Past and future global changes in Africa : modelling and databases

SEARCH WORKSHOP

University of Marseilles
2-4th May 2001

With the support of

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(INCO-DEV AND ENRICH PROGRAMMES)

1. RATIONALE

The project SEARCH (training and capacity building for data information in support of Euro-African collaboration on research in global change) is funded by the European Union (program ENRICH). It has the objective to promote close co-operation between Europe and Africa in the domain of global change research by assisting efforts to train young scientists in research over past environments and global changes in Africa. It has build a network of scientists working on environments and climates in Africa. With the willingness to gather data in databases in order to improve and facilitate research networking and to improve the flow and exchange of information on Global Change Research. Discipline involved are paleoclimatology (pollen, lake-levels data) and atmosphere chemistry. Participating teams are: Medias-France, Toulouse, University of Nairobi, Centre of Ecology and Hydrology of the NERC, Wallingford, Université P & M Curie, Université d'Aix - Marseille III, Max-Planck Institute for Biogeochemistry of Jena.

This project has the duty to organise several workshops and/or training courses where African and European colleagues are invited, in order to stimulate scientific exchanges. The first one has been organised in Toulouse (Medias-France) in November 1999 on the theme of global change databases. The second one was held in Marseilles in May 2001. We have focused on the international programs devoted to global change studies in Africa. We gathered young scientists and leaders of scientific programs concerned by Africa (APD, PMIP, ECOFIT, MIOMBO, IDAF, ...) during 3 days. In that workshop, some research results and projects have been presented and discussed.

Invited speakers and general topics related to international projects
- M. Hoepffner: introduction to project SEARCH and to meeting
- AM Lézine: the APD project
- J Guiot: climatic reconstruction and vegetation models, their use in PMIP
- JP Lacaux: atmospheric chemistry (Idaf database project)
- R. Moore: the hydrological database
- S. Harrison : The use of global databases to validate models (GLSDB, DIRTMAP)
- F. Gasse : PEP III and Africa
- D. Jolly: BIOME 6000 and PMIP
- L. Cournac: data and vegetation model used by ECOFIT
- F. Louis: the Caraib model
- D. Williamson: the CLEHA project
- N. Viovy: the Orchidee vegetation model
- M. Sykes: the ETEMA and ETJ models
- A. Alexandre : the interest of phytoliths for a better insight in herbaceous vegetation

All the participants have had the possibility to present their recent works (oral or posters).

2. LIST OF PARTICIPANTS

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3. PROGRAMME

Wednesday, 2nd May : Research projects and databases

10h00 - M. Hoepffner : Introduction to the SEARCH project and to meeting
10h30 - A-M. Lézine : the APD project

11h00 : coffee break

11h30 - J-P. Lacaux : Atmospheric Chemistry in Tropical Africa
12h00 - D. Williamson : Multiproxy database for Eastern Africa and catchment basin coupled modelling (RESOLVE/CLEHA)
12h30 - F. Gasse : PEP III

13h00 : lunch

14h00 - A. Alexandre : the interest of phytoliths for a better insight in herbaceous vegetation
14h30 – J.L. de Beaulieu : the Global pollen database and Africa
15h00 - M. Sykes : the ETEMA project
15h30 - S. Brewer : EPD and species migration

16h00 : Coffee break

16h30 - S. Fauquette : The Cenozoic Pollen database and climatic reconstruction of the North- and South-western Mediterranean Pliocene
17h00 - J. Guiot : Paleoclimatic reconstructions and vegetation models

Thurday, 3rd May : Vegetation and climate modelling

09h00 – M. Sykes : the LPJ model
09h30 – R. Moore: the Water Resources in Africa

10h30 : coffee break

11h00 - D. Jolly : Biome models and their use in paleoclimatology
12h00 - C. Favier : Models of tropical ecosystem evolution

12h30 – lunch

14h00 – N. Viovy : The Orchidee model
15h00 – L. François : The CARAIB model

16h00 : Coffee break

16h30 - C. Rathgeber : Application of BIOME3 to dendroecology
17h00 - S. Le Dizes : Modelling carbon responses of tundra ecosystem to temporal and spatial variations in climate (model MBL-GEM)
17h30 - V. Moron-Atmospheric models and rainfall prediction in the Sahelian region

20h00 : Conference dinner (offered by the SEARCH project)

Friday, 4th May : Recent researches in the frame of global change studies

09h00 - S.M. Rucina : Modern pollen-vegetation relationships in the Aberdare Mountains, Kenya
09h30 – R. Bonnefille : Paleoenvironement reconstruction for the Pliocene
10h00 – F. Chalié : Diatom as paleohydrological indicators: example from tropical Africa

10h30 : coffee break

11h00 - L. Cournac : Measurements and modeling in the frame of the ECOFIT project
11h30 - P. Yanda : the Miombo project
12h00 – J.L. de Beaulieu : Recent palynological research in North Africa
12h30 – H. Elenga : Recent research in the frame of the APD

13h00 : lunch

14h00 – T. Edorh : Palynological researches of the Togo mangroves
14h30 – I. Ssemanda : Pollen analysis of Lake Victoria
15h00 - A. de Vernal : Reconstrution of North Atlantic Ocean environmenents from dinocysts
15h30 – C. Hillaire-Marcel : Reconstruction of deep-intermediate water formation in the NW Atlantic ocean

16h00 : coffee break and various presentations on computer and the internet

17h30 – 18h00 : Discussion and conclusion of the workshop

4. **ABSTRACTS**

Summary

- Alexandre.L. Bremond L., J. Guiot.: Interest of phytolit for a better insight in herbaceous vegetation
- Raymonde Bonnefille: The use of Pollen data Base for palaeo-climatic reconstruction in tropical East Africa
- Simon Brewer, Rachid Cheddadi, JL de Beaulieu and M. Reille: EPD And Species Propagation
- Marc Dubois, Charly Favier & Jérôme Chave, Laurent Cournac, Bernard Riéra, and members of the ECOFIT group: Measurements and modelling in the frame of the ECOFIT project : tropical forest dynamics
- Thérèse Edorh: Palynological researches of the Togo mangroves
- Hilaire Elenga: Recent research in the frame of the APD
- Séverine Fauquette: The Cenozoic pollen database and climatic reconstruction of the North- and South-western Mediterranean Pliocene
- Charly Favier, Jérôme Chave, Marc A. Dubois: Modelling intertropical vegetation changes
- Louis François and Dominique Otto: The CARAIB vegetation model
- Joël Guiot: Paleoclimatic reconstruction and vegetation models
- Joël Guiot: Multiproxy databases and modelling
- M. Hoepffner, A-M. Lezine, Joel Guiot , E. Odada, R. Moore, JP Lacaux, S. Harrison: Search, a training and capacity building project for data information in support of Euro-African collaboration on Research in Global Change
- Dominique Jolly & I. C. Prentice: Biome model and their use in palaeoclimatology
- Jean-Pierre Lacaux: The IDAF (Igac Debits Africa) Programme: Atmospheric Deposition in Tropical Africa
- Vincent Moron: Atmospheric models and rainfall prediction in the Sahelian region
- Immaculate Ssemanda and Annie Vincens: Vegetation changes and their climatic implications for the Lake Victoria region during the late Holocene
- Martin T. Sykes: Etema – The European Terrestrial Ecosystem Modelling Activity
- Martin T. Sykes: The LPJ model: Simulating ecosystems and their processes from the patch scale to the globe
- Anne de Vernal and al.: Late Quaternary variations of sea ice and sea-surface conditions in the Arctic and circum-Arctic based on dinocyst assemblages: preliminary results and methodological issues
- Nicolas Viovy: The Orchidee Model
- David Williamson and Joël Guiot: Lacustrine basin environment observatories and multiproxy databases for eastern Africa: a clue to develop Catchment Basin Coupled Models and to improve the understanding of climate-environment interactions

INTEREST OF PHYTOLITH FOR A BETTER INSIGHT IN HERBACEOUS VEGETATION

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The wide range of grass-dominated biomes are distinguished with difficulties by common vegetation proxies such as pollen, charcoal or carbon isotopes. This lack makes vegetation models weaker (Prentice et al., 1992 ; Haxeltine & Prentice, 1996). Phytolith proves itself as a promising tool to fill this lack, using morphological analysis of phytolith assemblages from soils, buried soils and sediments. Grass-dominated biome records can be based on four phytolith indices:

- The first indice (d/p) indicates the proportion of ligneous dicotyledons versus grasses (Alexandre et al., 1997; 1999; Barboni et al., 1999).
- The second indice (Ic) indicates the proportion of C4-grasses versus C3-grasses (Twiss, 1992; Fredlund and Tieszen, 1994; 1997).
- The third indice (Iph) characterizes the proportion of C4-short grasses (Chloridoideae subfamilly) versus C4-tall grasses (Panicoideae subfamilly) (Diester-Haass et al., 1973; Fredlund and Tieszen, 1994; 1997; Alexandre et al., 1997; 1999; Barboni et al., 1999).
- The fourth phytolith indice (F,C) characterizes the drought adaptation of grasses (alexandre, 2000).

Because these physiognomic and physiological vegetation features are also linked to bio-climatic constrains, direct relationships between phytolith data and bio-climatic parameters are investigated.

We have in project to calibrate these phytolith indices with several grass-dominated biomes located either in tropical or temperate and cold areas.

To start with, samples collected in grazed Mediterranean grasslands and forest parcels have been investigated. Results show that the tree cover density cannot be traced by the related phytolith indice because widespread oak-trees do not produce any characteristic phytolith. However herbaceous biomass of non-grazed parcels appears well-recorded by phytolith assemblages.

A second study investigated phytolith assemblages from soil samples collected along a rainfall gradient in West-Africa (Senegal, Mauritania, Lezine (1988)). Climate data for the studied sites were interpolated from the climate database of Leemans and Cramer (1991) using the artificial neuronal network method. Multiple regression analysis show a good relationship (r=0.8) between a combination of two phytolith indices (Iph and F,C), and the amount of growth-limiting drought stress on plants expressed as the Priestley-Taylor coefficient □. This relationship has to be verified on another set of data. Such a new proxy for mean annual rainfall and □in dry tropical areas should help to improve coupled vegetation/Atmospheric General Circulation Models.

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THE USE OF POLLEN DATA BASE FOR PALAEO-CLIMATIC RECONSTRUCTION IN TROPICAL EAST AFRICA

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All published fossil pollen data, and most modern ones collected by the members and Ph'D students of the CNRS palynological laboratory, under R Bonnefille's supervision (Laboratoire de Géologie du Quaternaire, Luminy, Marseille), from 1970 to 1999, are now included in the African Pollen data base. Future users of these pollen data should be aware that pollen counts are in fact "interpreted data", and not exact data such as meteorological measurements. Because taxonomy of pollen grains based on botanical classification of plants is a real issue, reliability of pollen identification depends upon qualified expertise and state of knowledge. This is particularly critical for the highly diversified tropical flora. During these years, taxonomy of pollen was based on analysis of pollen morphology, mainly carried out by palynologists from the botanical community who described pollen morphological characters according to species attribution among botanical families. We have described regional pollen flora from forests and savanna and consulted published atlases from other authors (ref in the APD Webb page). We also use comparison with a reference collection of more than 20 000 species, (less than 20 % of the total tropical flora), including most common plants in East Africa and focusing on trees. During those years, the pollen taxonomy has been a shared knowledge. Name attributed to the pollen taxa has been subjected to discussion and agreed upon, therefore using the species present in East Africa. This is particularly important with regards to statistical analysis because such data can be considered homogenous. However, if the list of taxa provided by the APD represents a today "state of art", the precision of pollen identification can always be improved in the future, as needed for a better attribution of pollen taxa to Plant functional Type (PFT) and Biome.

As an example of using Pollen Data Base, we present collaborative studies carried out from several radiocarbone dated time-sequences extracted from peat bogs, located in the same climatic region of the Burundi highlands (Bonnefille & Riollet, 1988; Bonnefille et al., 1991; Bonnefille et al., 1996). The total arboreal pollen reflect the variations in forest tree cover through time. It indicates that deforestation in this region started a few centuries ago. Precipitation values have been reconstructed by the mean of the best analogue method and a modern calibration data set of East Africa (Bonnefille, Chalié 2000). They show little increase from the present day value at each site. The concerned area lies 4° south of the equator. During the Holocene, mean annual rainfall has not increased for more than 20 % present values. However an interesting pattern emerge from the synthesis of the eight different sequences. At the resolution of the order of the century, the early Holocene exhibits regular rainfall values, whereas late Holocene, post 5 kyr BP, shows variations of strong amplitude, which may indicate stronger variability in rainfall. Another climatic reconstruction achieved by the use of the PFT method emphasizes the geographical pattern of slight rainfall increase(±50 mm) at 6kyr BP in Central Africa, whereas stronger increase is shown further north in Ethiopia; the reconstructed humidity index shows the same pattern (Peyron et al., 2000). As opposed to the Holocene, the reconstructed rainfall during the Last Glacial period was considerably reduced (40%) from the present day ones. This is recorded both in the Burundi highlands and in lake Tanganyika (Bonnefille et al., 1992; Vincens et al., 1993), a result in agreement with our knowledge of lake level data (Farrera et al; 1999). Other interesting results have been obtained from cores in valley swamps, at mid elevation. They illustrate migration routes of plants from north to south. Deciduous *Celtis* appears at 9 kyr BP at Gatovu site (1350 m) whereas, at Kuruyange (2000 m), it increased later, only after 4.5 kyr BP (Jolly et al.,1991; 1994). The extensive *Papyrus* swamps, now well developed west of Lake Victoria, appeared only in the last two centuries (Hillaire -Marcel et al., 1989). Strong modifications in the vegetation occurred during the last few thousand years when swamp forests of different composition alternate with sedge swamps.

As a final example we discussed the application of the different methods of climatic reconstruction to Pliocene pollen data. They evidence a noticeable decrease in temperature and increase in rainfall at the base of the Mammoth subchrone event, between 3.4 to 3.3 Myr ago, in the lower part of the section yielding hominid remains of *Australopithecus afarensis* (Bonnefille, 1999). This application to older geological deposits has been performed on different pollen counts of the same sample. The results showed that the amplitude of the reconstructed climatic parameters strongly depends upon the quality of the initial pollen counts, the best results being obtained by the highest well diversified counts.

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EPD AND SPECIES PROPAGATION

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The analysis of pollen deposited in lake sediments and peatbogs shows that the vegetation of Europe has changed substantially over the past 15,000 years (Berglund et al., 1996). At the end of the last ice-age, the prevailing climatic conditions led to the domination of the European continent by steppe-tundra, with the temperate taxa confined to isolated 'refugia', located principally around the Mediterranean sea (Bennett et al., 1991). Following the end of the glacial period, temperate taxa spread across the continent, displacing the existing flora higher in either latitude or altitude.

Whilst the overall change in flora follows a similar pattern at sites across Europe (i.e. from dry and cold to warm and humid), the behaviour of individual taxa varies widely. We have used a database of pollen sites (the European Pollen Database; http://medias.meteo.fr/paleo/epd/epd_main.html), distributed across Europe to map the changes in distribution of several temperate taxa during the postglacial period (Acer, Alnus, Betula, Carpinus, Corylus, Fagus, Fraxinus, Quercus, Salix, Tilia and Ulmus), and so reconstruct, for each taxa, the location of the glacial refugia, the routes and the rates of propagation. In addition, this information has been used in comparison with phylogeographic studies, in order to further define the postglacial histroy of these species.

The time of first appearance of each taxa was estimated at each site in the data-set. These dates were then interpolated onto a 25km grid covering Europe, to obtain a contour map showing the front of propagation (isochrone maps). Rates of spread were calculated for each grid-cell using the age difference between it and the oldest neighboring cell. Histograms were prepared to show the range and distribution of rates of spread for each 1000 year period during the Holocene for Fagus.

For each taxa, three pieces of information were obtained from the maps. Firstly, the assumed glacial refugia were identified. These are located predominantly around the three southern European peninsulas, but a further refugium was identified in western Russia (e.g. Alnus). In addition, taxa have been identified that appear to have been less restricted during the glacial period, surviving in populations scattered across Europe, with subsequent swift recolonisation of the continent. Second, the principle routes of spread were identified from the maps. These routes are largely dependent on the positioning of the refugia. However, some routes were identified that were important for several taxa, for example a route westward from the northern Balkans, along the northern slopes of the Alps. Lastly, the maps help identify the timing of the propagation. The taxa, in general, spread at different times, showing a 'succession' of spread. Based on this information, the taxa have been classified into three "types". These are: early spreading taxa from few refugia (e.g. Alnus, Quercus); late spreading taxa from few refugia (e.g. Carpinus, Fagus); taxa spreading from small populations widely scattered across Europe (e.g. Betula, Corylus). Within these types, however, there are substantial differences in the location of refugia and the routes of spread.

Comparison with range-wide surveys of chloroplastic DNA (cpDNA) provides enables further detail to be obtained on the routes of spread. Populations of trees isolated in refugia during glacial periods develop distinct genetic haplotypes. These are preserved in the maternally inherited cpDNA during the expansion from these refugia (Petit et al., 1997). These can be used to trace the routes of migration from the modern populations to the glacial refugia at much higher detail. For example, in the a recent survey of the white oak complex (Petit et al., in press), four haplotypes were found in the Iberian peninsula. Of these, the three most westerly types have spread past the Pyrenees, along the Atlantic coast of France and northwards into the United Kingdom and southern Sweden. The fourth type has spread within Spain, but has not passed the arrier of the Pyrenees, where it is replaced by haplotypes from Italy and the Balkans.

Estimations of the rates of spread further underline the individualistic nature of the taxa. In general, however, taxa spreading earlier were able to reach higher speeds of propagation. The later spreading taxa may have been limited by a competition for environmental niches already occupied by the earlier taxa.

Further investigation of the range of speeds reveals information about the nature of the dispersal of the plant. The histograms of rates of spread prepared for Fagus, show that when the average speed increases, the distribution becomes skewed, whilst at lower average rates, the distribution is closer to normal. This suggests that during periods when the environmental conditions are favourable, the spread is accelerated by rare long-distance events. The modal class, which remains constant, thus represents the speed of propagation by diffusion. This use of on long-distance events to drive the propagation at higher speeds has been previously observed in the oak and beech in North America (Webb, 1986), and in the white oak complex in Europe (Bossema, 1979).

It has been shown that the spread of plant taxa is controlled by climatic factors over a millenial timescale, and by edaphic factors such as soils at shorter periods (Whitlock and Bartlein, 1997). This work shows that certain chance or stochastic factors may also influence the propagation. The importance of rare long-distance events for the acceleration of the rates of spread has been discuessed above. In addition, the location of the glacial refugia, the 'origins' of the spread appear to have a strong influence. Quercus, one of the few taxa to spread from the Iberian peninsula (Brewer et al., in press), reached very high rates of propagation in this area, possibly as a result of the absence of competition for resources. Alternatively, it may be hypothesised that the rapid expansion of Quercus prevented the expansion of other taxa. A number of articles have recently argues for the existence of refugia for other temperate taxa, notably Fagus (e.g. Ramil-Rego et al., 2000) in the Iberian peninsula. However, no subsequent expansion has been observed from thse proposed refugia.

The combination of spatial information from the phylogeographic studies and temporal information from palynological studies gives a highly detailed data-set for the reconstruction of postglacial spread. This data-set may prove useful for the development and testing of models of the spread of forest trees, allowing more confident predictions of landscape changes under future climatic change.

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MEASUREMENTS AND MODELLING IN THE FRAME OF THE ECOFIT PROJECT : TROPICAL FOREST DYNAMICS

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The ECOFIT program (Ecosystèmes et Paléoécosystèmes des Forêts Intertropicales) has initiated a modelling approach of structure and dynamics of tropical forests (Chave 1999, Chave *et al.* 2001), based on multidisciplinary palaeoecological research concerning fluctuation of tropical forest limits during the Holocene, essentially in Amazonia and in West Tropical Africa. Its purpose is to help understanding the parameters, related to climate variations or human impact, which determine forest transgressions in these areas. In order to build up this modelling, it appeared that a metrological effort should be developed in order to give reliable forest structure data, at scales compatible with those of the models. These data are scarce in the tropics, notably due to access difficulties and poor experimentation logistics. We will focus more particularly on two fast methods that we have developed for characterising tropical forest structure

Leaf area index (LAI) measurements : a simple apparatus designed for dense forests (Cournac *et al.*)

LAI is an important descriptor of vegetation density, and conditions in a large part the carbon, water and energy balance of forests. This is a widely used parameter in vegetation modelling. We developed an easy to use, lightweight**,** and inexpensive light sensor using a photoresistor, spy-hole optics (acting as a cheap 180° fisheye lens) and a digital multimeter. Its spectral response and sensitivity are well suited for LAI measurements. Light under the canopy is measured by the device, the light flux above the canopy is corrected from ground-based visual criteria. Values obtained with this method are quite comparable to LAI measurements achieved with the commercial instrument LAI2000 (LICOR) along a transect in French Guiana and exhibit good reproducibility with less dependence upon local weather conditions. The easy availability of such a method will allow to expand LAI monitoring in tropical areas. It can be used for ecological monitoring, disturbance quantification, seasonal variability etc. LAI mapping could be envisaged on significant areas in relation with remote (satellital) sensing programs.

Estimation of stem diameters repartition (DBH) from ground-based picture analysis (Dubois *et al.*, 2000)

Stem diameters inventories are widely used to describe tree settlements, but practically, tree measurement and counting on a large scale are often difficult to achieve in tropical forests. We investigated how an analysis of standardized photographs taken within the forest could be used to approximate DBH distributions. For that we chose a neural network learning approach, the principle of which can be summarised as follows :

1. Build a standardised picture database (focal length, aperture, etc.) in recently inventoried areas
2. Use this database as the training set of an artificial neuronal network:
   - A dedicated analysis of the pictures is designed to build the input vector (information given)
   - DBH repartitions are approximated by a function; the parameters of this function constitute the output vector (guess)
3. Use the neuronal network, once calibrated, to estimate DBH repartitions in new areas.

Encouraging results were obtained in French Guiana, and this method needs now to be validated on a larger scale, by expanding the learning database. It can be used complementarily to LAI measurements for ecological monitoring, mapping, and remote sensing programs validation.

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PALYNOLOGICAL RESEARCHES OF THE TOGO MANGROVES

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My work is made on 33 sites samples taken in the South- East of Togo located in coastal zone. The vegetation of this zone is caracterized by mangroves and seasonaly inondated savanna.

Palynological researches shows

- a high floristic diversity
- a good presence of botanical taxa in palynological diagramm
- sometimes, almost the same frequence of taxa in botanical and palynological researches
- a light fluvial deposit in mangroves
- pollen of *Rhizophora racemosa* in high pourcentages
- pollen of *Avicennia germinans* in light pourcentages
- pollen of *Acrostichum aureum* in high pourcentages where mangrove is degraded
- pollen of Cyperaceae, *Drepanocarpus lunatus, Mimosa pigra* and *Paulinia pinnata* in mangroves and in seasonaly inondated savanna
- pollen of *Mitragyna inermis* in seasonaly inondated savanna

The comparaison of this work with palynological research on peat of the same zone shows higher pourcentages of *Rhizophora racemosa* in the past.

RECENT RESEARCH IN THE FRAME OF THE APD

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Currently the APD contains 177 pollen records and more than 1200 modern pollen spectra. This data set represents information from over 80% of already published african data. The compilation consists of the entry of pollen count, the elaboration of a standardised list of taxa and associated informations such as site description, 14C ages, chronology and relevant publications.

The principal publications accomplished under the APD project includes general publications (Jolly et al., 1998 ; Peyron, O., 1999 ; Farrera I., et al., 1999 ; Elenga H., et al., 2000 ; Peyron et al., 2000 and Ssemmanda, I., 2001) and general presentations (Jolly et al., 1999 a and b and Elenga, H. and Mangiocalda, R., 2000).

The most important results can be summarised as follow :

- Biome reconstruction from pollen for Africa at 0 shows good agreement with the modern principal vegetaion zones.
- At 6ka, biome distribution shows the shift of the steppe bundary on the actual desert area indicate more humid conditions than the present. These interpretations are consistent with previuos based on a more qualitative interpretation of the data at a continental sacle.
- At 18ka, biome reconstruction shows coherent spatial pattern and indicate large changes between the Glacial and Holocene vegetation. It support previuos interpretation which inferred a major reduction of tropical rain forest in western Africa into the seasonal forest, a general lowering of vegetation zones throught the mountain regions of southern and eastern Africa and the shift toward south of the steppe boundary.

In conclusion, the future efforts of the APD will focus on increasing the African coverage of its database holdings, and make the APD a more visible component in the scientific community.

The APD will in the future enable a better interpretation of the pollen data in terms of palaeoclimate and vegetation history.

THE CENOZOIC POLLEN DATABASE AND CLIMATIC RECONSTRUCTION OF THE NORTH- AND SOUTH-WESTERN MEDITERRANEAN PLIOCENE

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In the framework of the EEDEN programme (Environments and Ecosystem Dynamics of the Eurasian Neogene; an ESF scientific programme) the Cenozoic Pollen database and Climatic values (C.P.C.) is at the present time created.

This database is created in order to gather and make available pollen data of high and constant quality (high quality in pollen identifications according to botanical nomenclature and high quality in counting) covering the whole Cenozoic of Europe, North Africa and Middle East. The database will make easier the development of transfer functions (paleoclimate, paleoreliefs) and paleovegetation maps from pollen data.

The database will include pollen counting, climatic estimates (when calculated), detail information on sediments, the biostratigraphy (foraminifers, nannoplankton), the magnetostratigraphy, and the approximate ages for each sequence.

All the data will be stored and accessible on the Medias-France web-site but the access to the database will be restricted (following the rules defined by the executive committee and agreed by the advisory board) to scientists providing their pollen data (under the above mentioned conditions about quality) to the database and to the EEDEN contributors.

Publications, based on the use of the database for any type of topics (syntheses, transfer functions (paleoclimate, paleoreliefs, paleovegetation maps, biodiversity, etc.) will associate the authors of the pollen data as co-authors (or "C.P.C. members" in the case of a large number of pollen records).

Some of the pollen data that will be available in the database have already been used to reconstruct the Pliocene climate of the West Mediterranean region.

The method used to quantify the Pliocene climate from pollen data is the "Climatic Amplitude Method" (Fauquette et al., 1998) based on the study of modern climatic requirements of plants to interpret fossil data. This method has been especially elaborated for period which do not know any modern analogues of the vegetation. Indeed, the Neogene vegetation is composed of taxa still present in Europe and in the Mediterranean region but also of subtropical, and even tropical, taxa that no longer live in these regions. These combinations of plants cannot be found occurring together in the modern landscape, thus precluding the use of previous methods such as the best analogue method for climatic reconstruction (Guiot, 1990).

This method had allowed to obtain, in particular, estimates for the Early Pliocene climate (Fauquette et al., 1999). At that time the climate was warmer and more humid than today in the North-western Mediterranean area (mean annual temperature from 2 to 3.5°C higher than today and an available moisture from 20 to 35% higher than today) and warmer and drier than today, or almost equivalent, in the South-western Mediterranean area (mean annual temperature from 3 to 5°C higher than today and an available moisture from 8 to 35% lower than today).

The causes of this warmer climate than today in the Mediterranean region are still unknown. May be climate models could answer to this question.

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MODELLING INTERTROPICAL VEGETATION CHANGES

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Three intertropical ecosystem models, each corresponding to one level of descritpion, have been developed for ECOFIT Program (Ecosystems and Paleoecosystems of Intertroical Forests).

A first model, LANDSCAPE, describes the evolution of functional groups (pioneers and shade tolerant) structured into two vertical layers on a landscape scale. It provides a fast tool for testing long term modifications of the rain forest cover under climatic changes.

A second model, TROLL, is a mechanistic individual-based spatially-explicit succession model, taking into account competition for light, trefall gap formation and recruitment.

The third model, being developed, FORSAT, is a cellular automaton based model of tropical forest-savanna transgression in anthropic environment. Four states of vegetation are considered (herbs, pioneer settlings, young forest, forest) and the transitions are modelled by stochastic rules. So far, the only human action considered is fire in savanna, which is modeld by a stochastic algorithm.

Moreover, climate and soil heterogeneity parameters are taken into account. The current results consist of a phenomenological exploration of the model. FORSAT has been shown to reproduce qualitatively well the different modes of transgression identified in nature. We now plan to validate the model by using field data, aerial photographs and satellite images, to be able to carry out specific studies (e.g. testing scenarios in a specific zone, effects of Chromolaena Odorata).

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THE CARAIB VEGETATION MODEL

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The CARAIB (CARbon Assimilation In the Biosphere) model is a global terrestrial biosphere model which has been developed to study the biosphere contribution to the global carbon cycle (Warnant et al., 1994; Nemry et al., 1996; Gérard et al., 1999). The primary purpose of the model is hence the calculation of the CO_2 exchange flux between the vegetation-soil system and the atmosphere. The model is composed of 5 main modules describing (1) soil hydrology, (2) stomatal regulation and photosynthesis, (3) carbon allocation, growth and autotrophic respiration, (4) litter/soil carbon storage and heterotrophic respiration, and (5) competition of plant functional types (PFTs) and biomisation (biogeography). The model calculates the evolution of 2 hydrologic reservoirs, snow and soil water, and 5 carbon pools, metabolic (leaves and fine roots) and structural (wood) biomass, metabolic and structural litter, and soil carbon. The time step for updating these reservoirs is 1 day, while photosynthesis is calculated every 2 hours and, hence, captures the diurnal cycle. The spatial resolution usually used in global model runs is $0.5° \times 0.5°$.

The latest module implemented into CARAIB is the biogeography module. To simulate the competition of trees and grasses, two vegetation storeys have been introduced in the canopy submodel. This allows us to determine the light available to grasses as a direct function of the leaf area index (LAI) of the forest canopy. Both of these storeys are potentially composed of several PFTs. The cover fraction of each PFT within each storey is estimated according to its respective net primary productivity (NPP). A biome is assigned to each grid cell on the basis of three physiological criteria: (1) the cover fraction of most abundant PFTs, (2) the grid cell and tree NPP, and (3) the grid cell and tree LAI, and two climatic constraints: (1) yearly total of growing degree-days with a threshold at 5°C (GDD5), and (2) the absolute minimum temperature reached during the cold season (T_{min}), which are well-known indices of vegetation expansion boundaries.

The model has been applied to reconstruct the vegetation distribution and the biospheric carbon stock at the last glacial maximum (LGM, 21 ky BP). In this reconstruction, CARAIB has been forced with eight LGM climatic scenarios from the Paleo Modelling Intercomparison Project (PMIP; Braconnot, 2000) corresponding to four general circulation models (MRI2, UGAMP, LMD4, and GEN2) using prescribed (CLIMAP, 1981) and computed sea surface temperatures (SSTs). The land area was expanded over the continental shelf consistently with a sealevel lowering of 105 meters and the atmospheric CO_2 level was decreased to 200 ppmv. In the control simulation, the model was forced with a modern climate and a preindustrial atmospheric CO_2 level of 280 ppmv. As a test of the model, the reconstructed biome distribution is compared, for the modern climate, with two distributions of potential vegetation (Matthews, 1983; Mellilo et al., 1993). The model simulation reproduces the broad-scale patterns of the modern vegetation distribution. Globally, the pixel by pixel agreement of the model with both potential vegetation maps reaches ~ 40 %, which is comparable to the level of agreement among the two potential vegetation distributions. For the LGM, the model-predicted vegetation was compared with a set of 214 pollen data (Crowley, 1995). The pixel by pixel agreement of the LGM simulations with this set of data reaches 19-31 %, depending on the climatic reconstruction used. It is highest for the GEN2 and MRI2 computed SST simulations. In general, computed SST simulations provide higher levels of agreement than prescribed SST ones.

With regard to the carbon cycle, the results indicate an increase in NPP from the LGM to the present by 16.0–21.8 Gt C yr^{-1}, and an increase in the total biospheric carbon stock by 828–1106 Gt C, depending on the climatic forcing used. Sensitivity analyses were performed to discriminate the relative effects of the atmospheric CO_2 level (CO_2 *fertilisation* effect), the climate (present or

LGM), and the sea level. Our results suggest that the CO_2 fertilisation effect is mostly responsible for the total increase in NPP, vegetation and soil carbon stocks. The four GCMs diverged in their predicted responses of continental climate to calculated SSTs. Only one of them, MRI2, predicted a marked decline of the continental temperatures in the computed- versus prescribed- (CLIMAP) SST simulation. This trend is consistent with recent paleodata suggesting that the SSTs are too warm in the CLIMAP reconstruction (Guilderson et al., 1994). For this GCM, the prescribed SST simulation predicts an increase of the biospheric carbon stock by 1037 Gt C from LGM to pre-industrial times, while this increase is only 828 Gt C in the computed SST simulation. Colder SSTs may thus result in substantially higher estimates of the LGM biospheric carbon stock.

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PALEOCLIMATIC RECONSTRUCTIONS AND VEGETATION MODELS

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Classical climate reconstruction based on statistical method implicitly assumes that all the environment conditions (at the exception of the climate that we want to reconstruct) have not changed in comparison with the modern ones. We know that it is not true, the most evident “a contrario” example is the atmospheric CO_2 concentration, which has greatly fluctuated during the Quaternary. The statistical methods use calibration on modern data and thus we are obliged to use “high CO_2” vegetation samplings to understand “low CO_2” records. In order to test this assumption, we have used a process-based vegetation model (BIOME4) in inverse mode to reconstruct from pollen data the most probable climate under lowered CO_2 concentration in the biosphere. Appropriate tools to match the model outputs with the pollen data are developed to generate a probability distribution associated with the reconstruction (Monte Carlo sampling and neural network techniques).

The method is illustrated with Last Glacial Maximum pollen spectra in Europe and former Soviet Union and with pollen diagrams coming from the Jura mountains. Two experiments are devised: one with 340 ppmv of CO_2 and one with 200 ppmv. The comparaison of the two experiments together and with the statistical reconstruction results show that the low CO_2 does not bias really the temperature reconstruction in temperate regions but it can bias the reconstruction of the water stress on the vegetation. Similar results have been obtained in Africa. This kind of approach must still be validated as it is dependent on the vegetation model used. Nevertheless it is promising especially in a multiproxy approach of paleoclimates.

MULTIPROXY DATABASES AND MODELLING

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During the second day of the meeting, extensive presentations of vegetation models have been done in relation with paleodata. Two types of models have been distinguished: area-based models and individual-based models. The first category mainly comprehends global models which was, at the origin equilibrium models (BIOME, BIOME4, CARAIB …) but are now more and more dynamic (LPJ, ORCHIDEE, IBIS). These models can be used to be validated but also to help to understand impacts of climate on past vegetation with continental syntheses of paleodata (pollen, plant macrofossils, charcoals, phytoliths …). The second category of models are much more local at the size of a landscape or a catchment basin. They are used, for example, to better understand variation of tree-line (MBL-GEM) or forest-savanna limit (ECOFIT). Global models can also be adapted at the local scale: so BIOME3 has proved to be efficient to predict forest biomass in relation with tree-ring series.

Paleodata gathered in multiproxy databases enable us to reconstruct the variations of our environment in relation with climatic changes. Dynamic models taking into account vegetation, hydrology and soil erosion are needed to better understand the processes represented by these time-series. Some sites in southern Europe and Africa are totally adequate to reconstruct and understand these variations. The workshop was concluded with the proposition of an integrated approach where relational databases and catchment basin modelling are intended to provide some answers to the question of future impact of global changes on some sensitive ecosystems.

SEARCH : TRAINING AND CAPACITY BUILDING FOR DATA INFORMATION IN SUPPORT OF EURO-AFRICAN COLLABORATION ON RESEARCH IN GLOBAL CHANGE

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This concerted action, financially supported by the Enrich (European Network for Research in global change) programme, has developed a network working on environments and climates in Africa with the willingness to gather data in database, and has developed the African database centre at the Pan African Start Secretariat (PASS).

Two meetings have been organised in the framework of Search:
- A training session in Toulouse from 15 to 19 October 1999 on the building of database
- A workshop at Marseille from 2 to 4 May 2001 on the use of database for modelling the environments

The last one will be held in Nairobi for a « show-case » workshop, organised jointly with the APD project.

Three trainees have been supported :
- The first from January to July of 2000 at the Cerege in order to allow the writting of a thesis
- The second from January to April 2001at Medias-France for the training of the Unix Administrator of the Pass Database Centre
- The third and the fourth from July to December and from August to September 2001 at the University of Paris (UPMC).

And the equipment needed for the Pass Centre has been installed and are currently in service.

BIOME MODEL AND THEIR USE IN PALAEOCLIMATOLOGY

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Biome models

Biomes are structurally and functionally distinct complexes of ecosystems that are characteristic of particular climates. The association between ecosystem structure and climate arises because of biophysical and physiological constraints on the success of different land-plant survival strategies in different climates (Woodward, 1987). Models based explicitly on the physiological characteristics of different plant types were introduced by Box (1981). The BIOME 1 model of Prentice *et al.* (1992) was designed to be as mechanistic as possible within the limitations imposed by its simple structure. BIOME 1 computes three main bioclimate variables: mean coldest month temperature (T_c), growing degree days on a 5°C base (GDD), and a moisture availability index (α). Given climate data and the algorithms for the bioclimatic variables, BIOME 1 determines first which plant functional types can occur and secondly, among these, which can dominate. Only the type(s) with the lowest dominance number (D) can dominate. "Second generation" biome models are being developed that incorporate not only the basic constraints on plant type distribution, but also quantitative aspects of the ecosystem (e.g. leaf area index, net primary production), and competition among the various plant types that can co-exist in the same ecosystem (e.g. BIOME 3: Haxeltine and Prentice 1996). The new models also predict a response of biome distributions to changing atmospheric CO_2 concentration, due to the physiological (non-climatic) effects of CO_2 on plants. Several dynamic global vegetation models (e.g. IBIS: Foley *et al.* 1996) simulate fast physical and physiological processes (such as variations in stomatal conductance, evapotranspiration and photosynthesis) in the same way as the mechanistic "land surface models" that are being coupled to AGCMs to improve the representation of energy and water exchanges between land and atmosphere in AGCMs. The objective is to couple such vegetation models directly and interactively with AGCMs and thereby to simulate the entire spectrum of possible biogeophysical feedbacks from changes in vegetation structure and function to climate.

Asynchronous coupling to AGCMs output

Biome models are very useful in palaeo applications, as "forward models" to translate snapshot climate scenarios, based on climate model simulations, into simulations of the vegetation patterns that would be in equilibrium with the simulated palaeoclimate (Kutzbach *et al.* 1998). Several recent applications have used BIOME 1 (e.g. Prentice *et al.* 1993, Claussen and Esch 1994, Jolly *et al.* 1998). In this context the non-dynamic nature of biome models is no handicap, because snapshot palaeoclimate simulations are usually designed to represent equilibrium conditions applying around periods of relative stability in climate. The differences in ecosystem distribution, for example between 6000 yr B.P. and present, are large enough to be approximated as differences between biospheric equilibria corresponding to the past and present climates.

Feedbacks analyses

An extension of the use of biome models as forward models is their application in coupled atmosphere-biosphere modelling experiments. Biome distributions affect the physical conditions of the land surface, and can thus have substantial feedback effects on climate. Claussen (1994) has modelled atmosphere-biome interactions by asynchronously coupling BIOME to the ECHAM climate model. (Asynchronous coupling means that the biome distribution does not change at every timestep of the atmospheric model. Instead, the atmospheric model is run for a number of years to produce an average climate, which drives the biome model; the new biome distribution is used to provide a new set of boundary conditions to the atmospheric model, which is then again run for a number of years; and so on until an equilibrium is approached). Claussen used the direct approach in which the atmospheric and biome models were made to run on the same grid. De Noblet *et al.* (1996) have modelled atmosphere-biome interactions by asynchronous coupling of BIOME to the LMD-LMCE climate model, using the anomaly approach to generate biome distributions on a 0.5° grid and scaling-up algorithms to aggregate the resulting land-surface characteristics to the coarser scale of the climate model. It seems likely that coupled atmosphere-biome modelling along these lines will soon be a commonly used approach in palaeoclimatology, as the results with palaeoclimate conditions are expected to show substantial differences from the results of conventional "one-way" coupling (in which biome distributions are assumed to passively follow changes in climate). In any case, biome modelling and pollen data provide tools to help determine whether such refinements produce improvements in the simulation of past climates (Texier *et al.*, 1996)..

Sensitivity analyses

The low atmospheric CO_2 concentration may have contributed, independently of its effects on climate, to the observed treeline lowerings in the mountains (Street-Perrott 1994; Jolly and Haxeltine 1997) and forest reductions in the lowlands (Jolly et al. 1998). This type of effect presents a problem for the application of statistical inverse models. For example, the glacial-age temperature depression on East African mountains may have been overestimated (Jolly and Haxeltine 1997). However, the problem could be circumvented by applying a second-generation biome model in inverse mode with the appropriate value of atmospheric CO_2 concentration. Mid-Holocene climate in the tropics was always very difficult to reconstruct. With transfer functions, it is possible to estimate climatic parameters such as mean annual temperature and the total annual amount of precipitation. Pollen data collected in Africa at high and low altitude have shown that after 6 ka, pollen of deciduous trees (such as *Celtis*) increase their relative percentage, suggesting (i) the beginning of a drier climate or (ii) the increase of the length of the dry season. Until now, we were not able to reconstruct potential changes in the seasonality of precipitation, using taxon-climate or plant functional type-climate transfer functions. So, we have decided to use another method. We have run a physiological-based terrestrial vegetation model (BIOME 3) in an inverse mode. Different climatic *scenarii* (soil nature, temperature and cloudiness constant) are tested at the location of three sites chosen according an quasi-equatorial transect. We prescribe several patterns of monthly distribution for the same annual amount. These simulations were then evaluated by a direct comparison with appropriate pollen data. The first result show a good agreement between the simulated biome with an actual distribution of precipitation and the observed potential vegetation (biome reconstructed with pollen data). The length of the dry season induces some simulated biome changes. With the palaeodata, it exists a qualitative agreement, this climate effect induces an increase of the deciduous forest type when the last of the dry season increase. So, it seems necessary to take into account the seasonal distribution of the precipitation when we reconstruct past climate from pollen (Cassignat *et al.*, in press). Results obtained using a more sophisticated vegetation model (CARAIB), with a more realistic carbon flux estimate, were similar to the previous ones, showing the necessity to take account of the seasonal distribution of the precipitation in monsoonal areas (Gritti *et al.*, submitted to *Quaternary Research*).

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THE IDAF (IGAC DEBITS AFRICA) PROGRAM: ATMOSPHERIC DEPOSITION IN TROPICAL AFRICA

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In 1998, in the framework of the IGAC operational plan **DEBITS** (**D**eposition of **B**iogeochemically **I**mportant **T**race **S**pecies) has been refocused to encourage existing and new activities in the final step of the biogeochemical cycles: the atmospheric deposition of the chemical species to the Earth's surface. The chemical content of depositions, signature of numerous physical and chemical mechanisms, allows tracing temporal and spatial evolution of atmospheric chemistry and is a pertinent indicator to evaluate the natural and anthropogenic influences.

The DEBITS scientific activities are mainly based on measurements of controlled quality of precipitation chemistry to quantify wet deposition and aerosol (bulk sampling) and gases (passive sampling) concentrations to estimate dry deposition. DEBITS has been expanded in 1994 to Africa, with the launch of the IDAF (IGAC DEBITS AFRICA) program. Ten sites representative of the great african ecosystems (dry and wet savanna, equatorial forest) are active in 2000. We presented in this talk depositional fluxes from six stations located in a transect of ecosystems, from the sahelian savanna to the congolese equatorial forest. Seasonal sources (marine, terrigenous, biogenic and biomass burning) and heterogeneous or multiphase chemical processes are taken into account to explain the characteristics and the relative contribution of dry versus wet deposition.

ATMOSPHERIC MODELS AND RAINFALL PREDICTION IN THE SAHELIAN REGION

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It is well known that seasonal rainfall variability in the tropics is partly forced by the continental and oceanic surface anomalies. This link is used in seasonal forecast schemes. The notion that anomalous sea surface temperature (SST) is exerting a significant impact on the atmospheric circulation has been supported by numerous experiments with atmospheric general circulation models (AGCMs) forced by prescribed SST, as in the AMIP experiment, and also by empirical studies (for example Rowell et al. 1995; Ward 1998; Moron et al. 1998). The impact of the continental surface anomalies on the atmospheric circulation is more debated since the preliminary study of Charney (1975). The Sahelian rainfall variability is dominated by long-term decrease since the 50's with two extremely dry periods centered around 1972-73, and then around 1982-84. Even if the rainfall increases weakly during the 90's, it doesn't recover from the 50-60's levels. The long-term decrease of rainfall is related to an interhemispheric SST dipole. At interannual time scales, the relationships between the SST and the Sahelian rainfall are unstable with an increased influence of the ENSO phenomenon since the 70's. Before this date, the SST dipole in the Tropical Atlantic was the main SST forcing. SST doesn't provide the sole forcing of the monsoon anomalies and several empirical studies (Fontaine et al. 1999: Fontaine and Phillipon 2000) demonstrated that pre-season surface conditions on the Guinean area are very important for the Sahelian monsoon rainfall, particularly for the dry period (since 1968).

The exact role of the various forcing could be studied with AGCMs forced by prescribed surface anomalies. Several studies analysed the SST forcing on the rainfall variability. Results show those SST forces only 15-30% of the modelled regional rainfall anomalies at interannual time scale. This proportion seems to be model-dependent (Sud and Lau 1996)

The exact role of the various forcing could be studied with AGCMs forced by prescribed surface anomalies. Several studies analysed the SST forcing on the rainfall variability. Results show those SST forces only 15-30% of the modelled regional rainfall anomalies at interannual time scale. This proportion seems to be model-dependent (Sud and Lau 1996) and increased when the long-term decrease of rainfall is considered (Rowell et al. 1995). The systematic errors of each model could be carefully studied when an ensemble of AGCMs forced by the same prescribed SST is analysed. In that case, the years, which are reproducible amongst the ensemble, could be considered as the result of a robust SST forcing. On the contrary, some years are not reproducible and appear not to be forced by the SST. The skill, relative to the observed anomalies is also useful to estimate the relative weight of the SST forcing when it exists. It is possible that some reproducible years are not skilful at all if SST forcing is dominated by another one (from the continental surfaces for example) or if the AGCM doesn't properly transform the SST forcing onto the rainfall anomalies.

The way seems open now for an evaluation of the predictability itself. It will be extremely interesting to know in advance if a prediction from SST or from continental surfaces have some chance to be good or not.

VEGETATION CHANGES AND THEIR CLIMATIC IMPLICATIONS FOR THE LAKE VICTORIA REGION DURING THE LATE HOLOCENE

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The pollen sequence of the core V95-2P (00° 58.67' S, 033° 27.32' E, 67 m depth) from Lake Victoria mirrors larger extension of forests between ca. 6500 and ca. 4100 yr. B.P., implying a wetter climatic conditions than during the later period. Highest humidity was experienced in the region prior to ca. 6500 yr. B.P., before the semidecidious forest formations became widespread in the region.

From ca. 5000 yr. B.P., the forests around Lake Victoria were mainly of semidecideous character with increasing abundance of *celtis* associated with *Holoptelea grandis*, mixed with some Guineo-Congolian elements such as *Tetrorchidium.*

The period ca. 4100 to ca. 3000 yr. B.P. shows a progressive decline of the semideciduous forest formations and the establishment of open vegetation with Capparidaceae and Gramineae attesting to a dry climate.

After ca. 3000 yr. B.P., the pollen data particulary that from high altitude, evidence an amelioration of climate. The dry montane forest with *Podocarpus* and *Juniperus procera* underwent significant extension which reached a maximum at ca. 1700 yr. B.P. At low altitude, the extension of the semideciduous forests in relation to this improvement of climate, is evidenced mainly until ca. 2200 yr. B.P. During this sub-humid climatic phase, either the amount of precipitation was inadequate or the dry season was too long for a large development of evergreen forests in the Lake Victoria region. Pollen data from this core and from the other cores in the region indicates that the increase in rainfall during this period was larger and lasted for a longer duration in the high altitude sites than at low altitude.

From ca. 1700 yr. B.P., the significant decrease in the abundance of the pollen of the regional taxa indicates a decline of the *Juniperus-Podocarpus* dry montane forest or a reduction in precipitation at high altitude. During this dry period, both the montane and the semideciduous forests decline at the profit of the open grass dominated formations: open woodlands and probably savannas.

ETEMA – THE EUROPEAN TERRESTRIAL ECOSYSTEM MODELLING ACTIVITY

Funded by EU Environment and Climate Change Programme (FP4).

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The objective was to develop a comprehensive, process-orientated, modular modelling framework for the coupled dynamics of structure and function in natural and semi-natural ecosystems. The framework should allow simulation of ecosystems at patch (0.1km) to regional (10-100km) scales based on species or broad functional categories.

Subsystem studies formed a major part of the project and had the objective of comparing a range of feasible model representations of some of the ecosystems processes. Studies included a Planetary-Boundary Layer (PBL) model integrating fluxes from heterogeneous landscapes; the modelling canopy CO_2 fluxes assessing the big-leaf approach; a comparison of two approaches to modelling vegetation dynamics; designing and testing a generic cohort model of soil organic matter (SOM) decomposition; coupling of a fire module into a dynamic global vegetation model.

In the framework ETEMA minimises complexity by adopting two spatial scales and links between them: macro cells 10-50km adjoining on a grid differing by macroclimate, soils, landscape features and micro cells with one or many inside a macro cell – modelling within each micro cell vertical fluxes of water and carbon. Temporal scales include fast time steps (e.g. 1-3 hours) for canopy-atmosphere exchange, PBL dynamics and soil moisture dynamics, intermediate (e.g. 1 day to 3 months) including phenological processes, whole plant aspects of plant physiology, litter decomposition and SOM dynamics; slow (1 year +) including vegetation dynamics, establishment, mortality, migration.

In the framework modules can be linked by state variables associated with a particular module and can be updated each time a module is used, these can then be passed to other modules.

Testing of the ETEMA modelling framework was done as a spatial comprehensive inter-annual simulation of the carbon balance of European ecosystems for the 20th century. Two experiments were done. One using the "ETEMA model" was run in potential vegetation mode estimating the carbon fluxes and pools for Europe on the basis that all land was covered by potential vegetation. The second used the CORINE land cover map to obtain a simple plant cover classification that was matched to broad PFT definitions in the model. Results show in broad terms carbon and water fluxes and fire disturbance in European ecosystems can be simulated as a function of climate, CO_2 and land cover type using the "ETEMA model". Fluxes are more reliable than pools of live or dead biomass since they depend on year-to-year changes and less on site history which was poorly reflected in the simulations. Key uncertainties in estimating carbon balance of Europe relate to land management.

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THE LPJ MODEL: SIMULATING ECOSYSTEMS AND THEIR PROCESSES FROM THE PATCH SCALE TO THE GLOBE

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Dynamic ecosystem modelling is concerned with simulating the interactions between vegetation and climate. Models such as the LPJ (Lund-Potsdam-Jena) dynamic vegetation model simulate vegetation distributions, dynamics, disturbances and the biogeochemical processes occurring in ecosystems. LPJ is an approach to modelling based on modularity where different combinations of modules can be used together to address different questions. LPJ-DGVM is an area-based average individual (population) based model of vegetation and ecosystem processes for regional to global scale questions. LPJ-GUESS a general ecosystem model has individual based vegetation dynamics similar to a gap model (e.g FORSKA) with the average individual within each Plant Functional Type (PFT) or species describing an age-cohort or a population. LPJ-GUESS is valid for local patch to landscapes to regions and has similar outputs to LPJ-DGVM but includes stand descriptions based on age classes.

LPJ uses both woody and herbaceous plant functional types and in the case of LPJ-GUESS also species. Typical outputs include NPP, NEP, PFT LAI, PFT FPC, leaf biomass, sapwood biomass, root biomass, heartwood biomass, average height, soil carbon, litter, slow and fast pools, fractional grid cell burnt, fire return times. It also predicts daily photosynthesis, maintenance and heterotrophic respiration, runoff, snow cover, AET and soil moisture status.

Model results with various experimental and field data such as FACE experiments have been made. Simulations of NPP as a response to raised CO2 compares well to the short period experimental data. Comparisons of AET and NEE were also done with data from EUROFLUX sites and with soil moisture data through the year. LPJ also compares favourably with observation data from sites in the northern hemisphere with regard to the seasonal cycle of atmospheric CO_2. LPJ has been used in regional simulations of biome and ecosystem changes into the future e,g. in the USA (VEMAP 2) and China. Modelling of CO_2 and methane exchange in northern wetlands has been compared to field data from a number of sites and also simulated at the northern hemisphere scale.

LPJ-GUESS grows individual trees competing for light, water and nutrients. It has been used generally throughout Europe including both northern forests and savannah type vegetation in southern Europe without re-parameterisation. It is also being developed at the species level for a range of North American species and for Europe for use with regional climate model outputs.

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LATE QUATERNARY VARIATIONS OF SEA ICE AND SEA-SURFACE CONDITIONS IN THE ARCTIC AND CIRCUM-ARCTIC BASED ON DINOCYST ASSEMBLAGES: PRELIMINARY RESULTS AND METHODOLOGICAL ISSUES

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In order to document changes in sea-surface conditions, notably in the extent of sea ice cover over the Arctic and sub-Arctic, extensive studies of organic-walled dinoflagellate cysts (dinocysts) in surface sediments and late Quaternary cores were undertaken at GEOTOP, in collaboration with several other institutions. Dinocysts constitute sensitive tracers of past sea-surface conditions in such environments because their distribution patterns are closely related to seasonal changes in the sea ice cover, in addition to temperature and salinity conditions. Moreover, dinocysts are well preserved in these sediments, and they yield relatively abundant and diversified assemblages, unlike many other microfossils. The development of a dinocyst data base permits the use of transfer functions for the reconstruction of sea-surface conditions throughout the northern North Atlantic during the last glacial maximum (cf. de Vernal et al., 2000). This database also allows us to establish a late Quaternary time series of paleoceanographic changes in subpolar environments.

The establishment of an international working group specifically focused on dinocysts from the Arctic and circum-arctic seas has given access to surface sediment samples that are used to develop an accurate reference database. The working group also contributed to the establishment of standardized systematics, which is a prerequisite for the establishment of reference databases to be used in transfer functions. The "modern" dinocyst database representative of middle to polar latitudes of the northern Hemisphere has been recently updated. It includes 677 sites, and the validation exercise yields reasonably accurate results for the "polar" domain, allowing application of transfer functions in the Arctic for reconstruction of past conditions (cf. de Vernal et al., submitted). In order to improve the accuracy of the reconstruction some methodological issues are currently being addressed.

(1) The actual hydrographical and sea ice data used for the calibration (NODC 1994 for temperature and salinity, and NCDC 1953-1990 for sea ice) include many extrapolations and are not very accurate throughout the polar domain. They need to be better constrained. A comprehensive compilation of newly available data is underway that includes the joint U.S. Russian Atlas of the Arctic Ocean, and the National Snow and Ice Data Center, in addition to the NODC and NCDC data.

(2) Among the taxa which seem to be diagnostic of harsh Arctic conditions and which are most important in both qualitative and quantitative reconstructions of sea ice and temperature, are morphotypes of ubiquitous species (notably *Operculodinium centrocarpum* and *Algidasphaeridium*? *minutum*). These morphotypes are probably phenotypes adapted to Arctic environments. Therefore, they require more attention, through systematic morphometry and image analyses, in order to improve the accuracy of the dinocyst sensitivity for hydrographical reconstructions in polar environments.

(3) One of the weaknesses of the statistical approach presently used for the reconstructions (i.e., the analogue method) is the heterogeneity in the spatial distribution of the reference database. Alternative approaches are currently being explored to get around this limitation and to improve the accuracy of the reconstructions (cf Peyron and de Vernal, submitted).

Despite some uncertainties, reconstructions can be made on the basis of dinocyst assemblages from the Arctic seas. In particular, a few Holocene series spanning approximately the last 8000 years are available from tdifferent Arctic regions: the northernmost Baffin Bay, the Barents Sea, and the Chukchi Sea. Rich dinocyst assemblages occur at these three locations, indicating a high productivity, at least during the middle and late Holocene. The transfer functions indicate variations in sea-surface temperature and the extent of sea ice cover, but they do not show identical trends at all sites. In the western Arctic there are indications of reduced sea ice cover and much warmer conditions than at present, notably around 3, 5, and 6-7 ka, and for a late Holocene cooling (cf. Darby et al., unpublished data). In northernmost Baffin Bay, there is also evidence for a mid-Holocene minimum in sea ice cover and for a late Holocene cooling trend (cf. Levac et al., 2001). However, in the Barents Sea, the results show that sea-surface conditions during the mid-Holocene where not much different than those recorded at present with only minor cooling pulses during the latest Holocene (cf. Voronina et al., in press). These results are preliminary, but they demonstrate the variability in time and space of the sea ice cover during the Late Quaternary.

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THE ORCHIDEE MODEL

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1. Introduction

ORCHIDEE (ORganizing Carbon and Hydrology In Dynamical Ecosystems Environment) is a new global land surface model developed at IPSL in Paris.

The main objective of the model is to study carbon cycle in terrestrial biosphere and more generally all the interactions between the land surfaces and the climate. The main philosophy that have driven the development of ORCHIDEE is

1. A coherence between all the processes especially the physical and biogeochemical processes to be included in the complete "earth model" of the IPSL
2. A model that can address issues from regional to global scale which imply a relatively high level of complexity
3. A high modularity to easily change modules of the model.

2.1 Basics of ORCHIDEE

ORCHIDEE is heavily based on two different existing models and one newly developed model:

The land surface scheme SECHIBA, has been developed as a set of surface parameterizations for the LMD atmospheric circulation model (Ducoudré *et al.*, 1993) : SECHIBA describes the short time scale processes (of the order of a few minutes to hours) of energy and water exchanges between the atmosphere and the biosphere as well as the soil moisture budget.

The parameterizations of vegetation dynamics : fire, sapling establishment, tree mortality, etc., which take place at a yearly time step have been taken from the LPJ DGVM (Sitch *et al.*, 2000)

The biogeochemical processes such as photosynthesis, carbon allocation, litter decomposition, soil carbon dynamics, maintenance respiration, growth respiration and phenology form together the STOMATE submodel. All these processes except photosynthesis are computed on a daily basis.

ORCHIDEE can be coupled to an AGCM or forced by climatic data. Likewise, the dynamic vegetation module and the LAI can be either simulated or prescribed.

2.2 Brief description of STOMATE processes.

STOMATE uses the concept of plant functional types (PFT) to describe vegetation distribution. In its present version the model simulates 12 PFTs. In every grid cell all different PFTs may coexist.

Photosynthesis is based on the Farquhar model (Farquhar *et al.*, 1980) and stomatal conductance on Ball&Berry (Ball *et al.*, 1982). Carboxylation rate V_{max} is a function of PFT and leaf age. Maintenance respiration is a function of biomass and is linearly related to temperature (Ruimy *et al.*, 1996). Growth respiration is a fixed part of allocated photosynthates (30%). Heterotrophic respiration (decomposition) parameterization is essentially taken from CENTURY (Parton *et al.*, 1988). The most original parts of STOMATE are the parameterizations of phenology and allocation. Budburst is based on a new scheme calibrated from remotely sensed data and based on parameters like the number of growing degree days and chilling days or changes in soil water content (Botta *et al.*, 2000). Leaf senescence is a function of leaf age modulated by water and temperature stresses. The allocation submodel is based on resource optimization (Friedlingstein *et al.*, 1998).

ORCHIDEE have been validated using several sources of data.: Towers fluxes from several sites of EUROFLUX and FLUXNET, remote sensing vegetation index and ground NPP measurements (EMDI project).

3. Perspectives

Several development are plan in the future to improve ORCHIDEE:

1. Improve parameterization of managed ecosystems (crops, pasture, forest), including land use practices. It will be done by coupling of ORCHIDEE with specific models (PASIM, STICS …)
2. Develop techniques of assimilation of remote sensing in ORCHIDEE to improve simulated CO2 and water fluxes simulated by the model.

The main projects in which ORCHIDEE is involved are:

1. Several validation/intercompararison programs (EMDI,CCMLP)
2. Mapping of CO2 source and fluxes of carbon at european scale (CARBCONTROLE, GREENGRASS)
3. Simulation of climate and CO2 fluxes in the full coupled "earth" model of IPSL. This model couple together ORCHIDEE with LMDZ: an atmospheric general circulation model, ORCA an oceanic general circulation model, PISCES a marine biochemistry model and INCA a tropospheric chemistry model. This fully coupled model will be used for simulation of climate and carbon cycle for the next century and paleoclimate applications.

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LACUSTRINE BASIN ENVIRONMENT OBSERVATORIES AND MULTIPROXY DATABASES FOR EASTERN AFRICA: A CLUE TO DEVELOP CATCHMENT BASIN COUPLED MODELS AND TO IMPROVE THE UNDERSTANDING OF CLIMATE-ENVIRONMENT INTERACTIONS

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Global change, but regional and local responses of tropical ecosystems

In eastern Africa, lacustrine "multiproxy" palaeoenvironmental records have been provided in a wide range of geomorphologic, hydroclimatic, vegetation and landuse contexts. At low time resolution (~10^3 yr) and at regional scale (~10^6 km^2), such records currently indicate that the intertropical environments have been closely connected with global circulation changes as driven by insolation (especially in the southern tropics)(e.g., Partridge et al., 1997; Thevenon et al., sp), northern hemisphere ice-sheets and regional sea-surface circulation patterns (Street-Perrott and Perrott, 1990; Broecker et al., 1998; Williamson et al., 1998; Gasse, 2000), or global atmospheric CO_2 levels (Jolly and Haxeltine, 1997; Street-Perrott et al., 1998).

However, one of the most striking features of continental paleoenvironmental records is the observation of local, non-linear responses to climate change. Owing to biological, chemical and physical thresholds in terrestrial or aquatic plants (e.g., mean annual rainfall, temperature of the coldest month, water salinity), in soils (e.g., porosity, nutrient levels, critical momentum flux) or in the lake reservoir itself (e.g. closed/open lake level barrier, water mixing regime), and to the interaction between vegetation cover, pedogenesis, erosion and hydrology, the response of continental environments to climate change may present, at high resolution scale (1-100 yr), dramatic consequences in terms of primary productivity, soil erosion, water budget or landuse, i.e. determinant variables for the current economy of developing regions and countries.

Since they are key-observations for identifying regional climate change, examples of such internal climate-environment interactions are easily provided in the past.

In Ethiopia, the open Ziway-Langano-Abijata-Shalla holocene paleolake at 9 kyr BP has been clustered around 5.5 kyr (Chalié, this volume) in four smaller interconnected lakes having different hydrological budgets, and presenting different sensitivities to regional climate variability (Vallet-Coulomb et al., 2001). In the same way, the stable, high stand lake Rukwa (Tanzania) between 15 and 7 cal. kyr BP was replaced from 7 to 3 cal. kyr BP by shallow, brackish water bodies and ephemeral swamp environments (Barker et al., s.p.; Thevenon et al., sp). Owing to the local sensitivity of basin environments, major hydrological thresholds may be reached in a few years. This is the case of Lake Magadi (Kenya), which closure and subsequent drop below the Magadi basin-Natron basin topographical barrier, at the beginning of the Younger Dryas event, likely resulted from a slight decrease in interannual P-E budget (Roberts et al., 1993).

Interactions between terrestrial ecosystems, hydrology and aquatic ecosystems are especially observed in small lakes, which provide more accurate reconstructions of the vegetation. In lake Tritrivakely (Madagascar), between 35 and 20 kyr BP, terrigeneous runoff inputs from the watershed are closely associated with Ericaceae vegetation changes and meromixis in the lake. During this period, the coupling between increased runoff, high primary production and stratified water bodies favoured the rapid burial of iron-rich terrigeneous material and organic matter at anoxic levels. This, in turn, intensified methanogenesis processes (Williamson et al., 1998).

Peculiar evidences of the coupling between vegetation, soil and hydrology and associated climate/environment thresholds are also provided in Lake Massoko (Tanzania). During the last 4000 years, production of biogenic silica in the lake was synchronous, at less than 20 year resolution scale, to iron-rich terrigeneous inputs from catchment andosols. As showed from diatom assemblages (Barker et al., 2000) and runoff magnetic proxies (Williamson et al., 1999), an arid period starting around 1700 yr BP was abruptly followed around 1600 yr BP by deforestation, intensification of biomass fires and development of herbaceous vegetation in the vicinity of the lake (Thevenon et al., 2001).

How to improve the understanding of climate-environment interactions?

Attempts are made to synthesize current paleoenvironmental and paleoclimate datasets from East Africa, and to develop analytical work and catchment basin modelling on Ethiopian and Tanzanian dedicated lake observatories. Indeed, these regions provide adequate sites i) to study climate-environment interactions along contrasted hydroclimatic gradients, ii) to compare archaeological records of human activities and landuse with regional environment/climate proxies, and iii) to validate and develop Catchment Basin Coupled Models (CBCMs) by coupling, at catchment scale, dynamic models of vegetation, hydrology and erosion. Points i) and ii) were initiated in the frame of the CLEHA-ECLIPSE project ("interactions Climat-Environnement-Homme en Afrique de l'Est depuis 20 kyr" of the french INSU ("Institut National des Sciences de l'Univers"). Point iii) is the aim of the RESOLVE project ("REponse du Système SOl-Lac-VEgétation à l'échelle du bassin" of the ACI "Ecologie Quantitative" of the french Ministry of Research.

In the frame of these two projects, a CLEHA-RESOLVE site-multiproxy database should be developed with the aim:

i) to archive regional field data, references to samplings, measurements, published and unpublished studies and data;

ii) to strengthen scientific exchange in between scientists working on complementary environmental topics in different teams and laboratories;

iii) to allow comparison of (new) specific data with existing (palaeo)environmental and archaeological multiproxy data;

iv) to allow coupling and validation of climate, vegetation, hydrology, soil erosion, and biogeochemical models at the scale of dedicated basin observatories.

To reach these goals, this multiproxy database should have three entries: spatial, chronological, and thematic/proxy. Considering i) the occurrence of local and regional features controlling the response of environment to climate change, and ii) further methodological improvements in environmental science (e.g., new physical proxies, new isotope, molecular or genetic tracers), determinant proxies of environmental change may often differ from one site to another (see above). This is a major point in building a multiproxy database as dedicated to climate-environment interactions, because this implies a spatial, chronological and methodological scaling. In complement to thematic (e.g., pollen, diatom, lake-level) databases, the scientific priorities of CLEHA and RESOLVE make it necessary to access directly to multiproxy datasets at regional, basin and site-sampling scale, as provided at variable time resolution (e.g., 1 day to 50 year for instrumental data, 1 year to 100 years for specific time intervals in the Past).

To conclude, developing i) environment observatories on dedicated (lake) basins and ii) basin multiproxy databases is a key challenge to improve, through the comparison of data and the validation of future CBCMs, the understanding of climate-environment interactions.

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