Session i1

GLOBAL POLLEN DATABASES

Pollen influx and tree-lines: results from the pollen monitoring programme

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Annual pollen deposition is being monitored in a standardized way in many parts of Europe. The results of this monitoring are contained in PMPData, which is the database of the Pollen Monitoring Programme (PMP), a work group within INQUA (http://wdc.obs-mip.fr/paleo/pmp/pmp.html). The database has the same format at the Global Pollen Database with the exception that records for each monitoring location are added year by year as they become available and results can be reliably expressed as grains cm^{-2} $year^{-1}$ (in addition to percentages) since the time factor is always known. Because the intention is that the database will be used as a modern reference for interpreting fossil pollen assemblages more objectively, particular attention is being paid to the metadata, in terms of vegetation surrounding the pollen monitoring sites. In collaboration with the POLLANDCAL network, vegetation analyses (out to several kilometres) are made in a way that enables distance weighted plant abundance to be calculated, since this is an essential input to models of pollen dispersal.

Using this database an analysis is presented of pollen deposition across the latitudinal tree-lines of *Betula*, *Pinus* and *Picea* in northern Fennoscandia. The spatial distribution of the results, year by year, for the period 1982 - 2002 are visualized using the tool PMPTracker. Pollen monitoring takes place in two differing situations, in the centres of small mires (c. 200 m diameter) and inside the forest. It is evident that for one and the same type of forest, the actual quantity of pollen being deposited inside the forest is some three times greater than that being deposited in the mires. Since the mire centre situation is most comparable with the fossil situations preserved in peat profiles, only the mire centre data are considered here. Annual variation in pollen deposition reflects annual pollen production and is related to temperature in the year prior to pollen emission. The long term average pollen deposition, in contrast, reflects the abundance of the tree taxon in the surroundings of the monitoring site i.e. can be used to delimit tree-lines. The annual distribution maps produced by PMPTracker illustrate the manner in which both these signals (summer temperature and abundance of trees) are evident in the data.

The Argentinean modern Pollen Database (32° - 52° S)

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The modern pollen, vegetation and climate relationship for the Extra-Andean temperate Argentina (between 32° and 53°, lat. S) has been examined using isopollen maps and scatter and percentages diagrams. These analyses are based on an array of 500 modern pollen samples. Data are collected mainly from soil and there are representatives in all of the major vegetation and climate zones. The main pollen taxa are Poaceae, Asteraceae subf. Asteraceae, Asteraceae subf. Cichoroideae, Chenopodiaceae, Cyperaceae, Caryophyllaceae, Apiaceae, Rosaceae, Verbenaceae, Fabaceae, Brassicaceae, *Nassauvia*, *Colliguaja*, *Lycium*, *Ephedra*, *Larrea*, *Prosopis*, *Schinus*, *Condalia*, *Monttea*, *Capparis*, and extra-regional pollen (*Nothofagus*, *Austrocedrus* and *Araucaria*).

Modern distribution of percentages and isopollen maps of the main pollen types accurately reflects taxa abundance and the major phytogeographic units: Pampa grasslands, Espinal (xerophytic woodlands), Monte (xerophytic shrublands), Patagonian steppe, Grass steppe, Upper Andean (grass and shrub steppe). Poaceae and

Asteraceae suf. Asteroideae pollen are widely distributed since Chenopodiacae show maximum percentages in arid and semiarid regions. In contrasts, Cyperaceae illustrate sub-humid and humid areas. Different shrubby pollen type assemblages characterize the Espinal, Monte and Patagonian steppe.

We find significant correlations between modern mean annual temperatures and mean annual precipitation and pollen data, which suggest the potential of this database for quantitative climate reconstructions.

The North American and Global Pollen Databases

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Development of the North American Pollen Database (NAPD) began in 1990 with the goals of assembling pollen data from Quaternary deposits and modern surface samples into a relational database and making these data readily available to the scientific community. The database contains original pollen counts, radiocarbon dates, site data, bibliographic data, researcher information, and other relevant data. The database has been funded by the U.S. National Oceanic and Atmospheric Administration Climate and Global Change Program.

NAPD was developed with close collaboration with the European Pollen Database (EPD). These databases were developed independently but were compatible with identical table structure. The Global Pollen Database (GPD) was conceived in 1994 with the development of the Latin American Pollen Database (LAPD), which was integrated with NAPD from the outset. Beginning in 1997, the GPD has incorporated data from the Indo-Pacific Pollen Database, and the non-restricted data from the EPD are now incorporated into the GPD.

The database makes an important distinction between *archival* data and *research* data. Archival tables store the count data, radiocarbon dates as reported by the radiocarbon laboratories, and other basic data not expected to change, except to add missing information or correct errors. Research tables store data that are derived by manipulation of the archival tables and are of an interpretive or subjective nature. Probably the most important of the research tables are those containing age models and chronologies, including the assignment of an age to each pollen sample.

Funding for a new two-year grant entitled *Coordination of the North American and Global Pollen Databases* has been secured and began in September 2003. The primary objectives of this project are to (1) to assemble and process pollen data from North America, including both fossil sequences and modern surface samples, (2) to carry out final processing of data contributed to the GPD by other cooperative pollen databases (e.g. EPD, LAPD), and (3) to develop an XML format for fossil-pollen data and associated metadata, and (4) to develop Windows software for data entry and retrieval.

The GPD and regional subsets such as NAPD are available from the World Data Center for Paleoclimatology, which is hosted by the U.S. National Climatic Data Center and is located in Boulder, Colorado. In addition to the database tables themselves, the data are available in several file formats via the World Wide Web (http://www.ngdc.noaa.gov/paleo/pollen.html). The web site features a search engine and map interface (WebMapper) for locating data and links to various pollen database cooperatives. New data are organized, verified, and made available by various regional data cooperatives.

Surface pollen data from northern Eurasia: collection and use for the vegetation and climate reconstruction

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'Northern Eurasia' is a large region, which occupies an area of the Former Soviet Union and Mongolia. This region was selected as a study unit in BIOME6000 and PMIP global-scale international projects dealing with pollen-based vegetation and climate reconstruction and data-model comparison (TARASOV et al. 1998; 1999a;

1999b; 2000a; GUIOT et al. 1999; KAGEYAMA et al. 2002). The large plains and plateaus of this area support vegetation and climate distributed in a generally zonal pattern and provide a good opportunity for modeling and data-model comparison. Modern vegetation ranges from polar desert and tundra north of 67-70°N, through a broad forest belt, to the steppe and deserts occupying the continental interior south of 50-52°N. The surface pollen dataset from this area consisting 1110 samples are of major importance to global and regional palaeonvironmental studies. In the present paper we report the most recent results of the reconstruction of the late Glacial and Holocene vegetation and climate at the sites from the transitional zones of northern Eurasia (e.g. forest-steppe and forest-tundra), which show a quick response to the temperature and precipitation changes (ANDREEV et al. 2003; in press; TARASOV et al. 2000b). Pavel Tarasov current research is supported by the AvH fellowship.

ANDREEV, A.A. et al. (in press). Vegetation and climate changes around the Lama Lake, Taymyr Peninsula, Russia during the Late Pleistocene and Holocene. **Quat. Int.**: in press.
ANDREEV, A.A. et al. 2003. Vegetation and climate changes on the northern Taymyr, Russia during the Upper Pleistocene and Holocene reconstructed from pollen records. **Boreas**: 32: 484-505.
GUIOT, J. et al. 1999. The climate of the Mediterranean Basin and of Eurasia of the Last Glacial Maximum as reconstructed by inverse vegetation modelling and pollen data. **Ecologia Mediterranea** 25: 193-204.
KAGEYAMA, M. et al. 2001. The Last Glacial Maximum climate over Europe and western Siberia: a PMIP comparison between models and data. **Clim. Dyn.** 17: 23-43.
TARASOV, P.E. et al. 2000a. Last Glacial Maximum Biomes Reconstructed from Pollen and Plant Macrofossil Data from Northern Eurasia. **J. of Biogeogr.** 27 : 609-620.
TARASOV, P.E. et al. 2000b. Holocene vegetation and climate changes in Hoton-Nur basin, northwest Mongolia. **Boreas** 29: 117-126.
TARASOV, P.E. et al. 1999a. Climate in northern Eurasia 6000 years ago reconstructed from pollen data. **Earth and Planet. Sci. Lett.** 171: 635-645.
TARASOV, P.E. et al. 1999b. Last Glacial Maximum climate of the Former Soviet Union and Mongolia reconstructed from pollen and plant macrofossil data. **Clim. Dyn.** 14 : 227-240.
TARASOV, P.E. et al. 1998. Present-day and mid-Holocene Biomes Reconstructed from Pollen and Plant Macrofossil Data from the Former Soviet Union and Mongolia. **J. of Biogeogr.** 25: 1029-1053.

The African Pollen Database, state of the art

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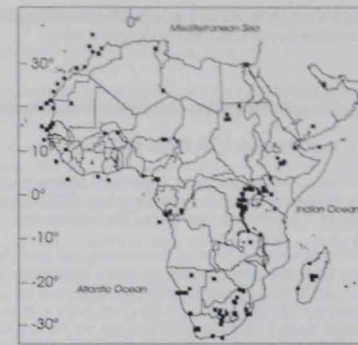
APD has been founded in 1996 with the aim to assemble pollen data from Quaternary deposits and modern surface samples in Africa into a relational database and to make these data freely available to the scientific community. The database contains original pollen counts, radiocarbon dates, site data, bibliographic data, researcher information, and other relevant data from 202 fossil sites and 1170 modern surface samples (Gajewski et al., 2000). Fossil sites include lakes, peat bogs and oceans cores. They are primarily located in the inter-tropical zone and in Southern Africa. Now, APD is closely collaborating with its European counterpart (EPD) to gather additional pollen data form Mediterranean areas. All these data (as "tilia" files or "paradox" tables), together with "quick-look" pollen diagrams and related literature are available through the Web at the following address: "http//medias.obs-mip.fr/apd".

The pollen flora in both modern and fossil data contains about 2000 taxa deduced from originally 3740 items. Each "taxon" may refer to several botanical species, genera or families depending of the complexity of pollen morphology and consequently of accuracy of pollen determination. In 2003 and 2004, special attention has been paid on pollen morphology and nomenclature: (1) the special tool for pollen determination elaborated by Medias-France contains new photos of tropical pollen grains from Central and East Africa; (2) an homogenous pollen nomenclature has been adopted using Lebrun and Stork (1991-1997) and biological and phytogeographical information have been compiled for each pollen taxon (Vincens et al., in progress). In 2004, the APD user interface will be improved and developed by Medias-France allowing easier data access.



APD - location of fossil pollen sites

Progress towards a multiproxy database integrating pollen and other paleo data

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Paleoclimatic and paleoecological data, including fossil pollen data, form a dense, complex thicket for researchers. These data derive from a multitude of sources, each with its own strengths and weaknesses, rewards and perils. Providing awareness, understanding, and access to them is a major challenge.

Raw data are at the foundation of science. Published results of scientific research are secure, but the information on which these results were based is always at risk of disappearing. On the one hand, computerization and the spread of inexpensive database technology should enhance the lifetime of raw data. Technology, however, changes rapidly, and unless care is taken, the data may quickly become indecipherable. An unfortunate rule is that the least fragile electronic formats are also those that are the most difficult to work with. There is also an abundance of data that remain outside of any data management endeavor, and are on a short path to extinction. The raw data collected tomorrow will suffer the same fate, unless convenient, reliable, and long-term data management is available to their producers.

Members of two groups from the paleoenvironmental research community, The World Data Center for Paleoclimatology (WDCP), and the Paleoenvironmental Arctic Sciences (PARCS) project, have recently initiated a project to streamline their data management efforts. The WDCP exists to preserve in perpetuity the data produced by global paleo-scientists, and to make it freely available to all that are interested. PARCS has the goal of understanding past environmental change in the Arctic by studying proxy data from a network of sites across the Arctic and synthesizing the results. Together these two groups represent the management and user sides of data management, and this collaboration will lead to a more user-friendly system.

Over recent years we have designed and built, redesigned and extended a variety of internal database systems. In this talk we will describe our current thinking and the design for an object-relational database to handle multiproxy paleo data. We will also describe the results of our initial efforts to input and output data from this system. Additionally, we will describe some ideas for the different classes of users that we envision with some emphasis on *power users* with direct read-access to the database itself.

Although our efforts are preliminary, we are interested in presenting them in the hope of enlisting others in the project. To this end we have been working towards a comprehensive, open, multiproxy database. Open is the keyword for us: we want others to contribute and build on our foundation. We do not think we will have created the last database anyone will ever need. We do hope that it will be useful to others, especially to short-term research projects that will produce significant volumes of data. There is considerable computing talent in the Paleo community. Too often it results in repeating what others have already done. If we can instead provide a common base, then applications written for one proxy may work against many.

A graphic-guided pollen Database-Key system

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Most palynologists identify pollen types based on their memory and published pollen atlases. However, due to the great number of plant species and great similarity on pollen morphology between species, genera, or even families, the well identified pollen types in anyone's memory is only a small portion of all pollen types. Most published pollen atlases are not searchable. Even though some keys were made to be an accessory assistance, most keys often do not work well because many pollen characteristics can not be well defined or can not be well-recognized in pollen grains. One misidentification of a pollen characteristic will mislead the search and turn out a completely wrong result. Any characteristic in the key cannot be skipped even though some times the users may have problem to define it.

We developed a database-key system using FileMaker. Up to twenty nice characteristics **and six** photographs from different views are given to describe pollen morphology of each species. All characteristics in the system are well-illustrated with linked graphs located on different interfaces. Search could be based on any one or more of the characteristics, or based on names.

The general advantages of using this system to search pollen are as follows:

Graph-guided: the graphs accurately define the characteristics used for search. An interface is made to illustrate each characteristic. Users may easily find the correct description for their pollen grains from the graphs in the interface, without worrying about unfamiliarity with the terminology.

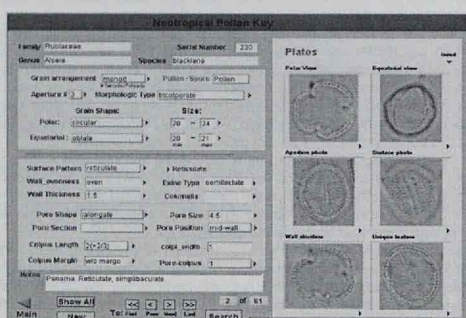
Multi-criteria search: users may search a pollen type based on multi criteria at same time. They may enter only the criteria they are sure is correct, and leave the uncertain criteria blank.

Multi-choice for each characteristic: if a characteristic is not well defined, more than one possible type of a characteristic may be selected to ensure that the correct one is included.

Interactions between users and the system: the users may modify the criteria based on the turnout results until the best result is reached. In the first search, some characteristics may be misidentified or not accurately define, it is always easy to go back to modify the criteria and re-do the search.

Convenient for pollen learning: users may learn pollen simply by using taxon names as searching criteria. All pollen species in the required taxa will be listed and all features and photographs of the pollen types could be viewed in details. This is especially useful for beginners.

In future, ecology and distribution of pollen taxa will be added to the database.



Developing the Indo-Pacific Pollen Database

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The Indo-Pacific region extends from tropical India, tropical China and Hawaii in the north to the sub-Antarctic islands in the south. The unifying feature of the region are the palaeotropical and Gondwanic floras which reflect the ancestral development of the floras of west Gondwana and the subsequent rafting of that flora on the Indo-Australian and neighbouring plates (MORLEY 2001). The complex evolutional history has produced striking sub-regional floras, such as that of Australia, but the Pacific has an attenuated Malesian flora and even Australia has a significant Malesian component. Thus many pollen taxa can be found scattered across the region, particularly in the tropics and sub-tropics.

There are no pollen or indeed taxonomic floras covering the whole area, nor are any expected given the size of the flora. The Indo-Pacific pollen atlas is initially attempting to include only taxa that are important components in Quaternary pollen diagrams, as an aid to palynologists working in new regions and to assist in integrating existing pollen data to an agreed taxonomic usage. Progress has been very slow on this project although about 800 taxa have been identified. Data is segregated into 24 natural biogeographic regions that correspond with particular pollen floras. Australia, for example, has seven regions, one of which also includes lowland New Guinea. The Atlas aims to be integrated with the World Pollen Database taxonomic lists and to be interrogatable by internet.

The Indo-Pacific site database is intended to cover about 25 countries and to record all dated Quaternary pollen sites. It thus overlaps with several national database projects, notably those of New Zealand, China, the US and India, but does not see itself as being in competition. While detailed data, such as pollen counts, need not be duplicated (provided that the national database is reasonably open) it is useful to record relevant sites over a large region.

Although envisaged as a data cooperative, the Indo-Pacific database has had limited success in encouraging donations of data and information. It currently logs available publications and corresponds with authors to solicit data. Some metadata has been generated where original counts have been lost. It has provided primary data to some national databases. The task of revising the taxonomic names of pollen types has not progressed so that some requests for the supply of the complete data files have not been able to be met. However files are being sent to the World data base as they become available. A listing of sites and primary literature sources is being published and should also be available on the web

MORLEY, R.J. 2001. **Origin and Evolution of Tropical Rain Forests**. Wiley, Chichester and New York.

The Japanese Pollen Database

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The Japanese Islands are small and narrow, but long from the southwestern islands (subtropical region) to Hokkaido (boreal region). Although, more than 2000 pollen records are available in Japan, almost papers are written by Japanese. So, many pollen data are not convenient for the world users. Therefore, the Japanese pollen database is expected to become open in the web site. In the Biome 6000 project, we constructed the pollen database for time slice for modern, 6 ka and 18 ka (Takahara *et al.*, 2000). Also, Gotanda *et al.* (2002) offered the surface pollen data digitalized from pollen diagrams. However, at present, no Japanese data is in the World Pollen Database. We are preparing the pollen data sets in the area from the western Japan to Hokkaido Island.

Outline of pollen data in Japan are as follows. Many data for the last glacial and interglacial periods are available, because Japanese Islands had never been covered by Ice sheet in the glacial period. Also, continuous long cores included several glacial-interglacial cycles were obtained in Lake Biwa (Miyoshi et al., 1999) and the Kamiyoshi Basin (Takahara *et al.*, Abstract of this volume). More than 10 pollen records of long cores reached to the last interglacial or the early glacial became available, recently. Much more pollen data for the Last Glacial

Maximum are published in Japan. For the Holocene, pollen data includes cores from peat bogs, lake sediment and archaeological sites. Recently charcoal data also available from Japanese palaeoecological data set.

These data are very useful for clarifying world vegetation and climate histories. Therefore, we hope to make available Japanese pollen data for scientists all over the world through the Japanese Pollen Database (JPD). Now, we are developing the JPD through the cooperation of some Japanese palynologists.

The format of the JPD is almost the same as that of the NAPD. Also, the JPD will have the pollen count data sets from the original investigators. The number of data sets in the JPD is still small, but fifty or more data sets will be available in the summer, 2004.

GOTANDA, K., NAKAGAWA, T., TARASOV, P., KITAGAWA, J., INOUE, Y. & YASUDA, Y. 2002. Biome classification from Japanese pollen data: application to modern-day and Late Quaternary samples. **Quat. Sci. Rev.** 21: 647-657.

MIYOSHI, N., FUJIKI, T. & MORITA, Y. 1999. Palynplogy of a 250-m core from Lake Biwa: a 430,000-year record of glacial-interglacial vegetation change in Japan. **Rev. Palaeob. Palynol.** 104: 267-283.

TAKAHARA, H., SUGITA, S., HARRISON, S. P., MIYOSHI, N., MORITA, Y. & UCHIYAMA, T. 2000. Pollen-based reconstructions of Japanese biomes at 0, 6000 and 18,000 yr BP. **J. Biogeogr.** 27: 665-683.

The Latin American Pollen Database

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The LAPD was established in 1993 being hosted at the World Data Centre, Boulder. Since 1999 there has been a phase of development in Amsterdam that has seen number of advances and a suite of new features to be incorporated within the LAPD. Data from a range of recently studied sites, particularly from Brazil, Colombia and Venezuela is ongoing and has been hamper by the lack of dedicated support. Committed support for the LAPD will soon be available at the Universidad Nacional de Colombia in Bogotá, allowing these data and advances to be available to the palaeoecological community in 2004. In addition to having dedicated support for data entry it is envisaged that there could soon be a Latin American base for the LAPD at the University of Bogotá where a number of projects using and adding value to the data can be developed that incorporate the LAPD community. In addition to the current developments it is envisaged that pollen identification, via a linked photo database, combined with information on ecological constraints and growth requirements of plants will be imbedded within the LAPD to increase the potential educational value.

The LAPD-Newsletter issues are released twice a year during the last two years that was an initiative to ensure wider dissemination of the LAPD news and engender broader involvement in the development of the LAPD. Within the LAPD Newsletter a list of forthcoming congresses, workshops and seminars, current events and web sites of interest to broad paleo-community is announced. In a number of issues short articles are submitted by the LAPD-researchers describing and sharing the experiences and new results from their scientific projects. With a current circulation of twice times per year is envisaged the LAPD-Newsletter will spread this valuable information to palynologist working in Latin America.

Of course the LAPD contributors are thanked for submitting their data, making it possible to build a way of data usage and exchange, and a specially acknowledgement must go to Vera Markgraf for her initiative in developing the LAPD and encouraging the young scientists to be part of it.

A federated multi-proxy tool for palaeoclimatological data

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In the field of the reconstruction of paleoenvironments and paleoclimates, for different purposes (abrupt events, validation of models, etc.), scientists working at wider scales than that of the site scale have to use large data sets. An integrated and quantitative multi-proxy approach is also decisive to provide a correct interpretation of individual signals.

To integrate different proxies in a paleo-environmental or paleo-climatic study, new methods are always under development.

Here we propose to present examples on which Medias-France is currently working. Data policies, metadata formats, and software needs for the mono-proxy tool were first defined. The main programs within which Medias-France is in charge of either creating or maintaining a mono-proxy tool, are dealing with European and African regions. They are for example Format (Tree-ring database in southern Europe), EPD (European Pollen Database), and APD (African Pollen Database), a compatible structure of the European Pollen Database for African pollen data archival.

Having defined the mono-proxy needs, our current step is to elaborate a tool that will facilitate the intercomparison between data types and between sites for the reconstruction of the paleoenvironments through a multi-proxy multi-size database.

Medias-France is building a tool for quickly and easily consulting various mono-proxy data for a region and/or a period, with the following features:

Such a database shall be spatially distributed, with the ability for the database administrator and scientific supervisor to maintain control and for them to manage the multi-proxy tool.

This multi-proxy tool shall be used on the web without particular computer competencies.

The tools shall be freeware, simple, and reliable.

The development of this multi-proxy paleoclimatological tool will not lead to the disappearance of mono-proxy databases. The mono-proxy databases will be organised into Relational Database Management Systems with metadata in the FGDC standard or in the ISO 19115 norm, and periodic mirroring procedures will transfer and format on this Multi-Proxy tool the existing mono-proxy databases.

Session i2

APPLICATIONS OF POLLEN DATABASES

Ecological and climatological reconstruction from pollen data for the last 15000 years: an application of a new probalistic method based of plant attributes

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The reconstruction of vegetation history from palynological records is an important source of information for climate, environmental and human impacts upon landscapes . Most recent studies used quantitative multivariate techniques to reconstruct past climatic variable and more qualitative approaches to reconstruct ecological and anthropic conditions.

We used a new probabilistic method to investigate the relationship between pollen assemblages and specific climatic, environmental and human factors. This method relies on a pollen taxa characterization using a set of chosen attributes. The plant life form, types of leaves, phenology, biogeography, plant dispersion mode of pollen and seeds, habitat, conditions of soil (humidity and acidity) and light requirement have been documented for 196 taxa from European Pollen Database (EPD). Pollen indicators of land use (ruderal, weeds of cultivated land and cereal) are included to tentatively estimate the human impact.

The method has been applied to late-glacial and Holocene pollen records from Jura Mountains. The late-glacial period is dominated by heliophilous communities whose rapid composition changes are related to major climatic shift. Special attention is drawn to the effect of altitudinal gradient and its influence to the palaeoenvironmental conditions. The Holocene vegetation is characterized by the succession of mixed deciduous forests to "*Abies, Fagus, Picea*" woodland. We will discuss the ability of the method to differentiate human and climatic influences upon the landscape.

Plant functional types, plant traits and climate reconstructions in Europe: what works the best?

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We investigate the potential for new methods relying on pollen data and plant functional traits to reconstruct climate in Europe. The analyses are based on modern pollen data sets from the circum-Mediterranean region (assembled as part of the CiMBIO project, MPI-BGC, Jena, Germany) and Europe (European Pollen Database). All pollen taxa represented in those data sets were assigned plant traits modes. The traits we consider are plant morphological, phenological and vital characteristics that are assumed to be to external expressions of plant adaptations to environmental conditions.

In order to estimate the most accurate measure of the relative importance of a plant trait in the vegetation at a given site, trait scores calculated as a function of the pollen abundance will be compared to trait probabilities of occurrence, which are dependent not only of the pollen percentages but also on the frequencies with which taxa co-occur in the entire pollen dataset. Another test will be performed to estimate how limiting is the low taxonomic identification of pollen grains to the use of plant traits for reconstructing environmental parameters.

Both trait scores and trait probabilities of occurrence indicate that there are strong correlations between the relative abundance of certain plant traits and some climatic parameters. However, it is necessary to investigate how strong are these correlations when the dataset is extended. In particular, we will test if the trends in trait relative abundance with climate are stable when the dataset is extended from the Mediterranean region to the whole Europe.

Biome reconstructions rely on plant functional types (PFTs) that are combinations of climatic affinities (tropical, boreal...) and plant traits describing the habit (tree, shrub, forb...) and the leaf phenology (evergreen, summergreen...). Such PFTs allow reconstructing regional and global biomes. However, preliminary results seem to indicate that combinations of traits (or PFTs) may carry less strong climatic signal than individual plant traits. In

order to identify the most efficient method to reconstruct climate in Europe, we will carry a test of sensibility among the various techniques that have been developed since the last decade. We will compare how efficient are artificial neural networks and the method of modern analogues to reconstruct temperature and humidity using classical PFTs, trait scores and trait probabilities. Furthermore, we will see how PFTs and plant attributes perform compared to pollen taxa in reconstructing climate in Europe.

Quantifying the relationships between the abundance of plant traits and climate parameters provides an improved basis for vegetation modelling. It also contributes to improve the climatic reconstructions based on pollen data.

An extended probabilistic approach of plant vital attributes: an application to 0 ka and 6 ka data from the European Pollen Database

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We present a probabilistic method of pollen spectra analysis. This method relies on a pollen taxon characterization using a set of biotic and abiotic plant attributes modes, and their occurrence in a given pollen spectrum at a specific site. This type of analysis can then provide an interpretation which can lead to the reconstruction of the biome and, to some extend, of biotic and abiotic conditions at the site.

The analysis has been carried out at the European scale using data provided by the European Pollen Database for about 1000 sites. We assign plant attributes modes to each pollen taxon represented in the set of pollen assemblages that we use. The plant attributes we consider have been selected according to their relevance to biome reconstruction, but also on the amount of information available from the literature. By using the probability of occurrence of each taxon in a given pollen spectrum, we calculate an affinity index for the spectrum to the attribute considered, and thus to estimate the relative importance of this attribute in a plant community. To reduce the uncertainty caused by pollen identification in poorly diversified pollen spectra, we used in parallel a concept of co-occurrence that takes into account in a probablistic way the underlying idea of assemblage.

The method has been validated on a set of 1327 modern surface samples distributed all over Europe. The results which are compared to the major climatic and environmental variables that control the distribution of the vegetation show the validity of this approach. Then we apply the method to the 6 ka BP data. We focus here on the interesting results obtained for plant dispersion mode of pollen and seeds. The modes related to insect interactions, were much more extensive in central Europe at 6 ka than at present but are now restricted to southern Europe. It may be related to the increase in human activities during the last 6000 years and especially to the intensification and modernisation of agricultural practices. This modernisation has a very strong impact on insect populations by fragmenting their habitats and lead to a decrease in the size of insect populations able to pollinate and disperse seeds. Moreover, in western Eurasia, most of the anemophyllous taxa are represented by cold taxa such as Pinaceae or temperate taxa such as Betulaceae or Fagaceae. Entomophyllous taxa, are represented by temperate warm and mediterranean taxa such as Oleaceae and Rosaceae. The analysis of evolution of their occurrences through time suggests once again that at 6 ka, the climate was supporting a mixed vegetation characteristic of a mild climate when now a clear segregation is obvious between the warm entomophyllous taxa and the temperate –cold taxa suggesting a development towards a colder northern climate and a warmer southern climate at the present. Another attribute is also analysed. It concerns the heliophilous mode which is actually dispersed mostly around the Mediterranean basin but was widely spread in Europe at 6 ka.

The obtained results show that probabilistic method is a powerful tool for the pollen spectrum analysis. It allows reconstruction of various characteristics of the vegetation at the continental and even global scale for periods and sites with significantly different climate conditions. This method can also be used to compare maps of differents vegetation attributes for comparison and validation of the new generation of generalised dynamic ecosystems models.

Postglacial climate of southern Québec: local and regional pollen-based reconstructions

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The modern analogues technique (MAT) has been applied to seven pollen diagrams from the BDPMQ (Quebec Pollen and Macrofossil Database) that possessed reasonable chronological control (3 to 10 radiocarbon dates in addition to palynostratigraphical dating: *Ambrosia* rise and *Tsuga* decline). The pollen diagrams are all from lake sediments, except one from a deposit that evolved from a lake to a marsh, then to a forested swamp. Three sites are located in the western St. Lawrence Lowlands and two in each of the adjacent Appalachian and Laurentian Highlands (Muller *et al*., 2003). Individual reconstructions (Guiot & Goeury, 1996) were averaged to time-slices of 250 years with the aim to obtain a regional assessment of postglacial climatic changes. The regional climatic ouput is : 1) dry and cold late-glacial conditions; 2) a rapid increase in temperature and precipitation between 12 500 and 11 000 cal. yr BP; 3) a drier period from 10 000 to 5500 cal. yr BP; 4) a thermal optimum between 9000 to 5500 cal. yr BP recorded in both July and annual temperature, and in degree-days above 5°C as well; 5) slight and progressive decrease in summer temperature, increase in winter temperature, and increase in precipitation during the last 5000 to 4500 years.

Past lake-level changes of an additional site (Lake Hertel) located in the central part of the studied area were assessed from sedimentological, pollen and macrofossil records from a single lateral core. Four stages of low lake-level were reconstructed: before 8000, between 7600 and 6600, between *ca*. 5000 and 3400, and between 2600 and 1800 cal. yr BP. A lake-level change constraint applied to the search of modern pollen spectra analog to the fossil ones did not affect notably the climate reconstructions. In that constraint, a lake-level change of 3 m was representing a change of 130 mm for the regional water balance (P-E).

The reconstructions for individual sites will be examined in order to specify their respective contribution to the regionally-averaged climatic reconstructions from Muller *et al*. (2003), and to identify the pollen taxa responsible for the outliers. A comparison is made possible with the Western Great Lakes, where Davis *et al*. (2000) applied a similar MAT to reconstruct climate from a similar set of pollen diagrams. Chronologies are also revised to take into account the very recent development in ice retreat chronology in southern Quebec and conterminous USA.

The sensitivity of lake water balance and of vegetation to hydroclimatic changes will be examined in the bioclimatic context of southern Quebec.

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GUIOT, J. & GOEURY, C., 1996. 3Pbase – a software for statistical analysis of paleoecological and paleoclimatological data. **Dendrochronologia** 14 : 123-135.

MULLER, S.D., RICHARD, P.J.H., GUIOT, J., DE BEAULIEU, J.-L & FORTIN, D. 2003. Postglacial climate in the St. Lawrence lowlands, southern Quebec : pollen and lake-level evidence. **Palaeogeography, Palaeoclimatology, Palaeoecology** 193 : 51-72.

The Relative Magnitude of Millennial- and Orbital-Scale Climatic Change in Eastern North America during the Late-Quaternary as Inferred from Pollen Data

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Multiple paleoenvironmental records have identified millennial-scale variability in various components of the Earth system, but the dynamics underlying these records remain poorly understood. Assessing millennial-scale climatic variability in the context of long-term climatic change is important because orbitally-forced changes could induce and modulate millennial-scale variability through feedbacks, thresholds, and other non-linearities in the climate system. Here, we measure differences between fossil pollen samples from across eastern North America to measure the amount of climatic change that occurred on sub-millennial to multi-millennial (orbital) time-scales since the last glacial maximum (21,000 cal yr B.P.). Square-chord distances (SCDs) between pollen samples show that little changed across individual millennia and shorter time-steps, except at the beginning and end of the Younger Dryas chronozone (YDC; 12,900-11,600 cal yr B.P.). SCDs across all millennia averaged 0.08, whereas SCDs spanning the beginning (13,000-12,000 cal yr B.P.) and end (12,000-11,000 cal yr B.P.) of the YDC averaged 0.20 and 0.18 respectively. Like the difference between individual hours during the diurnal cycle, the difference from one millennium to the next during the last glacial-interglacial cycle was typically small. The changes associated with the YDC were the only millennial-scale changes that equalled the magnitude observed across longer time steps. SCDs across 3000-yr intervals averaged 0.20 and, thus, commonly exceeded the minimum difference between samples from different biomes today (0.15). Because different biomes represent different climatic zones, large climatic differences therefore can be inferred from the large SCD values. The magnitude of long-term change decreased during the later half of the Holocene, but remained larger than millennial-scale changes. The pattern of change matches well with shifts in the combination of major climatic controls, including insolation, ice sheet extent, and atmospheric composition. Given the large-magnitude, long-term changes, orbitally-forced change in the Earth system likely mediated short-term variability, even if millennial-scale external forcing was involved.

Hydrological conditions in Africa 6000 years ago

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[5] African Pollen Database group is a multi-institutional consortium of palynologists studying late-Quatemary environmental changes in Africa. The pollen contributors are A. Ballouche, P. Brénac, G. Buchet, D. Bumey, R. Cheddadi, A.C. Hamilton, H. Elenga. H. Lamb. A.M. Lézine, J. Maley, M. Reille, G. Riollet, L. Scott, I. Ssemmanda, H. Straka, D. Taylor, M. Umer, E. Van Campo and M. Waller.

Mid-Holocene precipitation empirical estimates in Africa have varied widely, especially in the Sahara. To quantify precisely these climatic changes, we have applied two different methods -fue best analogues method and a transfer function based on plant functional types- to 95 pollen samples dated 6000 ,lo 500 years B.P. These fossil samples are located in the whole Africa. Both annual rainfall and actual evapotranspiration over potential evapotranspiration ratio have been estimated.

Results from the pollen-based quantitative reconstructions show that annual rainfall was considerably higher 6000 years ago in the Sahara (between +130 and+450 mm/year), and also in South Africa. We have compared fuese results with those obtained throughclimate simulations for the middle Holocene epoch using different Atmospheric General. Circulation Models.

Precipitations were comparable or slightly lower in central Africa and in Madagascar (0 to -300 mm/year). Here too, we have compared these results with AGCMs simulations.

Another way to test the accuracy of our results has been to compare them to lake-levels variations (lacustrine data from 6000 years B.P. have been compiled for 88 African lakes).

In conclusion, fue pollen-based reconstructions showthat 6000 years BP was not an optimum climatic everywhere in Africa.

Relation between modern pollen deposition and plant distribution in Tropical Africa, implication for climate reconstruction

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Climate changes have had considerable effect on the geographic location of ecological systems, and species mix they contain. Environmental conditions in tropical Africa from about 18,000 before present (BP) till now are quite well known, thanks to of the numerous pollen data available in the African Pollen Database: for instance, pollen data show that forest boundaries greatly shifted and that tropical forest extent was strongly reduced at the time of the most recent high-latitude glacial advance about 18,000 years ago (Lézine, 1998). During this period, palynologists discovered that tropical forest biodiversity considerably increased since lowland rainforest communities accommodated cool-adapted species that are currently found on mountains (Elenga, 2000; Maley and Brenac, 1998). Another example can be found during early to mid-Holocene climate optimum (about 8-6000 years ago), when tropical trees extended north, probably using wadis as migration routes, and co-existed with steppe (dry) species at the southern boundary of the present-day Saharan desert (Lézine, 1988). Consequently, during a significant portion of recent history, the distribution of pollen types provides "no analogue" associations to today's vegetation communities suggesting that *plant species responded to climate change individually, not as communities*.

In this paper, we compare pollen/climate (Gajewski et al., 2000) and plant/climate response surfaces using distribution maps of African plants species, based on herbarium databases or literature (e.g., Lovett *et al.*, 2000; Mutke *et al.*, 2002; Taplin and Lovett, 2003). In association with land surface and climate data from satellites (Leemans et Cramer, 1991) and field observations, these maps allow to precisely characterise climate and geographical range of each of the plant species belonging to a same pollen taxon (Vincens et al., in progress). This method aims to evaluate to which extent each individual pollen taxon can be used for plant (biome) or climate reconstructions under past analogue or no analogue situations.

A 14,000-year record of vegetation change in the Bale mountains, Ethiopia

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A 16m sediment core from a small lake at 4000m altitude in the Bale mountains of Ethiopia provides a 14,000-year record of vegetation and climatic change. The site was deglaciated by 14000 ^{14}C yrs BP. Sediments dating between 14000 and 10000 ^{14}C yrs BP are predominantly clastic silts, with low concentrations of herb pollen, indicating a sparse vegetation cover in an arid climate. Sedimentation rates increased during the Younger Dryas interval, and Amaranthaceae/ Chenopodiaceae pollen abundances decreased, suggesting increased available moisture, perhaps due to decreased evaporation rates resulting from lower temperature. The early to mid-Holocene (10,000 – 4300 ^{14}C yrs BP) vegetation was dominated by Ericaceous shrubs and grasses, similar to the present local vegetation. Tree pollen increased at 4300 ^{14}C yrs BP , at a time of regional change to arid climate, possibly indicating that trees expanded onto plateau areas in response to a change to more seasonal rainfall distribution. The present-day composition and extent of *Juniperus-Podocarpus* forest became established about 2000 years ago. Whether this response reflects climatic and or anthropogenic forcing needs further investigation.

Modern pollen-vegetation relationships in the United States and Canada

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This paper and the companion paper by Shuman et al. present a new atlas of modern pollen distributions for the United States and Canada, grounded upon an expanded surface pollen dataset comprising over 5,400 samples. The dataset, built from data holdings at the Global Pollen Database, Brown University, University of Ottawa, Paleoenvironmental Arctic Sciences (PARCS), and the University of Arizona, will be archived at the World Data Center for Paleoclimatology upon publication. This paper focuses on modern pollen-vegetation relationships at a continental scale; the paper by Shuman et al. explores modern pollen-climate relationships. All surface sample locations have been assigned a land cover type from each of seven land cover schemes from the IGBP DISCover 1-km global land cover maps, and percent tree cover values for needleleaved and broadleaved trees from the University of Maryland Global Land Cover Facility. We explore the distribution of pollen abundances within and among land cover types, and the relationship between pollen abundances and needleleaved and broadleaved tree cover values. One cost of expanding to a continental scale is the increased taxonomic imprecision gained by incorporating more plant species within each genus or family. Nevertheless, accurate reproductions of the modern vegetation using analog analyses and validations using the leave-one-out approach demonstrate that interregional differences in floristic and palynological composition overcome the loss of information associated with individual plant taxa.

Colombian vegetation at the Late Glacial Maximum – a comparison of model and pollen-based biome reconstructions

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Colombian vegetation, at the ecological level of the biome, is reconstructed at the Late Glacial Maximum (LGM) using two methods. Firstly, biomes are reconstructed for eight sites using pollen data assigned *a priori* to plant functional types and biomes. A reconstruction of modern biomes shows for the majority of the sites, the pollen data accurately reflect the potential vegetation, even though much of the original vegetation has been transformed by agricultural practices. At 18,000 radiocarbon years before present (^{14}C yr BP); a generally cool and dry environment is reflected in biome assignments of cold mixed forests, cool evergreen forests and cool grassland/shrub; the latter extending to lower altitudes than presently recorded. Differential responses of the vegetation to climatic shifts are related to changes in moisture sources and the importance of edaphic control on the vegetation.

Secondly, biomes at the LGM are also investigated by applying a vegetation model (BIOME-3) set to operate at CO_2 levels of 200 ppmV and with climatic data from twelve meteorological stations that encompass a range of environments within Colombia. The model is set to reconstruct biomes analogous to those derived from the pollen data. The signals of vegetation change documented by the pollen data are translated to the main environmental controls of temperature and moisture to indicate the degree of environmental change needed to record the vegetation change depicted by the pollen data. At lower altitudes it is apparent that moisture is the dominant control on driving vegetation change whereas temperature becomes more important at higher altitudes. The combined reconstruction of biome-scale vegetation dynamics in Colombia allows an understanding of the environmental controls on these to be developed that demonstrates the need to invoke different factors to explain the vegetation change rather than a uniform reduction in temperature or moisture.

Reconstructing past ranges with fossil and molecular data

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One of the most persistent ideas to have emerged from the field of paleoecology is that the ranges of temperate tree species expanded rapidly after the last Ice Age. This idea is the consensus view among syntheses of fossil pollen data at continental scales over the course of the Holocene, but it is subject to established uncertainties in the ability of fossil data to record the range limits of expanding populations. We were unable to reconstruct the modern ranges of two species that are well represented in sediments using pollen and macrofossils from sediment surface samples. The ranges of American beech (*Fagus grandifolia*) and yellow birch (*Betula alleghaniensis*) contain large areas where these species are present, but not abundant, and these were impossible to systematically identify using pollen and macrofossil data respectively. It is likely that these species and others like them existed at low densities over extensive areas in the past, and such areas would not be accurately mapped using fossil data.

Surveys of cpDNA variation may be more sensitive to the historical dynamics of small populations. Patterns of cpDNA variation in eastern North America suggest that the fossil based reconstructions that are the basis for estimates of rapid postglacial migration fail to identify northern populations of common eastern tree species. Accounting for these cryptic northern populations reduces estimates of postglacial migration considerably.

Forest history mapped from pollen data by classification of entire pollen Databases using artificial neural networks

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Classification is done by assigning a sample to a group or a category of similar properties. The categories in this case are forest types, which we here describe using the dominant tree taxa. The maps in the figure below are constructed from pollen percentages that were calibrated or transformed in order to later be interpolated over a grid. For each grid-cell a predicted pollen composition is calculated and later classified by a classification model.

The classification model is an artificial neural network as trained on an entire database of actual pollen assemblages, resulting in a classification model able to classify pollen samples to a forest type. This classification

model is then used on the grid of interpolated fossil pollen assemblages to produce the forest history maps. Fennoscandia is mapped from 10500 BP to present at 500 year intervals. Three of the 22 maps are shown below.

Most classification methods are able to group the most similar samples, but somewhere a decision has to be made on how many classes or groups to use. We have chosen the number of classes which has the highest reproducibility, in this case 6 classes (when data are transformed or calibrated). We have also found the number of classes with the highest reproducibility of the entire European Pollen Database to be 9.

The maps show mixed deciduous forest far to the north in Fennoscandia at 6000 BP. Broadleaved forest is widespread in the south and there is a marked east-west boreal to broadleaved gradient in southern Sweden. By 3000 BP, deciduous forest types persist as far north as central Sweden. Spruce dominance is increasing in Finland. Almost all of Fennoscandia is dominated by the spruce forest type at the present time. The method we have developed makes pollen data accessible to non-specialists and the proposed forest types are comparable with developing classifications of European forest inventory data.

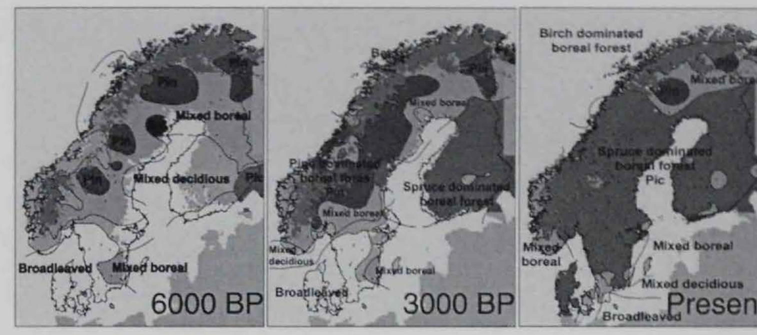

Figure: Forest history mapped using fossil pollen data.

European Pollen Database. http://www.ngdc.noaa.gov/paleo/epd/epd_main.html