Greenland ice-core $\delta 18O$ record closely, is used as proxies for the climatic forcing (Schwander et al., 2000). Pollen analysis (Wick, 2000)

shows hardly any vegetation response to the climatic cooling of the Younger Dryas, whereas when the pollen data is used to quantitatively reconstruct past climate a depression of between 2-3° C in summer temperature is inferred for the Younger Dryas cold period. This temperature reconstruction agrees well with independent reconstructions using aquatic organisms such as Cladocera from the same site (Lotter et al., 2000). However, during the early Holocene (Preboreal) cladoceran inferred summer temperatures show considerably higher summer temperatures than the pollen. This discrepancy is likely the effect of migrational lags of temperate vegetation at the onset of the Holocene.

A second example concentrates on the reaction of the vegetation to the 8.2 ka event in the alpine foreland of Switzerland. Correlation of a pollen record from annually laminated sediments with the oxygen isotope record of Greenland (GRIP) revealed pronounced and concurrent response of vegetation to the climatic change at 8.2 ka (Tinner and Lotter, 2001). Concurrent to a collapse of hazel trees such as pine, birch, and linden expanded rapidly and the invasion of beech and fir into Central Europe was triggered. These vegetational changes are likely the effect of reduced drought stress leading to vegetation assemblages with taller growing, shade tolerant trees forming denser canopies, thus out-competed first hazel and subsequently other thermophilous trees such as oak, elm, ash, and linden.

A third example focuses on vegetation changes in reaction to the Little Ice Age (LIA, ca. 1500-1900 AD) in Alaska. The comparison of a pollen record from Grizzly Lake (Copper River Basin) with regional evidences of climate change such as oxygen-isotope inferred temperature reconstructions (Hu et al., 2000) and glacier fluctuations suggests conversions from boreal forests to tundra and *vice versa* in response to climate cooling and subsequent re-warming. Boreal-forest diebacks were characterized by declines of *Picea mariana and Betula* trees. Concurrently, tundra shrubs such as *Alnus viridis* and *Betula glandulosa/nana* could expand. Correlations between marked increases in charcoal abundances and pollen fluctuations (e.g. *Epilobium*) suggest that fire increases exacerbated LIA effects on boreal vegetation.

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Preboreal climatic oscillations in Europe

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Accurate chronologies are essential for linking palaeoclimate archives. ^{14}C wiggle-match dating (WMD) was used to produce an accurate chronology for a number of Early Holocene sequences from The Netherlands (e.g., VAN DER PLICHT et al., 2004). With the WMD method, a series of uncalibrated AMS dates can be matched to the ^{14}C INTCAL98 calibration curve, using the stratigraphical position of the ^{14}C dates samples.

The Dutch palaeobotanical records show that following the Younger Dryas/Preboreal transition, two climatic shifts could be inferred. Around 11,400 cal BP the expansion of birch (*Betula*) forest was interrupted by a dry continental phase (Rammelbeek Phase) with dominantly open grassland vegetation. Botanical evidence points to relatively dry and warm summers (i.e., Poaceae, *Urtica*, *Nymphaea* and *Ceratophyllum*), although winter temperatures may have been low. During the following Late Preboreal, which started at ca. 11,250 cal BP, birch forests expanded again and in many records there is a sudden transition to wetter local conditions.

Using the dating accuracy based on WMD we are now able to compare in detail vegetation based climate change with atmospheric ^{14}C changes (STUIVER et al., 1998) and with the Greenland ice core data (JOHNSEN et al., 1997). During the Preboreal period, the two cosmogenic nuclides ^{14}C and ^{10}Be (MUSCHELER et al., 2000) show similar, contemporaneous fluctuations, which suggests changes in the production rate, most probably caused by changes in solar activity.

Our records show that the continental climate with warm, dry summers and cold winters of the Rammelbeek Phase in The Netherlands was coeval with cooling (PBO = Preboreal Oscillation) in Greenland, as observed in the GRIP ice core, and occurred during a period of high solar activity (low $\Delta^{14}C$-values). At 11,250 cal BP a sudden shift to a humid climate occurred. This second change appears to be contemporaneous with: 1) sharp increases of atmospheric ^{14}C and of the GRIP ^{10}Be flux; and 2) a temporary decline of atmospheric CO_2 (WAGNER et al, 1999). The onset of a more humid period in NW Europe thus coincides with a return to normal interglacial conditions over Greenland. The close correspondence with excursions of cosmogenic nuclides points to a decline in solar activity, which may have forced the changes in climate and vegetation at around 11,250 cal BP.

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WAGNER, F., BOHNCKE, S.J.P., DILCHER, D.L., KÜRSCHNER, W.M., VAN GEEL, B. & VISSCHER, H. 1999. Century-scale shifts in Early Holocene atmospheric CO_2 concentration. Science 284: 1971-1973.

The response of the vegetation to the cold event 8200 years ago in Estonia, Eastern Europe

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The cold event at 8200 years ago is the most extreme cold event after the Younger Dryas that has been unambiguously observed in various biological and physical proxies and in different sedimentary environments. In order to detect the occurrence of the cold event and its potential impact on the vegetation in Eastern Europe we sampled an annually laminated Lake Rouge (local name Rouge Tougjärv, 57°44'N, 26°54'E) in southern Estonia. A 730-cm-long core was recovered from the deepest point of the 17-m-deep lake in 2000. The stable isotope and sedimentological data suggest cold conditions at 8400 – 8100 years ago.

The pollen-stratigraphical data show that the cooling at 8400 years ago induced rapid declines of temperate, thermophilous broad-leaved trees, such as *Alnus*, *Corylus*, *Ulmus*, and *Tilia*, and a corresponding rise in *Betula*. The decline of *Alnus* from >20% to <10% is particularly noteworthy because, unlike other species, it does not occur near its northern distribution limit in Estonia. *Alnus* begins to grow and flower early in the season and is particularly sensitive to frost damage in the early spring. In line with the formation of paler varves, this suggests that winters and early springs were particularly cold in the study region during the cold event at 8200 years ago. This is further supported by the establishement of *Picea* during the event. In contrast to the temperate tree species, the successful sexual regeneration of *Picea* in the southern Boreal Zone is favored by adequately cold and snowy winters. The temperate deciduous tree species recovered at about 8100 years ago.

These abrupt pollen-stratigraphical changes during the decline and recovery do not necessarily indicate major changes in population sizes or in the species composition of the forest, but probably partly reflect the high inter-annual variability in pollen production of tree species at their range limits. Pollen production of the thermophilous species was constrained by the low temperature and short growing-season at 8400-8100 years ago, while climatic conditions became more favorable for flowering and pollen production of these species at 8100 years ago.

High velocity response of the Mediterranean vegetation to climatic changes during Heinrich events

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ODP Site 976 (36°12N, 4°18W), has been drilled in the Alboran Sea close to the Atlantic/Mediterranean gateway, and exhibits a high sedimentation rate which have allowed high resolution analyses multiproxy analyses (pollen, dinocysts, isotopes). Chronology is based on AMS ^{14}C dating and oxygen isotopes record. According to this chronology the uppermost 20 meters span a time interval corresponding to the last 50,000 yr in which we present here -with a high resolution- the intervals synchronous with Heinrich events 1 to 4. High-resolution pollen and dinocysts assemblages have been used here in combination with oxygen isotope stratigraphy and foraminiferal counts in order to reconstruct the changes in western Mediterranean marine and continental paleoenvironments and climate during H1 H3, H4 and H5.

We assumed that the pollen rain on Alboran Sea mainly originate from west Mediterranean borderlands. Modern environments range from a thermomediterranean belt (*Olea*, *Pistacia* and some semi desert representatives as *Artemisia*, Chenopodiaceae, *Ephedra*) to a mesomediterranean belt (sclerophyllous oak forest then a humid-temperate oak forest with eurosiberian trees (such as *Quercus*, *Betula* ... and Ericaceae), and a supramediterranean belt with a cold-temperate coniferous forest (*Pinus*, *Abies*, *Cedrus*) at the higher altitudes (Ozenda, 1975 ; Rivas-Martinez, 1982). Today the region experiences long dry summers and mild rainy winters (Walter *et al.*, 1975). 120 pollen taxa were identified. Pollen spectrum range from semi-desert to mountain deciduous and coniferous forest ones.

Results show abrupt development of the steppic association while forest trees like *Quercus* forest retreats very rapidely. This expresses a reinforcement of dryness in the west Mediterranean at time of Heinrich events. In detail it seems that the response of the vegetation was not homogeneous during all the Heinrich events. In H3 to H5 we observe a very quick response with simultaneous increases in *Artemisia* , Amaranthaceae-Chenopodiaceae and sometimes *Ephedra*; in H1 the reaction of the plants seems more progressive with, in first, the development of *Artemisia* followed by *Ephedra* and then by Amaranthaceae-Chenopodiaceae. In marine environments, these Heinrich event times are marked by increases in abundance of *Bitectatodinium tepikiense* (a dinocyst indicative of high seasonal contrast in the sea surface temperature), in phase with the optimal representations of *Artemisia* and are preceded by peak abundance of the cold indicator Neogloboquadrina pachyderma (senestral coiled). Before the Heinrich events a peak abundance of the altitudunal *Cedrus* forest indicates that the temperature already began to decrease on the continent before the onset of dryness. After the Heinrich events, return to humid climate is marked first by a slight increase in *Isoetes* abundance indicating the first fresh water input and then by rapid development of the *Quercus* forest.

Climate and vegetation changes in northwest Iberia during the last 25.000 years based on the multiproxy analysis of deep sea core MD99-2331

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Pollen, planktonic foraminifera, alkenone, carbonate content and coarse fraction analyses as well as magnetic susceptibility (MS) and $\delta^{18}O$ measurements have been obtained from a high-rate sedimentary deep-sea core (MD99-2331, 42°09'00 N and 09°41'90W) retrieved in the northwestern Iberian margin. This core covers the last three climatic cycles. The seven uppermost meters record the climatic variability of the last 25,000 years: end of the Last Glacial period (LGP), Bölling-Alleröd interstadial (B-A), Younger Dryas (YD) cold event and Holocene interglacial. Within the LGP two cold Sea Surface Temperature (SST) episodes linked to iceberg discharges have been detected. The old one, Heinrich event 2 (HE2), is characterised by a peak of coarse fraction sediments and maxima in polar foraminifera *N. pachyderma* (s) percentages as well as by two peaks of magnetic susceptibility. The youngest one (HE1) is marked by a peak of *N. pachyderma* (s) percentages. However, no coarse detritus are present. Between these two HEs, the LGM (Last Glacial Maximum) is characterised by a slight increase in SST. Following the HE1, an increase in SST values and a decrease of *N. pachyderma* mark the B-A interstadial, while a subsequent return to cool oceanic conditions shows the YD episode. After this, a gradual increase in SST up to the middle of the Holocene marks the first part of this interglacial.

Vegetation shifts are globally contemporaneous to these climatic changes. HEs 2 and 1 are associated with heathland and grassland development in northwestern Iberia with almost no deciduous tree vegetation. *Pinus* formations were also reduced during these cold periods. Even if SSTs slightly increase over the LGM, no deciduous forest expansion is detected in northwestern Iberia during this time interval. A *Quercus-Betula-Corylus* forest succession is triggered by the B-A warming phase. In this region, and contrary to what is observed in southern Iberia, the YD is recorded by drastic vegetation changes from open forest to heathland and grassland formations. Finally, the Holocene is marked by the gradual expansion of the *Quercus-Betula* forest followed by the maximum development of *Quercus-Corylus* woodlands paralleling the SST increase. However, a close observation of the SST evolution and the forest dynamic trends reveals several time-mismatching over the deglaciation. Relatively high SST values do not always coincide with *Quercus* forest expansion and, inversely, the beginning of *Quercus* development leads SST increase.

Contrasting responses of Iberian vegetation to abrupt climatic changes over the Last Glacial Period

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Vegetation shifts from terrestrial pollen sequences can reflect climatic changes or biotic processes such as migration and competition between species. To disentangle these processes LISCHKE et al. (2002) compared pollen data with simulations of a dynamic forest patch model , using independent temperature and precipitation estimates. This work indicates that vegetation in the Central Swiss Plateau responded with lags at the time-scale of centuries to millennia caused by secondary succession after rapid climatic changes such as at the Younger Dryas/Holocene transition or delayed immigration of dominant taxa. Another way to evaluate the timing of the vegetation response to a climate change is to analyse pollen from marine cores. The direct correlation between pollen-derived vegetation dynamics and pollen-independent climatic records (alkenones, $\delta^{18}O$, foraminifer and dinocyst assemblages) from the same marine samples allows us to track eventual time-lags in the response of the

vegetation to rapid climatic changes. The multiproxy study of marine core MD95-2043 (36°8'N, 2°37'W) retrieved in the Alboran sea, south eastern Iberian margin, indicates that vegetation and marine environmental changes related to the Dansgaard-Oeschger (D-O) millennial scale climatic variability were rapid, ~150 years, and synchronous (SANCHEZ GOÑI et al., 2002). The forest dynamic recorded from this core straightforwardly parallels the annual Sea Surface Temperature (SST) trend detected by the alkenone analysis. Further, after the rapid climatic change of the Heinrich 4 cold event a forest succession mimics the gradual increase of the annual SST over Interstadial 8 (Is8). The peak in the SST was synchronous with the maximum development of the open Mediterranean forest and this occurred c. 1,000 years after the onset of this interstadial. Core MD95-2042 retrieved in the southwestern Iberian margin confirms parallel trends between forest dynamics and SST evolution. This suggest, contrary to the conclusions reached by Lischke et al. for central Europe that the forest in southern Iberia responds with no major lags to abrupt climatic changes. Preliminary results from the multiproxy study of the northernmost core MD99-2331 (42°09 N; 09°41 W) retrieved off Galicia (NW Iberia) reveals, in contrast, several time-lags between peaks in SST and forest development. Furthermore, the forest response to the D-O climatic variability is weaker in the north than that observed in southern Iberia likely associated with small amplitude SST shifts in the former region.

LISCHKE, H., LOTTER, A.F., FISCHLIN, A. (2002) Untangling a Holocene pollen record with forest model simulations and independent climate data. Ecological modelling. 150: 1-21.

SANCHEZ GOÑI, M.F., CACHO, I., TURON, J.-L., GUIOT, J., SIERRO, F.J., PEYPOUQUET, J.-P. , GRIMALT, J. & SHACKLETON, N.J. (2002). Synchroneity between marine and terrestrial responses to millenial scale climatic variability during the last glacial period in the mediterranean region. *Climate Dynamics* 19: 95-105

Ecological thresholds and amplitude of millennial-scale stadial events: the response of vegetation in Greece during the last glacial period

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Perhaps the most important development in our understanding of Quaternary environments during the 1990s has been the realization of the pervasive and extreme nature of millennial-scale climate variability, especially during intervals of increased ice volume. This has dispelled previous notions of glacial monotony and replaced them with a view of dynamic and unstable climate regimes. Abrupt, high-amplitude air-temperature fluctuations have been recognized in Greenland and shown to be coeval with iceberg discharges and sea-surface temperature variations in the North Atlantic throughout the past 110 thousand years. Much effort has since been devoted to mapping the spatial patterns of this variability on a global scale in order to gain an insight into the mechanisms involved in the origin and transmission of these events.

Here we review the structure of climate changes in the North Atlantic during the last glacial and examine their expression in southern Europe, with particular reference to the vegetation response. Inspection of three pollen records from contrasting bioclimatic areas in Greece suggests that differences in the magnitude of cold events as recognized in the North Atlantic and Western Mediterranean are expressed in terms of tree population changes only in areas with a range of favourable habitats. By contrast, records from sites where populations approach their tolerance threshold do not appear to resolve differences in the amplitude of the climate oscillations. Understanding the importance of local factors in modulating the biological response to climate change is critical when attempting to establish the spatial pattern of millennial variability.

Vegetational response to the Younger Dryas at Saint-Hilaire, Quebec, Canada: the case of an island within proglacial Champlain Sea

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Saint-Hilaire Mountain (400 m) is located in the Saint-Lawrence River Lowlands near Montreal, Quebec, Canada. It harbours two structural depressions with complete postglacial deposits located respectively higher (Hemlock Carr, 243 m) and lower (Lake Hertel, 169 m) than the pro-, then postglacial Champlain Sea marine limit (~190 m in this area). Marine transgression occurred *ca.* 13 000 cal. yr. BP when the Laurentide Ice Sheet withdraw from the Appalachian Highlands (south) to the Laurentian Highlands (north) during the Alleröd, allowing the North Atlantic marine waters to invade the isostatically-depressed lowlands.

Saint-Hilaire was thus initially an island within Champlain Sea and, consequently, it experienced insular plant colonization during the final stages of the Late-Pleistocene.

The higher deposit (Hemlock Carr) was initially laid down in a steep-sided narrow lake and encompasses the Younger Dryas chronozone, according to three AMS radiocarbon dates on plant macrofossils. Loss-on-ignition clearly shows reversals in the increasing trend of organic matter accumulation, in two paired basal cores. Pollen analysis reveals assemblages typical of an initial quasi-desert followed by a tundra rich in arctic-alpine taxa, eventually replaced by trees. Macrofossil analysis supports the pollen-based vegetational reconstruction and enhances taxonomic determinations.

The lower deposit (Lake Hertel) was laid down in a depression initially occupied by Champlain Sea marine waters, as evidenced by a shallow water marine faunal assemblage. Loss-on-ignition shows very low and unchanging amounts of organic matter during the marine stage and also during the onset of the following lacustrine stage caused by the isostatic uplift of the earth's crust in the region. Pollen assemblages of the basal sediments show clear evidence of a tundra vegetation, but the initial quasi-desert stage is lacking. Plant macrofossils are very rare in the initial lagoonal environment, but intensive sampling (13 basal cores) allowed the finding of enough terrestrial plant remains for a basal AMS-dating. This effort lead to cross-dating of marine shells and terrestrial material, thus allowing the determination of the local reservoir effect on the regional chronology of ice retreat previously based on ill-corrected shell dates.

From those results, it is now possible to examine the timing and nature of vegetation response to the Younger Dryas climate oscillation in a very unique setting: an ice-proximal setting with the huge Laurentide Ice Sheet standing only *ca.* 100 km to the north, and actively building the Saint-Narcisse Moraine during the Younger Dryas; an insular setting, with cold marine waters surrounding Mount Saint-Hilaire within a radius of *ca.* 70 km; a revised chronological and paleogeographical setting of late Pleistocene ice-retreat at the scale of Eastern North America whereby inflow of glacial meltwaters from the Laurentide Ice Sheet to the North Atlantic through the Saint-Lawrence River Valley could not have occurred before *ca.* 13 000 ± 100 calibrated years ago, which potentially bears upon the triggering of the Younger Dryas itself.

Pollen analytical researches in the eastern Romanian Carpathians and the Southern part of Transylvania depression (Romania). Vegetation history and human impact

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Paleoecological studies of five wetlands from the Eastern Romanian Carpathians and from the southern part of Transylvania depression were accomplished (TANTAU, 2003; TANTAU et al, 2003). Eleven pollen diagrams established by 1165 pollen spectra and supported by 64 ^{14}C datings make it possible to reconstitute the Late Glacial and Holocene vegetation history.

During the Late Glacial interstadial the forest recolonisation begin with the *Pinus* development, without the *Betula* phase. *Picea* begin to expend from the regional refuges.

After a well marked Younger Dryas, the Holocene begin with the *Betula*, *Ulmus* and *Picea* expansion, followed, at about 9,000 B.P. uncal, by that of *Fraxinus*, *Quercus* and *Tilia*.

Corylus optimum is correlated with the Atlantic chronozone (after 8,000 B.P. uncal), that of *Carpinus* expands at about 5,000 B.P. uncal. The spread of the *Fagus* forests started at 4,000 B.P. uncal.

The first evidences of a cultivation of cereals appear around 6,500 B.P. uncal.

The evidences of regional diachronisms make it possible to reconstitute the migration routes of some forest taxa.

Key words: *Eastern Romanian Carpathians, vegetation history, ^{14}C datings, Late Glacial, Holocene*

TANTAU, I. 2003. Recherches pollenanalytiques dans les Carpates Orientales (Roumanie). Histoires de la végétation et de l'impact humaine. Ph.D. Thesis, Aix-Marseille III and Babes-Bolyai Universities.

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Vegetation changes during the last 15000 years in France: data-model comparisons

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The European Pollen Database (EPD) holds a dense network of palynological data in France. The purpose of the present work is to validate a vegetation model using these palynological data. We intend to use the validated model to predict future vegetation changes using different climate scenarios.

We have set up vegetation groups based on the climatic tolerances and requirements of each plant identified by its pollen grain. We will present the reconstructed ranges of two Bioclimatic Affinity Groups (BAG) during the past 15000 years in France. CARAIB model (Warnant *et al.*, 1994) has been adapted to simulate BAGs net primary productivity. Model simulations were calibrated with observed vegetation ranges and compared to reconstructed ranges from modern pollen samples.

Calibrated age models have been elaborated for all pollen records with available ^{14}C dates in the EPD. These age/depth models allowed us to extract pollen percentages for each time slice. As data are unevenly distributed, pollen percentages were interpolated using kriging method. A succession of maps each 500 years show BAGs distributions in France. We will present here some simulated and reconstructed BAGs distributions and discuss leads and lags between the two data sets.

WARNANT, P., FRANÇOIS, L., STRIVAY, D. & GÉRARD, J.-C. 1994. CARAIB: a global model of terrestrial biological productivity. Global Biogeochemical Cycles 8: 255-270.

Preliminary results of the multi-proxy data analysis of Les Echets (Ain, France)

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New corings were performed with a wide mechanical borer in the palaeolacustrine complex of Les Echet, formely studied by BEAULIEU et REILLE (1984), in order to reconstruct high resolution past climatic and ecological changes for the last climatic cycle and the end of the previous one. The site is located at low altitude (267 m) on the ante-würmian glacial drift of the Dombes Plateau (20 km N.E. Lyon). The main profile (EC1: 43.77 m) was extracted near to the centre of the depression with the intention of making the main biological, sedimentological and geochemical analysis. A double core of the Eemian was carried out. The second profile (EC3: 24.20 m) was cored along the former lacustrine littoral to analyse vegetal and insect macroremains (mainly Chironomids), and past lake-level fluctuations.

Pollen and magnetic susceptibility analysis indicate that the deepest profile EC1 correspond to the last 130 000 years, from the end of the rissian glaciation (which ends with a typical cold event similar to the Younger Dryas), the respectively temperate and cold oscillations of St Germain and Mélisey, and a thick alternately organic and minerogenic pleniglacial sedimentay section characterized by a boreal to arctic vegetation. During this glacial period, the sporadic presence of meso-to-thermophilous arboreal refuges, is attested, especially at the beginning of the continental analogous of OIS 4.

Most of the multi-proxy analysis are still in progress, among them organic matter characterisation with the Rock-Eval technics (KERAVIS *et al.*, 2003), Chironomids, Diatoms, pollen, $\delta^{18}O$ and micro-tephra mineralogy.

BEAULIEU J.-L. (de) et REILLE M., 1984. A long Upper Pleistocene record from Les Echets, near Lyon, France. *Boreas*, 13, 111-132.
KERAVIS D., BENMAMAR S., LALLIER-VERGES E., ANDRIEU-PONEL V., BEAULIEU J.L. (de), 2003. Utilisation de nouveaux signaux de la pyrolyse Rock-Eval pour retracer l'évolution de la composition de la matière organique sédimentaire déposée sous contrôle climatique. Application à la série lacustre des Echets (France). 9ème Congrès de l'Association des Sédimentologues Français, Bordeaux, 14-16 octobre 2003.
Research funding: Andra, CNRS, N.S.F.

Abrupt events within the last glacial period: records from Tropical and temperate Australia

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We present results for the first, continuous, high resolution sequences from terrestrial environments in Australia that provide evidence of vegetation and climate change through the whole or a substantial part of the last glacial period. They were constructed to determine whether abrupt events occurred within this part of the world and, if so, to examine the degree of synchroneity with well documented events from the northern hemisphere and, hence, contribute to causes of this scale of climatic variability.

Lynch's Crater in the humid tropics of north-eastern Queensland has provided a continuous, though generalised, record of vegetation change through the last c 200,000 years (KERSHAW 1986). Recent radiocarbon dating of the later part of the sediment sequence using acid-base-acid stepped combustion, combined with high resolution pollen and sediment analyses, has provided a firm basis for examination of patterns of change over the

last 45,000 radiocarbon years (c 48,000 cal. yrs) (TURNEY et al. 2001). Although the relatively homogenous composition of the eucalypt forest surrounding the site through much of the period has inhibited detailed palaeoclimatic interpretation, there are clear 1500 year oscillations in components of the swamp environment (the Poaceae/Cyperaceae ratio, degree of peat humification and charcoal) indicating variation in moisture availability. As the region is strongly influenced by the Southern Oscillation, these oscillations are considered to represent ENSO cycles. These cycles can be bundled into semi-precessional cycles that show longer-term shifts in ENSO with major 'dry' events centred on 40,000, 25,000 and 15,000 years BP. The strong frequency and phase relationship between these cyclical events and those recorded in the North Atlantic region suggest a causal relationship. As it is difficult to perceive of a mechanism whereby a North Atlantic signal can be transmitted quickly to this region, it is proposed that the tropical Pacific is playing a leading role in the generation of abrupt events at high latitudes.

A remarkable record of temperate environments has been constructed from a small swamp, Caledonia Fen, in the highlands of southeastern Australia. Pollen analysis of 20 m of sediment at 4 cm intervals provides a record that covers the whole of the last glacial-interglacial cycle. As the sediments of the last glacial period contain little organic matter, radiocarbon dating has been difficult but recently excellent results, covering the last 45,000 years, have been achieved from the dating of rare macrofossil and beetle remains. These are showing good agreement with OSL dates that are extending the chronology through the last glacial period. The period is dominated by alpine-steppe vegetation, punctuated by a number of abrupt events. Peaks of Poaceae are considered to represent dry, warm phases of millennial duration while combinations of peaks in eucalypts and short term swamp hydroseral developments suggest warm and wet, mainly sub-millennial events. A longer term abrupt event in the early part of marine isotope stage 3 is notable in that it suggests attainment of interglacial conditions lacking in substages 5c and 5a. It is hoped that completion of OSL dating will provide a robust chronology and allow realistic comparison of variability with that in the Lynch's Crater record and with established patterns elsewhere in the world.

KERSHAW, A.P. 1986. Climatic change and Aboriginal burning in north-east Australia during the last two glacial/interglacial cycles. Nature 322: 47-49.
TURNEY, C.S.M., BIRD, M.I., FIFIELD, L.K., KERSHAW, A.P., CRESSWELL, R.G., SANTOS, G.M. DI TADA, M.L., HAUSLADEN, P.A. & YOUPING, Z. 2001. Development of a robust 14C chronology for Lynch's Crater (North Queensland, Australia) using different pre-treatment strategies. Radiocarbon 43: 45-54.

A high resolution, multiproxy record of the Last Glacial Maximum to Holocene transition from the volcanic lake sediments of Tower Hill, southeastern Australia

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Rapid climate changes during the late Pleistocene to Holocene transition have been recognised globally. However, in many parts of the world and particularly much of the southern hemisphere, the lack of suitable sites and/or good chronological control have provided uncertainty as to the degree of synchronicity of change and consequently the recognition of causal mechanisms. Here we present a detailed, multiproxy record of the transition from the sediments of a small scoria cone lake situated within the volcanic maar of Tower Hill, on the Western Plains of Victoria, southeastern Australia. It is one of the few sites on the continent that demonstrated continuous sedimentation from the Last Glacial Maximum to present (D'COSTA et al. 1989).

High resolution pollen analysis provides a picture of dry land vegetation and is combined with detailed sediment, ostracod and diatom analyses and stable oxygen analysis of ostracod carapaces to provide details of the depositional environment. Additional data are provided from identification of plant macrofossils and Coleoptera remains that where preserved in some parts on the sediment sequence. Measures of biomass burning are provided by the calculation of densities for micro- and macro- sized charcoal particles. The chronology of the 4 m core section is well controlled by 32 AMS dates using ABA in combination with sieving and floatation. The age determinations were then converted to calendar ages indicating a continuous sedimentation sequence from about 22,000 to 7000 years BP.

The earliest part of the record indicates the existence of a shallow brackish lake (3 °/oo) surrounded by grassland-steppe vegetation. At about 17 ka cal. B.P. there was an abrupt change to saline, and perhaps ephemeral, lake conditions (4.7°/oo) and expansion within the area of eucalypt woodland. It is likely that a global temperature increase associated with the beginning of deglaciation resulted in an effective reduction in moisture within this area. From 14.9 ka cal. B.P, Casuarinaceae began to expand, perhaps as a result of some further rise in temperature, and this was followed, at 14.0 ka cal. BP, by both increases in temperature and precipitation with the dominance of Casuarinaceae open forest, marked reductions in steppe elements and the re-establishement of brackish water. After a slight climatic reversal between 12.3 and 11 ka cal. B.P, the development of freshwater within the basin and stabilisation of forest vegetation indicates warm and wet conditions that characterised much of the Holocene period. Overall, the record shows clear late glacial variability but this is difficult to relate to either Antarctic or North Atlantic patterns, possibly due to regional influences of climatic and oceanic circulation patterns and the inter-relationship between changes in temperature and precipitation.

D'COSTA, D.M., EDNEY, P., KERSHAW, A.P., & DE DECKKER, P. 1989. Late Quaternary palaeoecology of Tower Hill, Victoria, Australia. **J. Biogeog.** 16: 461-482.

Rapid vegetation response to climatic change in African and South American tropics around 4000 years before present: the responsive tropics and complacent poles

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Palaeoecological data recording a pronounced environmental shift centred about 4000 yr BP is presented from tropical Africa and South America. The environmental shift is particularly manifested as a change in the hydrological budget of numerous swamp and lake catchments. The majority of sites in tropical Africa record a shift to drier environmental conditions that is in opposition to South America, where a shift to a wetter environment is generally recorded. The strength of between site signals varies from being relatively complacent to dramatic, in some cases reflective of whole-scale vegetation change. The magnitude of change is mainly dependent of the location of the site and the proxy under investigation. These ecosystem changes are likely to reflect changed precipitation regimes, increased evaporation, and or an extension/contraction of the dry season. This pronounced environmental shift is particularly interesting, as the strong changes from the tropics are either weakly recorded, or non-existent, at more extensively studied temperate latitudes and Polar Regions.

The climate mechanisms responsible for this shift are reviewed and a model developed to explain such a strong signal from the tropical areas without associated changes at high latitudes, such as changes in polar ice sheet extent. We propose changes in Pacific Ocean sea-surface temperature regime, and the establishment of El Niño conditions have imparted a direct influence on tropical Atlantic SST that could explain the rapid changes in terrestrial palaeoecological records. Other components of the terrestrial-ocean-atmosphere system are also likely to be important contributory factors in the environmental shift, in particular the large changes in land surface conditions could contribute to the climate shift. Given the scenario for tropical environmental change, to a degree independent from high latitudes, targeted areas of future research are indicated that incorporate development of climate and ecosystem modelling and palaeoenvironmental investigation with a tropical focus.

Late Holocene abrupt climate change and the expansion of the Scythian cultures in southern Siberia and Central Asia

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The cultural blooming and expansion of the Scythian cultures in the steppe zone of southern Siberia and Central Asia started during the 9th century BC, which correlates well with the early Subatlantic shift to cooler, wetter conditions, dated to ca 850 cal. yr BC (2750 BP) in Europe. This abrupt climate change was triggered by a decline of solar activity (VAN GEEL et al. 1998). In order to understand a possible climatic cause of the Scythian expansion we analysed palaeoenvironmental changes during the mid- late Holocene in these arid areas. Pollen records of sediment cores from two lakes were obtained: the fresh-water Kutuzhekovo Lake (53°36'N, 91°56'E, 320 m a.s.l.), located at the forest-steppe ecotone of the Minusinsk depression in Southern Siberia, and the brackish White Lake (52°03'N, 93°43'E, 830 m a.s.l.), located within the steppe zone of the Uyuk intermountain depression in northern Tuva. The regional climate is mainly controlled by Siberian air masses, nevertheless the area may also be influenced by the Westerlies and the Asian monsoon, which reach their limits here.

The White Lake record shows a strong humid signal at ca 3930 BP after a period of long-term aridity during the mid-Holocene. The arid period is characterized by low pollen concentration and, among the xerophytic taxa, Chenopodiaceae dominance over *Artemisia*, indicating that desert and semi-desert persisted here. Biomass productivity, which is controlled by moisture availability in arid areas, was very low. A sharp rise of tree pollen values and total pollen concentration, taken together with a distinct decline of xerophytic taxa, is regarded as a wet signal. On the other hand, the highest concentration of shrub birch pollen indicates that it was cold at the transition to the wet period.

The Kutuzhekovo Lake record from the less arid Minusinsk depression, around 250 km north-west of White Lake, also shows a distinct climate shift to wetter conditions. The site has a higher temporal resolution during the late Holocene, which allows us to distinguish asynchronous trends in temperature and precipitation: the coldest phase started ca 4310 BP, while the maximum humidity occurred between ca 2985 and 2470 BP. The highest values of *Artemisia* and low tree pollen abundance indicate arid (cold and dry) conditions during 4-3 kyr BP, when steppe and semi-desert dominated in the depression and mountain forest was strongly reduced. A sharp rise of Cyperaceae and a decline of xerophytic taxa clearly reflect an increase in effective moisture shortly after 3000 BP. The pollen record of two pine species, with a different ecology, shows a progressive forest shift down-slope (*Pinus sylvestris* starts to rise) in response to increased moisture availability, while relatively cold conditions persisting in highlands prevented forest from spreading up-slope (*P. sibirica* has a low abundance).

Our records show corresponding climate change in both the Minusinsk and Uyuk depressions. In general, it was dry during the mid-Holocene, which is opposite to the widely perceived humid Holocene Optimum reported in Europe, eastern China etc., and even on a regional scale, such as Baikal and Western Siberia, but the dryness is consistent with data derived from arid to semi-arid zones in northern Mongolia (PECK et al. 2002) and Inner Mongolia (CHEN-TUNG et al. 2003). The discrepancy may be due to evaporation exceeding precipitation that reduced the effective precipitation. Conversely, during the cold period between 4-2 kyr BP a humidity maximum was recorded as a sharp climate shift, starting shortly after 3000 BP. Wetter and cooler conditions than today resulted in an increase in vegetation cover, higher biomass production and thus a higher carrying capacity in the Asian steppe zone, which became an attractive living area for Scythian nomads.

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VAN GEEL, B., VAN DER PLICHT, J., KILIAN, M.R., KLAVER, E.R., KOUWENBERG, J.H.M., RENSSEN, H., REYNAUD-FARRERA, I., WATERBOLK, H.T., 1998. The sharp rise of "14C ca. 800 cal BC: possible causes, related climatic teleconnections and the impact on human environments. Radiocarbon 40: 535-550.