INSTITUT DE FRANCE
Académie des sciences

Les Déserts d’Afrique et d’Arabie :
Environnement, climat et impact sur les populations

African and Arabic Deserts:
Environment, climate and impact on populations

Colloque de l’Académie des sciences
Académie des sciences, Institut de France

PROGRAMME ET RESUMES

8-9 septembre 2008

Institut de France
Grande salle des séances
23 quai de Conti – 75006 Paris

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Les Déserts d'Afrique et d'Arabie :
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PROGRAMME

Lundi 8 septembre

9h00- 9h30 Ouverture / **Welcome address**
Jean Dercourt, Secrétaire perpétuel de l'Académie des sciences, Paris

Anne-Marie Lézine, LSCE, Gif-sur-Yvette

9h30-10h15 Conférence Introductive / ***Introductory conference***:
La circulation de mousson au-dessus de l'Afrique et de l'Inde : état des connaissances / ***Monsoon circulation over Africa and India: state of the art***
Serge Janicot, Université Pierre et Marie Curie, UMR 7159 LOCEAN/IPSL, Paris

Le lac Tchad, un exemple d'enregistrement du changement climatique à long terme de l'Afrique sèche / *Lake Tchad: an example of recording long-term climate change in dry Africa*

Chair : Gilles Ramstein, LSCE, Gif-sur-Yvette

10h15-10h45 En Afrique sahélienne (Tchad, Egypte, Libye)… Sur la trace d'un nouveau berceau de l'humanité… / ***In Sahelian Africa (Chad, Egypt, Libya)… On the track of a new cradle of mankind…***
Michel Brunet & MPFT, Collège de France, Chaire de Paléontologie humaine, IPHEP UMR 6046, Université de Poitiers

10h45-11h15 Variabilité hydrologique du bassin du lac Tchad au cours de l'Holocène / ***Hydrological variability of the lake Chad basin since the Holocene***
Guillaume Favreau et al., UMR Hydrosciences Montpellier, Université Montpellier II

11h15-11h45 **Pause**

11h45-12h15 Tendances à long-terme et variabilité à l'échelle du millénaire du développement de la végétation dans le Nord-Ouest africain au cours des 4 derniers millions d'années / ***Long-term trends and millennial scale variability in the Northwest african vegetation development over the past 4 million years***
Lydie Dupont et Suzanne Leroy, Université de Brême, Allemagne et Université de Brunel, Londres

12h15-12h45 Le Bassin du Tchad : paléo-environnements du Sahara depuis la fin du Miocène (ca. 10 Ma)/ ***Chad Basin: paleo-environments of the Sahara since the Late Miocene (ca. 10 Ma).***
Mathieu Schuster & MPFT, Université de Poitiers, IPHED, Poitiers

12h45-13h15 Evolution climatique en Afrique depuis le Miocène d'après l'exemple du lac Tchad / ***Climate evolution of Africa since the Miocene with a focus on Chad Lake***
Pierre Sepulchre, Gilles Ramstein et Gerhard Krinner, LSCE, Gif-sur-Yvette et LGGE Grenoble

L'impact des cycles glaciaires-interglaciaires sur les déserts tropicaux d'Afrique et d'Asie / *Impact of glacial-interglacial cycles on African and Asiatic tropical deserts*

Chair : Françoise Gasse, CEREGE, Aix-en-Provence

14h30-15h00 **Introduction**
Impact de l'insolation sur la variabilité climatique à l'échelle des cycles glaciaires et interglaciaires / ***Impact of insolation on climatic variability during glacial and interglacial cycles***
Masa Kagemaya ,Pascale Braconnot, LSCE, Gif-sur-Yvette

15h00-15h30 Réponse de la dynamique éolienne et fluviale en changement climatique au cours du Quaternaire en Arabie du Sud-Est / ***Response of aeolian and fluvial dynamics to Quaternary climate change in SE Arabia***
F. Preusser et al., Université de Berne, Institut de Géologie, Suisse

15h30-16h00 Spéléothèmes d'Oman et du Yémen / ***Speleothems from Oman and Yemen***
Dominik Fleitmann et al., Université de Berne, Institut de Géologie, Suisse

16h00-16h30 **Pause**

16h30-17h00 Modélisation des variations des moussons africaine et indienne au cours de l'Holocène et téléconnections / ***Modeling the variations of indian and african monsoons during the Holocene, and teleconnexions***
Charline Marzin et Pascale Braconnot, LSCE, Gif-sur-Yvette

17h00-17h30 Paléolacs et paléoclimatologie de l'Est Saharien / ***Paleolakes and paleoclimatology of Eastern Sahara***
Stefan Kröpelin, Université de Cologne, Allemagne

17h30-18h00 Dynamique de la végétation dans l'Ouest africain au cours de l'Holocène : migration vers le nord de plantes tropicales types, en direction du Sahara / ***Vegetation dynamic in West Africa during the Holocene: The northward migration of tropical plant types towards the Sahara***
Julie Watrin et Anne-Marie Lézine, LSCE, Gif-sur-Yvette

POSTERS

Le lac Chad / Lake Chad

P8-1 *Assessment of Holocene surface hydrological connections for the Ounianga Lake catchment zone (Chad):*
C. Grenier, P. Paillou, A.-M. Lézine, P. Maugis

P8-2 *Hydrological model sensitivity to basin topography on Lake Chad, Africa:*
M. Le Coz, F. Delclaux, P. Genthon, G. Favreau

P8-3 *Mapping past landscapes of Sahara using orbital radar:*
P. Paillou

P8-4 *Neogene desertification of Africa:*
M. Pickford, B. Senut, L. Ségalen

P8-5 *Could Megalake Chad « fossil » water remain preserved in the phreatic aquifer?*
R. Zairi, J.-L. Seidel, G. Favreau, A. Alouini, I. Baba Gon

Cycles glaciaires-interglaciaires / Glacial-interglacial cycles

P8-6 *Palynological evidence for the emergence of the Persian civilization in southern section of the Zagros Mountains, SW Iran:*
M. Djamali, J.-L. de Beaulieu, V. Andrieu-Ponel, P. Ponel, R. Lak, N. Sadeddin, H. Akhani

P8-7 *Mid-Holocene vegetation in central Africa: Reconstruction from models and proxies*
C. Hély, S. Brewer, L. Bremond, J. Guiot

P8-8 *Are modern pollen data representative of West African dry ecosystems?*
A.-M. Lézine, J. Watrin, A. Vincens, C. Hély

P8-9 *Sub-guinean ecosystem survival in the Senegalese niayes during Holocene under hydrogeological forcing:*
P. Maugis, C. Grenier, A. Claude, R. Léger

P8-10 *A paleoenvironmental reconstruction of Pozm Bay (Oman Sea – east of the Strait of Hormuz) - a multiiiproxy approach:*
Ch.S. Miller, S. Leroy, H. Lahijani, A. Naderi Beni, M. Shah-Hosseini, P. Collins

Mardi 9 septembre

La fin de la période humide holocène et la mise en place de la variabilité actuelle du climat / *End of Holocene Humid Period and settlement of present-day climate variability*

Chair : Sylvie Joussaume, LSCE, Gif-sur-Yvette

9h00- 9h30 La fin de l'Holocène moyen de la période africaine humide : données fournies par des carottes océaniques. ***The Mid-Holocene end of the African humid period: a view from the ocean***
Peter deMenocal, Lamont-Doherty Earth Observatory of Columbia University, Palisades, USA

9h30-10h00 Changements climatiques et environnementaux à la fin de la période humide holocène : enregistrement pollinique au large du Pakistan ***/ Climate and Environmental change at the end of the Holocene Humid Period: a pollen record off Pakistan***
Sarah J. Ivory et Anne-Marie Lézine, Université d'Arizona, USA et LSCE Saclay, Gif-sur-Yvette

10h00-10h30 Calendrier des changements de végétation à la fin de la période humide de l'Holocène dans les systèmes de moussons atlantique et indienne/ ***Timing of vegetation changes at the end of the Holocene Humid Period in the Atlantic and Indian monsoon systems***
Anne-Marie Lézine, UMR 1572 CNRS, LSCE, Gif-sur-Yvette

10h30-11h00 **Pause**

11h00-11h30 La fin de la période humide holocène dans le désert saharien hyper-aride du Nord du Tchad / ***The end of the Early-Holocene humid period in the hyper-arid Sahara desert of northern Chad***
Dirk Verschuren, Université de Gent, Département de Biologie, Gent, Belgique

11h30-12h00 Modèles de climat et de végétation : comment fonctionnent-ils par simulation de la fin de la période humide africaine ? / ***Climate and vegetation models: How do they perform in simulating the end of the African humid period ?***
Christelle Hély et al. CEREGE, Université Aix-Marseille, Aix-en-Provence

12h00-12h30 A propos du changement brutal climat-écosystème de l'Afrique du Nord au cours de l'Holocène : modélisation, mécanisme, implication / ***On the abrupt change of North Africa Climate-Ecosystem in the Holocene: Modelling, Mechanism and Implication***
Liu Zheng-Yu, Université Winsconsin-Madison, Limnology and Marine Science, Madison, USA

L'homme et son milieu / *Man and his environment*

Chair : Nicole Petit-Maire, Cassis

14h00-14h30 **Introduction**
Extraction de richesses alimentaires par création d'une complexité sociale dans un pays en conditions de privation / ***Extracting wealth by creating social complexity from a land of starvation***
Serge Cleuziou, UMR 7041, Université Paris X, Nanterre

14h30-15h00 Exploitation du paysage dans un environnement en voie d'assèchement. Comparaison de deux études de cas : l'erg Uan Kasa et la vallée de Tanezzuft (Sahara central, Sud-Ouest du Fezzan) de l'Holocène inférieur à l'Holocène récent / ***Landscape exploitation in a drying environment. Two case-studies compared: the erg Uan Kasa and the Tanezzuft valley (Central Sahara, S.W. Fezzan) from Early to Late Holocene.***
Mauro Cremaschi, Université de Milan, Département des Sciences de la Terre, Italie

15h00-15h30 Faire face à l'incertitude : la vie néolithique dans le Dhar Tichitt-Walate, ca 3800-2400 BP/ ***Coping with Uncertainty: Neolithic Life in the Dhar Tichitt-Walata, ca 3800-2400 BP***
Augustin F.C. Holl, Université du Michigan, Département d'Anthropologie, Ann Arbor, USA

15h30-16h00 Contraintes de disette et itinéraires d'accumulation en Moyenne Asie aux temps préhistoriques / ***Scarcity constraints and pathways of accumulation in prehistoric Middle Asia***
Maurizio Tosi, Département d'Archéologie, Université de Bologne, Italie

16h00-16h30 Modalités et caractéristiques des occupations humaines au Yémen, pendant l'Holocène inférieur à moyen ***/ Modalities and characteristics of human occupations in Yemen during the Early/Mid-Holocene***
Rémy Crassard, Université de Cambridge, Département d'Anthropologie, Grande-Bretagne

POSTERS

L'homme et son milieu / Man and his environment

P9-1 *An Early Holocene dry phase recorded at 8.2 kyr BP in the central Sahara. Consequences on landscape and human communities*
M. Cremaschi, A. Zerboni

P9-2 *High-resolution analysis of fish otoliths as indicators of marine environment and fishing practises in North Mauritania at 6730 BP*
E. Dufour, R. Vernet, P. Tous, J.-F. Saliège

P9-3 *A study of the climatic crisis of the end of the Third millennium BC in South-eastern Iran through the lens of geomorphology and archaeology*
E. Fouache, C. Cosandey, C. Adle, M. Casanova

P9-4 *The role of earthquakes in the collapse of arboriculture during the Romano-Byzantine period in the Dead Sea region*
S. Leroy, S. Marco

P9-6 *Evolution climatique du Sahara et de la Péninsule arabique : les deux derniers Interglaciaires*
N. Petit-Maire

P9-7 *Chronologie des monuments à couloir et enclos d'Emi-Lulu, Datation croisée de l'émail dentaire et des os des squelettes des humains inhumés*
J.-F. Saliège, A. Zazzo, F. Paris

P9-8 *Dating the fishermen of Ra's al-Hadd (Sultanate of Oman)*
O. Munoz, A. Zazzo, E. Bortolini, G. Seguin, J.-F. Saliège, S. Cleuziou

CONFÉRENCES

C-1 **INTRODUCTORY CONFERENCE: MONSOON CIRCULATION OVER AFRICA AND INDIA: STATE OF ART**
S. Janicot

C-2 **IN SAHELIAN AFRICA (CHAD, EGYPT, LIBYA) ON THE TRACK OF A NEW CRADLE OF MANKIND…**
M. Brunet & MPFT

C-3 **HYDROLOGICAL VARIABILITY OF THE LAKE CHAD BASIN SINCE THE HOLOCENE**
G. Favreau, F. Delclaux, J. Lemoalle, J. Maley

C-4 **LONG-TERM TRENDS AND MILLENNIAL SCALE VARIABILITY IN THE NORTHWEST AFRICAN VEGETATION DEVELOPMENT OVER THE PAST 4 MILLION YEARS**
L. Dupont, S. Leroy

C-5 **CHAD BASIN : PALEO-ENVIRONMENTS OF THE SAHARA SINCE THE LATE MIOCENE (*CA*. 10 MA)**
M. Schuster and MPFT

C-6 **CLIMATE EVOLUTION OF AFRICA SINCE THE MIOCENE WITH A FOCUS ON CHAD LAKE**
P. Sepulchre, G. Ramstein, G. Krinner

C-7 **IMPACT OF INSOLATION ON CLIMATIC VARIABILITY *DURING GLACIAL AND INTERGLACIAL CYCLES***
P. Braconnot

C-8 **RESPONSE OF AEOLIAN AND FLUVIAL DYNAMICS TO QUATERNARY CLIMATE CHANGE IN SE ARABIA**
F. Preusser, I. Blechschmidt, A. Matter, D. Radies

C-9 **SPELEOTHEMS FROM OMAN AND YEMEN**
D. Fleitmann, S.J. Burns, U. Neff, J. Kramers, A. Mangini, M. Mudelsee, A. Matter

C-10 **MODELING THE VARIATIONS OF INDIAN AND AFRICAN MONSOONS DURING THE HOLOCENE, AND TELECONNECTIONS**
C. Marzin, P. Braconnot

C-11 **PALEOLAKES AND PALEOCLIMATOLOGY OF THE EASTERN SAHARA**
S. Kröpelin

C-12 **VEGETATION DYNAMIC IN WEST AFRICA DURING THE HOLOCENE : THE NORTHWARD MIGRATION OF TROPICAL PLANT TYPES TOWARDS THE SAHARA**
J. Watrin, A.-M. Lézine

C-13 **THE MID-HOLOCENE END OF THE AFRICAN HUMID PERIOD: A VIEW FROM THE OCEAN**
P. deMenocal, J. Cole, J. Arbuszewski, S. Goldstein, S. Hemming

C-14 **CLIMATE AND ENVIRONMENTAL CHANGE AT THE END OF THE HOLOCENE HUMID PERIOD: A POLLEN RECORD OFF PAKISTAN**
S.J. Ivory, A.-M. Lézine

C-15 **TIMING OF VEGETATION CHANGES AT THE END OF THE HOLOCENE HUMID PERIOD IN THE ATLANTIC AND INDIAN MONSOON SYSTEMS**
A.-M. Lézine

C-16 **THE END OF THE EARLY-HOLOCENE HUMID PERIOD IN THE HYPER-ARID SAHARA DESERT OF NORTHERN CHAD**
D. Verschuren

C-17 **CLIMATE AND VEGETATION MODELS: HOW DO THEY PERFORM IN SIMULATING THE END OF THE AFRICAN HUMID PERIOD?**
C. Hély, W. Zheng, P. Braconnot

C-18 **ON THE ABRUPT CHANGE OF NORTHERN AFRICA CLIMATE-ECOSYSTEM IN THE HOLOCENE : MODELLING, MECHANISM AND IMPLICATION**
L. Zheng-Yu

C-19 **EXTRACTING WEALTH BY CREATING SOCIAL COMPLEXITY FROM A LAND OF STARVATION**
S. Cleuziou

C-20 **LANDSCAPE EXPLOITATION IN A DRYING ENVIRONMENT. TWO CASE STUDIES COMPARED: THE ERG UAN KASA AND THE TANEZZUFT VALLEY (CENTRAL SAHARA, S.W. FEZZAN) FROM EARLY TO LATE HOLOCENE**
M. Cremaschi

C-21 **COPING WITH UNCERTAINTY : NEOLITHIC LIFE IN THE DHAR TICHITT-WALATA, CA 3800 – 2400 BP**
A. F.C. Holl

C-22 **SCARCITY CONSTRAINTS AND PATHWAYS OF ACCUMULATION IN PREHISTORIC MIDDLE ASIA**
M.Tosi

C-23 **MODALITIES AND CHARACTERISTICS OF HUMAN OCCUPATIONS IN YEMEN DURING THE EARLY/MID-HOLOCENE**
R. Crassard

INTRODUCTORY CONFERENCE: MONSOON CIRCULATION OVER AFRICA AND INDIA: STATE OF ART

Serge Janicot

UMR7159 Laboratoire d'Océanographie et du Climat : Expérimentations et Approches Numériques, Université Pierre et Marie Curie, Paris VI, case 100, 4 place jussieu, 75252 PARIS CEDEX 05. France.

Un bilan des connaissances est présenté sur les systèmes de mousson d'été boréal en Afrique et en Inde. Les grands traits de ces circulations atmosphériques sont tout d'abord décrits, incluant les principaux centres d'action météorologiques respectifs contrôlant le cycle saisonnier des pluies sur ces deux régions. Puis la sensibilité de ces deux systèmes de mousson aux conditions de surface océanique et continentale est présentée et comparée. L'analyse de la part de la variabilité interne de l'atmosphère et du contrôle par les conditions de surface est ensuite discutée dans le contexte des échelles de temps intra-saisonnière, annuelle, interannuelle et décennale, en séparant la variabilité régionale des téléconnexions tropicales. Les conséquences en terme de prévisibilité sont commentées. Enfin les scénarios climatiques du 4ème rapport du GIEC sur ces deux régions sont présentés.

A review is given of the summer monsoon systems in Africa and India. Features of the circulation are first described, including the main respective meteorological centres of action controlling the annual cycle of the rain bands over these two regions. Then sensitivity of these two monsoon systems to oceanic and continental surface conditions are presented and compared. The analysis of the part of internal atmospheric variability and of the surface conditions control is then discussed in the context of intraseasonal, annual, interannual and decadal time scales, by separating regional variability from tropical teleconnections. Consequences in term of predictability are commented. Finally IPCC4 scenarios of future climate over these two regions are presented.

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IN SAHELIAN AFRICA (CHAD, EGYPT, LIBYA) ON THE TRACK OF A NEW CRADLE OF MANKIND…

Michel Brunet[1] and MPFT[2]

(1) Collège de France Chaire de Paléontologie humaine, 3 Rue d'Ulm, 75231 Paris Cedex 05
Institut International de Paléoprimatologie et Paléontologie Humaine : Evolution & Paléoenvironnements (IPHEP, UMR CNRS 6046). Université de Poitiers F86022 Poitiers Cedex, France.
(2) The Mission Paléoanthropologique Franco-Tchadienne heads by Michel Brunet, is an international scientific transdisciplinary collaboration between Collège de France (Paris), University of Poitiers, University of N'Djamena and CNAR (N'Djamena) including more than sixty researchers from ten countries.

The idea of an ascendance for our species is quite recent (about 150 years ago).
But which was our ancestral group, when and where did it arise? ...If these questions are more constraints they are still always unresolved.

In the 80's, early hominids are known in South and East Africa ; the oldest being in East Africa led to propose an "East Side Story"the bipedal hominid original savannah hypothesis (Coppens, 1983).

From 1994 the M.P.F.T.[2] digging in Djurab desert (northern Chad) unearthed successively a new australopithecine nicknamed Abel (dated to 3.5 Ma), the first ever found West of the Rift Valley (Brunet et al., 1995) and later a new hominid, the earliest yet found (nicknamed Toumaï) *Sahelanthropus tchadensis* Brunet *et al*., 2002 from the late Miocene, dated to 7 Ma (Vignaud *et al.*, 2002; Lebatard et *al.,*2008). This new milestone suggests that an exclusively southern or eastern African origin of the hominid clade is unlikely to be correct.

Since 1994, our roots went deeper, from 3.6 Ma to 7 Ma today, with three new Late Miocene species: *Ardipithecus kadabba* Haile-Selassie, 2001 (5.2–5.8 Ma, Middle Awash, Ethiopia) and *Orrorin tugenensis* Senut *et al.*, 2001 (ca. 6 Ma, Lukeino, Kenya) while the oldest (7 Ma) is the Chadian one. These discoveries have a scientific impact similar to that of *A. africanus* Dart, 1925.

S. tchadensis displays a unique combination of primitive and derived characters that clearly shows that it is not related to chimpanzees or gorillas, but clearly suggests that it is related to later hominids, and temporally close to the last common ancestor between chimpanzees and humans (Brunet *et al.*, 2002 & 2005; C. P. E. Zollikofer & *al*., 2005). In Chad, the Late Miocene sedimentological and paleobiological data are in agreement with a mosaic landscape (Vignaud *et al.*, 2002). Today in Central Kalahari (Bostwana) the Okavango delta appears to be a good analog with a similar mosaic of lacustrine and riparian waters, swamps, patches of forest, wooded islets, wooded savannah, grassland and desertic area (Brunet et *al.*,2005). Among this mosaic the precise habitat of Toumaï is still in progress but probably, as the others known late Miocene Hominids, a wooded one. Moreover these three Late Miocene hominids are probably usual bipeds. So the models that involve significant role for savannah in the hominid origin must be reconsidered. Now, it appears that the earliest hominids inhabited wooded environments and were not restricted to southern or eastern Africa but were rather living in a wider geographic region, including also Sahelian Africa: at least Central Africa (Chad) and may be also northeastern Africa (Libya and Egypt) (Brunet, 2008).

According to, the early hominid history must be reconsidered within completely new paradigms.

Bibliographic references :

Brunet, M. & al. (1995) The first australopithecine 2 500 kilometres west of the Rift Valley (Chad). *Nature* 378: 273-274.
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Dart, R. (1925) *Australopithecus africanus*, the man-ape of South Africa. *Nature* 115: 195-199.
Haile-Selassie, Y. (2001) Late Miocene hominids from the Middle Awash, Ethiopia. *Nature* 412: 178-181.
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Senut, B. & al. (2001) First hominid from the Miocene (Lukeino formation, Kenya). *C R Acad Sci Paris*, Ser IIa, 332: 137-144.
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Zollikofer C.P.E. & al. (2005). Virtual Cranial Reconstruction of *Sahelanthropus tchadensis. Nature* 434: 755-759.

HYDROLOGICAL VARIABILITY OF THE LAKE CHAD BASIN SINCE THE HOLOCENE

Guillaume Favreau[1], François Delclaux[1], Jacques Lemoalle[2], Jean Maley[3]

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The Lake Chad Basin, with about 2.5MKm^2, is the larger endoreic basin in the world. In the center of the basin, Lake Chad is a shallow lake (few metres) of ≤ 25,000 km^2 that has shown great sensitivity to rainfall variability for the past two centuries. During the Holocene, much larger fluctuations of the lake occurred, in response to changes in climatic parameters (rainfall, evaporation). Hydrological modelling was performed in order to simulate, and eventually predict, the water budget of the lake under different climatic scenarios.

A chronicle of Lake Chad water levels was reconstructed for the period covering the Middle Holocene to the present. The maximal extent of the Lake was estimated of about 340,000 km^2 by joint analysis of sedimentary deposits and remote sensing data, during the humid period 8500 – 6300 BP (Leblanc et al., 2006). Several events of lake regression were also determined, with for instance, an almost complete drying up of the lake in the middle of the 15th century. The observed transition from a "great lake" (25,000 km^2) to a "small lake" (~4000 km^2) at the end of the 20th century therefore appears as the natural consequence of climate variability, to which lakeside populations have always adapted (Lemoalle, 2004).

Hydrological simulations were performed in order to quantify the sensitivity of Lake Chad to past climatic conditions. In a first step, calibration was performed over the observed water levels period ; in a second step, modelling was extended back to the last humid period of the Holocene, using climatic parameters outputs from global models. The results discussed will cover the recent period of measurements (1950-2000), and the humid-arid transition at 6000 BP.

References

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LONG-TERM TRENDS AND MILLENNIAL SCALE VARIABILITY IN THE NORTHWEST AFRICAN VEGETATION DEVELOPMENT OVER THE PAST 4 MILLION YEARS

Lydie Dupont[1], Suzanne Leroy[2]

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Records of Pliocene vegetation in Northwest Africa are scarce and still only one record exists that has a millennial temporal resolution, albeit this record has been published almost 15 years ago (Leroy & Dupont 1994, *Palaeo3 109:295-316*). Since then, several modelling studies (*e.g.* Haywood & Valdes 2006, *Palaeo3 237: 412-427*) and data compilations (*e.g.* Salzmann et al. 2008, *Global Ecol. Biogeogr. 17: 432-447*) have increased our knowledge about climate and global vegetation of the Pliocene and the differences with the present-day situation. These studies, however, neglect the climate cycles, which existed in the Pliocene as in the Pleistocene. Millennial scale land-cover variability of Northwest Africa is obvious in the marine high temporal resolution records from the subtropical East Atlantic (ODP Sites 658 and 659; *e.g.* Tiedemann et al. 1994, *Paleoceanograpgy 9: 619-638*). The pollen record of ODP Site 658 indicates alternations between savannah and sahel vegetation, and between sahel and desert vegetation during the Pliocene and Pleistocene, respectively. We'll show long-term trends of the past 4 Ma including the impact of the intensification of the Northern Hemisphere glaciations around 2.7 Ma on the vegetation in Northwest Africa. We'll compare this to the Southern Hemisphere savannah development in south-western Africa. We'll discuss the reduction of river discharge and the increase of the Trade Winds during the Pliocene.

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CHAD BASIN:
PALEO-ENVIRONMENTS OF THE SAHARA SINCE THE LATE MIOCENE (*CA*. 10 MA)

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Chad Basin is an intracratonic sag basin located in North Central Africa. In this basin, the Neogene and Quaternary sedimentation is exclusively continental and shows various fluvial, deltaic, lacustrine and eolian deposits.

Since the middle nineties, the *Mission Paléoanthropologique Franco-Tchadienne* (MPFT) conducts yearly field investigations in Chad Basin. These researches notably led to the discovery of two major early Hominids: (1) *Australopithecus bahrelghazali* which is the first australopithecine found out of the classical early Hominids sites from eastern and southern Africa and (2) *Sahelanthropus tchadensis* which is at time the earliest known Hominid.

Here we present some of the scientific results of the MPFT with focus on the study of the Chad Basin with various methods such as sedimentology, geomorphology, geophysics, numerical simulations and geochronology. We propose an overview of the sedimentary depositional environments of this part of Africa at significant time slices and at different scales of time (*i.e.*, season to Ma) and space (*i.e.*, local to basinal).

Four fossiliferous areas with Neogene vertebrate fauna are known from the Djurab sand sea (Toros-Menalla, 7 Ma; Kossom Bougoudi, 5.2 Ma; Kollé, 4 Ma; Koro-Toro, 3.5 Ma). There, the sedimentary deposits offer the possibility to investigate the dynamic of paleo-environments of north-central Africa from the Late Miocene to the Late Pliocene. That can be very basically schematized as interactions between lake and desert environments. But, contrasting with this basic desert-lake pattern, the sedimentary environments of deposition and correlatively the ecosystems, show a great diversity, with for example open lake, lake shorelines, water ponds, deltas, fluvial systems, paleo-soils, eolian dunes.

The evolution of paleo-environments at the scale of several thousands of years is explored through the pluridisciplinary study of the Holocene Lake Mega-Chad. With a latitudinal extension from *ca.* 10°N to 18°N and a water surface of more than 350000 km^2, this huge paleo-lake is the most striking facet of paleo-environment changes in the Sahara.

The present-day sedimentation in the Chad Basin, and notably the historic evolution of the Lake Chad itself illustrates the dynamic of modern environments at short time scale and reflects a strong control of climate.

Selected bibliographic references: Brunet *et al*., 1995, Nature 378. Brunet *et al*., 2002, Nature 418. Brunet *et al*., 2005, Nature 434. Duringer *et al*., 2006, Naturwissenschaften 63. Duringer *et al*., 2007, Pal. Pal. Pal. 251. Ghienne *et al*., 2002, Quaternary International 87. Lebatard *et al*., 2008, PNAS 105. Schuster *et al*., 2003, Earth Surface Processes and Landforms 28. Schuster *et al*., 2005, Quaternary Science Reviews 24. Schuster *et al*., 2006. Science 311. Sepulchre *et al*., 2006, Science 313. Sepulchre *et al*., 2008, Global and Planetary Change 61. Vignaud *et al*., 2002, Nature 418.

CLIMATE EVOLUTION OF AFRICA SINCE THE MIOCENE WITH A FOCUS ON CHAD LAKE

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Numerous fossil discoveries and sedimentological records from Chad revealed alternating arid and humid phases (leading to giant lacustrine areas) over Chad basin from the Late Miocene (ca. 7 Ma) to the Mid-Holocene. Understanding the underlying climate processes is crucial to better constrain the links between faunal evolution and environments; unfortunately paleoclimatic records are sparse for these timescales. Using an Atmospheric Global Circulation Model, we can assess the atmospheric mechanisms and physical drivers involved in climate evolution of Africa since the Miocene. First, we have tested the impact of the Miocene East-African uplift on the continental precipitation pattern. Through sensitivity experiments, we assessed the elevation influence of the East African Rift System on climate dynamics. We have shown that the uplift played an important role in triggering East Africa rainfall patterns; our simulations reveal that the Upper-Miocene eastern african aridification might have been caused by the Rift shoulders uplift only. On the other hand, we suggest no significant impact of the uplift on central and western Africa rainfall, including Chad basin.

Therefore, we designed another set of experiments to investigate different forcing factors. We have suggested that colder than present Sea Surface Temperature (SST) over the Gulf of Guinea could indeed enhance the West African monsoon by dynamical processes, and move northward the Inter-Tropical Convergence Zone (ITCZ) over the continent. Also, this mechanism, along with reduced albedo linked to changes in vegetation cover, could be stronger than the changes in insolation produced in an AGCM.

Another important local forcing factor is Chad lake itself. To understand the feedback of this giant lake area on the regional climate of Chad basin, we made the first steps of the implementation of a code dedicated to lake and swamp surfaces in the AGCM. First results infer a null to negative feedback of the giant lake on the water balance, as water evaporated from the lake does not feed the local deep convection and is rapidly exported over the western part of the continent.

A last mechanism cannot be implemented in GCMs for the moment : How underground hydrology evolved and influences giant lake Chad in the past ? This crucial question will have to be assessed in future studies.

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IMPACT OF INSOLATION ON CLIMATIC VARIABILITY DURING GLACIAL AND INTERGLACIAL CYCLES

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Monsoon is the major manifestation of the seasonal cycle in the tropical regions, and there is a wide range of evidence from marine and terrestrial data that monsoon characteristics are affected by changes in the Earth's orbital parameters. The African monsoon is embedded in a large scale atmospheric circulation pattern driven by the interhemispheric temperature contrast, the land-sea contrast, and the high elevated heat source on topography. Its intensity and seasonal evolution are controlled by insolation as well as by local features such as the soil albedo or the soil moisture, or remotely forced by sea surface temperature or teleconnection from the other monsoon regions (India and South-East Asia) as well as from changes in the Atlantic circulation. The relative intensity of these factors has varied in time to shape the African environment.

A wide range of simulations of the mid-Holocene (6000 yrs BP) and of the Last Glacial Maximum realised as part of the Paleoclimate modelling Intercomparison Project (Joussaume and Taylor, 1995; Braconnot et al., 2007) offers the possibility to analyse how the African monsoon has varied when the seasonal cycle of insolation was enhanced in the northern hemisphere or under cold condition with the presence of ice sheet and lower CO_2. These simulations allow us to infer the respective role of the orbital forcing, trace gazes and feedbacks from changes in the ocean circulation and in the land surface cover. The multi-model approach is also interesting to infer which aspects of the climate change are robust and which are model dependent and need further investigation. Both climates are characterised by different migration of the ITCZ in the African continent that have been quantified (Braconnot et al., 2007). Illustrations will focus of the role and of the vegetation in triggering the insolation forcing during Mid-Holocene, and on the reduction of the water vapour feedback and its link with precipitation for the Last Glacial Maximum. A discussion of the differences between model results will consider the possible contribution of model biases in the model response, as well as differences in the link between the large scale circulation, convection and surface parameters.

Coupled ocean-atmosphere simulations allow us to also study changes in the interannual to multi-decadal variability. Analyses of the interaction between the El-Niño phenomenon, characterized by unusual warming in the east tropical Pacific SST, and sahel precipitation show that the teleconnection was reduced during Mid-Holocene (Zhao et al., 2005). These results are in agreement with the reduction of ENSO intensity in the Pacific as recorded by several proxy indicators (Moy et al., 2002).

The analysis of the role of the insolation in triggering the African monsoon system has also be enlarged to other climatic periods covering the Eemien and the Holocene. Considering a set of simulations with the IPSL coupled model, it is possible to infer how the change in precession affect the seasonality of the African monsoon. The comparison of the different periods will also permit us to better understand the different factors affecting the length of the rainy season, the intensity and duration of dry spell, and threshold in the functioning of this system that are relevant for the understanding of future climate change, in a region for which future climate projection actually fail to produce a consistent view for the last century.

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Response of aeolian and fluvial dynamics to Quaternary climate change in SE Arabia

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The southern part of the Arabian Peninsula is today just north of the influence of Monsoon induced precipitation. However, from both lacustrine deposits and speleothem data it is known that the region was affected by the Monsoon several times in the past. The strengthening and weakening of the Monsoon caused important changes in the environmental conditions of the region. The aim of our investigation is in particular to identify the impact of past climate change on aeolian and fluvial dynamics and their palaeoclimatic implications. Optical dating indicates that periods of aeolian deposition in the Wahiba Sands, SE Oman, coincide with phases of mid-latitude glaciations, weak Monsoon circulation and low global sea level. The reconstruction of the low altitude wind field as deduced from aeolian bedding shows that the atmospheric circulation pattern during this time was apparently similar to that of the present day. The most striking issue of the circulation today and during glacial times is the position of the InterTropical Convergence Zone (ICTZ) during summer over the southern most part of the Arabian Peninsula, but north of the Wahiba Sands. This area is characterised by generally low wind velocity and the formation of star dunes. The West of the Wahiba Sands is made up of a huge floodplain consisting of debris originating from the Oman Mountains as demonstrated by the flow pattern seen in satellite images and by the petrography of the deposits. However, up to now the aggradation age of the braided plain was not known. New results of optical dating indicate that deposition of the sediment took place during at least three phases at about 340 ka, 220 ka and 130 ka ago, although the latter phase is only indirectly dated. All these phases coincide with increased Monsoon precipitation as identified in the speleothem record that implies a direct connection between fluvial sedimentation and the strengthening of the Monsoon.

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SPELEOTHEMS FROM OMAN AND YEMEN

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Speleothems (e.g., stalagmites) from Oman and Yemen document periods of more rapid growth only during interglacial periods. In Hoti Cave in northern Oman, a composite record of U/Th age determinations on 8 speleothems shows that rapid growth occurred during discrete intervals : the Early to Mid-Holocene, and time periods equivalent to marine isotope stages (MIS) 5a, 5e, 7a and 9. Similarly, age dating of a large stalagmite from southeastern Yemen indicates growth during MIS 5e, 7 and 9. Importantly, in both areas, individual stalagmites record growth during MIS 5, 7 and 9, suggesting that the intervening periods were continually too dry to result in speleothem reactivation. In all cases, the $\delta^{18}O$ values of speleothem carbonate are highly negative when compared to values compatible with the modern arid climate. The very negative values are attributable to monsoon rainfall. Other records of continental wetness support our chronology. Analyses of pollen in marine sediments from both sides of equatorial Africa show peaks in species indicative of tropical humid conditions during the Early Holocene and in sediments deposited during MIS 5a and 5e (e.g., Prell and Van Campo, 1986). These continental records of monsoon-driven changes in precipitation contrast greatly with records of Indian Ocean monsoon intensity derived from marine sediments in the Arabian Sea and Indian Ocean. Marine proxies for variation in monsoon winds are based on indicators of wind strength or wind-driven upwelling, for example, lithogenic grain size, carbon mass-accumulation rates, or relative percentages of foraminifers or coccolithophores. The majority of these records vary primarily with a periodicity of ~ 20 ka, close to the precessional cycle in the Earth's orbit records (e.g., Clemens and Prell, 2003).

For the Holocene high-resolution oxygen isotope $\delta^{18}O$ profiles of Holocene stalagmites from four caves in Oman and Yemen (Socotra) provide detailed information on fluctuations in precipitation along a latitudinal transect from 12° N to 23° N. $\delta^{18}O$ values reflect the amount of precipitation which is primarily controlled by latitudinal position and strength of the ITCZ and dynamics of the Indian summer monsoon (ISM). A rapid Early Holocene rise in $\delta^{18}O$ indicates a rapid northward displacement in the latitudinal position of the summer ITCZ and the associated ISM rainfall belt. Decadal- to centennial-scale changes in monsoon precipitation correlate well with high-latitude temperature variations recorded in Greenland ice cores. During the Middle to Late Holocene the summer ITCZ continuously migrated southward and monsoon precipitation decreased gradually in response to decreasing solar insolation, a trend which is also recorded in other monsoon records from the Indian and East Asian monsoon domains. Importantly, there is no clear evidence for an abrupt Middle Holocene weakening in monsoon precipitation, although abrupt monsoon events are apparent in all monsoon records. However, these events are clearly superimposed on long-term trend of decreasing monsoon precipitation. For the Late Holocene there is an anti-correlation between ISM precipitation in Oman and inter-monsoon (spring/autumn) precipitation on Socotra, revealing a possible long-term change in the duration of the summer monsoon season since at least 4.5 ka B.P. Together with the progressive shortening of the ISM season, gradual southward retreat of the summer ITCZ and weakening of the ISM, the total amount of precipitation decreased in those areas located at the northern fringe of the Indian monsoon domain, but increased in areas closer to the equator.

References :

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MODELING THE VARIATIONS OF INDIAN AND AFRICAN MONSOONS DURING THE HOLOCENE, AND TELECONNECTIONS

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This study investigates the role of insolation in controlling the Indian and African monsoons evolutions during the Holocene using coupled ocean-atmosphere simulations of 0, 4, 6 and 9.5 kyr BP climates, for which only the variations of Earth's orbital configuration are considered. The monsoon subsystems are enhanced at the beginning of the Holocene compared to present, as a result of the intensified seasonal cycle of insolation in the Northern Hemisphere. Emphasis is put on the impact of the precession on the seasonality, which partly explains why the relative amplification of the Indian and African monsoon varies between 9.5 and 6 kyr BP. Interestingly, in addition to their intensity, the timing and the length of the rainy seasons are affected by those different forcings. Moreover, the changes in snow cover over the Tibetan Plateau play a critical role in reinforcing the 9.5 kyr BP monsoon in India during spring. The results suggest that the teleconnection between convection over India and subsidence over the Mediterranean regions, through the Rodwell and Hoskins mechanism, has an impact on the development of the African monsoon at 9.5 kyr BP. We also discuss the impact of a fresh water flux from the North Atlantic on the development of monsoon systems using a similar set of simulations with a reduced fresh water flux in this area.

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PALEOLAKES AND PALEOCLIMATOLOGY OF THE EASTERN SAHARA

Stefan Kröpelin

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During the Early and Middle Holocene, the Eastern Sahara of Eastern Libya, Western Egypt, Northeast Chad and Northwest Sudan–presently the largest hyperarid warm desert on earth–, has been dotted with hundreds of lakes. Most of them occurred in deflation basins that were hollowed out during the preceding Late Pleistocene arid phase, or in dune-blocked valleys. The bodies of water ranged from small shallow ponds with a surface of merely 100 m² in the Great Sand Sea of Egypt to the 5,000 km² and 20 m deep lake system in Northwest Sudan that we have named "West Nubian Paleolake". Of all these paleolakes, only the tiny salt pool at Nukheila in the Sudanese desert and the few lakes at Ounianga Kebir and Ounianga Serir in Northeast Chad have persisted to the present day because of their exceptional hydrogeological setting.

North of latitude 22° N, the paleolakes were temporary rain-fed pools that were not supported by the regional sandstone aquifer and water-filled for weeks or months at best (so called "dry playas"). The siliceous mud of these seasonal to episodic lakes is typically void of any biological content. South of 22° N, there were mostly permanent freshwater lakes buffered by groundwater during the dry seasons and hence existing up to several millennia. Their carbonate deposits include a wide spectrum of microfaunal and microfloral remains, gastropods, bivalves and some 30 species of fish.

The paleolake shores were the principal habitats of wildlife and prehistoric populations. Along with archaeological material and valuable indicators such as charcoal remains, the lacustrine deposits provide the key archives for reconstructing past environments and climate variations in the Sahara even if open water surfaces have covered but a minor percentage of the total landscape.

The combined geological and archaeological data suggest a consistent model for a coherent region of sub-continental scale throughout the Holocene. The onset of semi-arid conditions in the north and semi-humid conditions in the south at around 10,500 cal BP was controlled by monsoonal rainfall which shifted the desert margin up to 800 km further north. This fundamental climatic change from terminal Pleistocene hyper-arid desert conditions to savannah-type vegetation and the formation of lakes and temporary rivers resulted in the rapid dissemination of wild fauna and the swift reoccupation of the entire Eastern Sahara by prehistoric populations. Relatively stable ecological conditions prevailed over the following 3,200 years until about 7,300 cal BP. The subsequent southward retreat of monsoonal precipitation can be tracked to the present by the discontinuance of aquatic deposits at decreasing latitudes and by the distribution of occupation sites which both indicate gradual desiccation and environmental deterioration, notwithstanding transitory climatic fluctuations at the desert margins. This is irrefutable evidence that the dominating rains feeding the lakes and recharging the groundwater came from and retreated to the tropical regions. Mediterranean winter rains have apparently only reached as far as the Tropic of Cancer, especially during the Mid-Holocene period.

Pre-Holocene lithostratigraphic records from the Eastern Sahara remain scarce and poorly dated. They consist of erosional remains of indurated carbonate crusts and lakeshore ferricretes. The incomplete evidence suggests that during the last interglacial (Eemian / MIS 5; 130-75 ka BP) several episodes of major lake formation occurred that apparently were unparalleled during the Upper Quaternary climatic cycles. The assumption of uninterrupted aridity from early to postglacial periods remains a matter of controversy.

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VEGETATION DYNAMIC IN WEST AFRICA DURING THE HOLOCENE: THE NORTHWARD MIGRATION OF TROPICAL PLANT TYPES TOWARDS THE SAHARA

Julie Watrin, Anne-Marie Lézine

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The review of palynological and paleobotanical data show that the Saharan desert experienced important phytogeographical modifications during the last few thousand years. Around 8500 yrs B.P., at the time of the maximum of the humid period, lakes and wet lands probably occupied 0.5% (in western Africa) to 5.8% (in eastern Africa) and 1.1% to 8.2% of the total land surface of northern Africa between 10 and 30°N (Hoelzmann *et al*., 1998), while large paleodrainage were formed or re-actived, in response to orbitally induced increase in monsoon rainfall.
It has been suggested that the direct consequence of this increase in rainfall was the northward displacement of the Sahara/Sahel boundary which is thought to have reached 23°N in the central and eastern northern Africa. Our study shows that land surface conditions in the Sahara testified from a more complex situation characterized by an increase in diversity as the desert steppe accommodated more humid-adapted species from Sahelian to Guinean tropical forests and Savannahs: Tropical plant species (e.g., *Alchornea, Celtis*, …), nowadays found some 400 to 500 km southward, probably entered the desert as riverine forest formations along rivers and lakes where they benefited from permanent fresh water. However, at the same time, Saharan trees such as *Ziziphus, Salvadora* and *Tamarix* persisted, testifying for a complex, "no-analogue" situation. In this paper, we first calculate the migration rate of tropical plant types from the Gulf of Guinea, where they persisted during the LGM to their northernmost position in central Sahara in response to the increase in rainfall at the beginning of the "African Humid Period" 15 000 years ago. It varied, according to species and time from 300 to 400m per year. Then we draw distribution map of selected plant species to discuss (1) the amplitude of the environmental change compared to the present and (2) the arrangement of species within the ecosystem. This study is based on the use of several data sets: a data set of modern plant distribution in northern Africa and related climate requirement (Watrin, in progress) and a data set of modern and fossil pollen sites (from the African Pollen Database).

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THE MID-HOLOCENE END OF THE AFRICAN HUMID PERIOD: A VIEW FROM THE OCEAN

Peter deMenocal, Jenna Cole, Jennifer Arbuszewski, Steve Goldstein, Sidney Hemming

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During the African Humid Period (AHP) much of modern hyperarid Saharan desert was vegetated, with numerous perennial lakes and supporting abundant fauna. In marine sediments off northwest Africa, the AHP is recognized as an interval between 14.5-5.5 ka BP with markedly reduced eolian dust fluxes. One of the remarkable features of this record is the abrupt, century-scale onset and termination of the AHP. Such abrupt climate transitions have been observed in some north African paleolake records, but recent pollen evidence from northern Chad (Lake Yoa) indicates much more gradual transitions.

This study uses Nd and Sr isotopic and major/trace element compositions of the terrigenous fraction at ODP Site 658 off Mauritania to assess the origin of the terrigenous depositional changes associated with the AHP. I will also be presenting preliminary new data from a recent sediment coring cruise along the NW African margin (a meridional transect of 28 coring stations from Gibraltar to Senegal) to address the timing, abruptness, and meridional extent of the AHP.

At ODP Site 658, the Nd isotope composition of terrigenous detritus shows little variability throughout the last 25 kyr, indicating that the contributing geological terranes have not measurably changed since the Last Glacial Maximum. In contrast, we observed large and abrupt changes in Sr isotope ratios and major and trace element concentrations associated with the AHP that closely follow the abrupt terrigenous sediment flux changes.
During the AHP, 87Sr/86Sr ratios are lower and sediments have higher chemical indices of alteration. Taken together, these data indicate the supply of an additional highly-weathered, authigenic mineral phase during the AHP (derived from the same parent material) that formed in and around lake margins. We propose that increased vegetation during the AHP reduced total terrigenous fluxes to the ocean, and these newly formed Mg-rich clays that formed in association with ephemeral lakes probably became available during seasonal drying, thus dominating the terrigenous component.

Our preliminary results from sediment cores recovered during the recent CHEETA (Changes in the Holocene Environment of the Eastern Tropical Atlantic) sediment coring cruise off NW Africa suggest that the abrupt termination of the AHP near 5.5 ka BP can be traced from Senegal to the Canary Islands (roughly 18-28°N). These results suggest that the end of the AHP was indeed abrupt along the west African margin whereas it was more gradual in the eastern Sahara.

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CLIMATE AND ENVIRONMENTAL CHANGE AT THE END OF THE HOLOCENE HUMID PERIOD: A POLLEN RECORD OFF PAKISTAN

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Pollen analyses from core SO90-56KA taken from the Oxygen-Minimum Zone on the continental shelf off the coast of Pakistan (24° 509N, 65° 559E; 695 m water depth) in the Arabian Sea provides the first high-resolution continuous record of the influence of the Indian Monsoon regime on climate and vegetation change from the Pakistan hinterland during the transition from the humid Mid-Holocene over the last 5400 cal yr BP.

The aridification associated with the weakening of the SW monsoon has long been thought responsible for the demise of the Akkadian civilization in western Arabia and the urban Harrapan society of the Indus valley. This change in the annual repartition of precipitation has been observed in many studies with studies reporting centennial or millennial arid-humid climate alternations (e.g., Gupta et al., 2003, Morrill et al., 2003), abrupt (Cullen et al., 2000), or gradual patterns (Caratini et al, 1994). Also recorded in some studies are episodes of enhanced winter rains (Enzel et al., 1999, Luckge et al 2001) brought by northwesternlies from the Mediterranean. The core site, 60 km south of the Makran coast, is located at the present day edge of domination of summer and winter precipitation, an important place detecting not only change in total annual precipitation but also repartition of annual precipitation.

In agreement with other studies recording total lake desiccation in southern Arabia (Lézine et al., in press), in the Thar Desert (e.g., Enzel et al., 1999) and the widespread extension of dry environmental conditions (Ansari and Vink, 2007) before 5500 yr BP, our results also show that aridity was already established in Pakistan by 5400 cal yr BP based on high percentages of xeric plant communities. However, despite the evident aridity, opposing trends of Amaranthaceae-Chenopodiceae and *Artemisia* against other humid indicators (Cyperaceae, Poaceae) suggest that the diminishing SW precipitation regimes associated with the summer monsoon and the installation of present vegetation progressed gradually.

Core SO90-56KA shows the end of humid period in Pakistan at 4700 cal yr BP which predates by about 1000 years previous observations from other pollen records from NW India. Superimposed on the overall evolution of climate directly linked to summer insolation in the northern hemisphere, several fluctuations in Summer and Winter monsoon strength are recorded throughout the last five millennia. Three main periods can be distinguished:
- from 5400 to 4700-(4200) cal yr BP is a wet period dominated by summer monsoon rains responsible for mangrove extension and fresh water input to the core site ;
- from 4200-2000 cal yr BP is a period of progressive dryness and the dominance of NE winter monsoon fluxes ;
- from 2000 to1000 cal yr BP, there is a brief return to SW-dominated monsoon fluxes in a general context of widespread aridity.

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TIMING OF VEGETATION CHANGES AT THE END OF THE HOLOCENE HUMID PERIOD IN THE ATLANTIC AND INDIAN MONSOON SYSTEMS

Anne-Marie Lézine

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Environmental reconstructions of tropical deserts during the Mid- to Late Holocene have mainly focused on northern Africa. There, lake level and pollen data have been used for regional reconstruction of past hydrological or vegetation changes (e.g., Lézine, 1998; Hoelzmann et al., 1998; Gasse, 2000) as well as for paleoclimatic models connecting environmental changes with variations in the Earth's orbit or investigating vegetation and ocean feedback in the climate system. By contrast, little is known about western Asia, one of the most arid areas of the world with extensive desert areas (Rub al Khali in the Arabian Peninsula, Thar desert in western India …), although recent studies on speleothems from Oman (Fleitman et al., 2003) or paleolake from Yemen (Lézine et al., 2007) yielded high resolution records of variations of the Indian summer monsoon during the Holocene. In such arid areas however, the scarcity of continuous sedimentary archives make it difficult any investigation of the impact of monsoon variability on vegetation and possible feedback of land cover changes on regional climate.

New pollen data from continuous and well dated sedimentary sequences from desert areas of northern Africa and western Asia are presented here to document the shift from humid to arid environmental conditions and the onset of the modern climate regime at the end of the Holocene Humid Period. The most striking features are: (1) the progressive setting of modern arid conditions at the northern edge of the tropical zone of influence (2) the reduction in tropical environments at 4700 cal yr BP in all records from northern Chad (Lake Yoa, Kröpelin et al., 2008), Oman (Kwar al Jaramah) and the Makran coast (Core SO90-56KA, Ivory and Lezine, this volume) suggesting a coherent climate signal on a regional scale.

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THE END OF THE EARLY-HOLOCENE HUMID PERIOD IN THE HYPER-ARID SAHARA DESERT OF NORTHERN CHAD

Dirk Verschuren

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Desiccation of the Sahara since the Mid-Holocene has eradicated all but a few natural archives recording its transition from the Early Holocene 'green Sahara' into the world's largest hot desert it is today. A critical issue regarding this natural, climate-driven desiccation is whether it was a slow process evolving over several millennia, or a more abrupt change, i.e. completed within a few hundred years, that might point to important feedback processes between declining rainfall and vegetation dynamics. A uniquely continuous lake-sediment record from Lake Yoa in hyper-arid northern Chad has now permitted parallel reconstruction of the evolution of the local aquatic ecosystem and of terrestrial vegetation on the surrounding landscape over the past 6000 years. This multiple-proxy reconstruction reveals a progressive drying of the region's terrestrial ecosystem between 5600 and 2700 years ago, in response to gradually weakening northern-hemisphere summer insolation forcing of the African monsoon. This drying followed a logical ecological sequence, in which tropical grassland trees and herbs were first replaced by typical sahel vegetation, followed by loss of grass cover and establishment of the modern-day sparse desert plant community. Lake Yoa's aquatic ecosystem experienced a more abrupt transition from freshwater to hypersaline conditions between 4200 and 3900 years ago, when a by then strongly reduced regional water balance interacting with site-specific hydrological thresholds stopped groundwater outflow and allowed salts to accumulate in the lake itself. Pollen- and dust-influx data indicate that the present-day regional wind regime with strong northeasterly trade winds blowing almost year-round through the Tibesti-Ennedi corridor was established around 2700 years ago. The Lake Yoa record illustrates the complex relationship between Saharan ecosystems and climate during Holocene aridification. The documented gradual rather than abrupt termination of the African Humid Period in the eastern Sahara, indicating a relatively weak biogeophysical feedback of vegetation on climate, implies that the iconic record of Saharan dust deposition in the tropical Atlantic Ocean cannot be considered representative for landscape history throughout dry northern Africa.

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CLIMATE AND VEGETATION MODELS: HOW DO THEY PERFORM IN SIMULATING THE END OF THE AFRICAN HUMID PERIOD?

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Paleoenvironmental studies carried out in tropical Africa have demonstrated that the Sahel and Sahara experienced strong variations in rainfall during the last thousand years. Holocene lake levels were 10-100 m higher than today, and the Lake Chad surface reached up to 340 000 km^2. Tropical vegetation expanded northwards, decreasing the desert area. However, several examples in sedimentary records illustrate successive « climate crises », developing over only a few years, inducing the drying out of lakes and subsurface runoff. In particular, an "abrupt" change in the atmospheric circulation has been recorded off the Mauritanian coast 5500 cal BP illustrating the end of the African Humid Period (AHP) and the onset of the modern climate regime. The drying of environmental conditions through this large decrease in water availability resulted in the retreat of tropical vegetation and the setting of modern, desertic conditions in the Sahara. How abrupt was the shift from moist to arid conditions is the matter of debate since the publication of the unique continental paleo-archive of Lake Yoa by Kröpelin and co-authors (2008). They show that Sahara drying was in fact a gradual process developing between 5600 and 2700 years ago.

Here we examine the PMIP2 simulations of mid-Holocene and the coupled AO IPSL-CM4 of four periods from Early Holocene to present day to understand and quantify the shift from humid to arid state. Model simulations show that the African monsoon is enhanced during the paleoclimate as a result of the intensified seasonal cycle in the Northern Hemisphere. The precipitation related to the monsoon of North Africa, especially in the SAHEL, is also enhanced. The simulations of IPSL model also show a gradually decreased of the summer precipitation in SAHEL from Early Holocene to present day. Associated to this large-scale general trend are the dry spells that changed in length and amplitude. We tested the effect of such changes in climate conditions on vegetation using a Dynamic Global vegetation Model (DGVM) that we run off-line, without any feedback from vegetation to the atmosphere. We also tried to take into account changes in soil hydrology, as a consequence of climate change, and their effects on vegetation in the model. Simulated vegetation response, in terms of composition, was compared with reconstructed biome vegetation from pollen samples. We discuss the sensitivity of simulated vegetation to dry spells as well as the DGVM efficiency to reproduce the kinetics of vegetation changes.

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ON THE ABRUPT CHANGE OF NORTHERN AFRICA CLIMATE-ECOSYSTEM IN THE HOLOCENE : MODELLING, MECHANISM AND IMPLICATION

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One of the greatest climate-ecosystem changes in the last 10,000 years occurred in North Africa. A green Sahara in the Early to Mid-Holocene changed to a present day desert, with a great reduction in vegetation cover and lake area. Moreover, this dramatic desertification occurred abruptly in the Mid-Holocene within centuries. Although the overall desertification is recognized to be caused by orbital forcing, with feedbacks from land and ocean, it has remained poorly understood why this desertification occurred so abruptly.

Modelling studies so far have exhibited a wide range of transient evolution behaviours, including an abrupt collapse in both the climate and ecosystem, an abrupt collapse in the ecosystem but a gradual reduction in climate, an abrupt change only in climate variability, and the absence of any abrupt changes.

Here, we will discuss these model simulations and examine the potential mechanism for the abrupt changes. A unified view is proposed to account for the variety of abrupt changes in the models, with the focus on the potential roles of vegetation feedback and climate variability in the generation of abrupt changes in the Africa climate-ecosystem. Furthermore, we discuss the implications of the modelling activities to the understanding of the mechanism of climate-ecosystem feedbacks. Finally, we will discuss the implications of the model simulations to the interpretation of the paleoclimate proxy records as well as the potential strategy for better future proxy records.

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EXTRACTING WEALTH BY CREATING SOCIAL COMPLEXITY FROM A LAND OF STARVATION

Serge Cleuziou

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Arid areas are often considered as places where emergence of new types of societies and economies are unlikely to happen, due to the environmental restrictions they impose on land use, food production and settlement patterns. It was not always considered as such and aridification of climate was for long accepted as a factor in the development of food production. This was in the late 1920s the scenario known as the *oasis theory* promoted by Vere Gordon Childe for the beginning of the Neolithic in the Near East. According to him, plants, animals and among them Man tend to concentrate around the places where water was still available. With the progress in climate studies and archaeological dating, the theory became replaced by Braidwood's nuclear zones scenario according to which domestication of plants and animals occurred in areas where both were naturally abundant, leading human societies to select those that were useful to them and try reproducing progressively these relations in less favorable areas by protecting useful fields and herds. Desertification of vast areas that once could have been flourishing, such as the Sahara then became a popular topic, and theories linking the collapse of the earliest complex societies are now rather successful. We would like to advocate here that, although it would be unrealistic not to consider climatic change, both in short and long term, as an important factor in the development of human societies, a purely deterministic approach is simply irrelevant. Whatever their level of complexity, societies perceive climatic change and react to it according to their representations of nature and to their history. We may imagine cases where transformations in climate and landscape may create new opportunities for successful new land use and new social organizations that cannot be directly predicted. In other words, establishing a direct correlation between indicators of climatic change and social organization is unrewarding. We advocate here that modeling social evolution in conjunction with environmental changes through the use of non linear multi agent models, although its implementation in the field of human sciences is complex and difficult, is probably a much more fruitful way to understand in the *longue durée* the relation between Man and climate, to propose informed and responsible social action, not fear of natural or Man induced changes, as a way to face the situation as it is perceived during these early years of our 3rd millennium AD.

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LANDSCAPE EXPLOITATION IN A DRYING ENVIRONMENT. TWO CASE STUDIES COMPARED: THE ERG UAN KASA AND THE TANEZZUFT VALLEY (CENTRAL SAHARA, S.W. FEZZAN) FROM EARLY TO LATE HOLOCENE

Mauro Cremaschi

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The Erg Uan Kasa and the wadi Tanezzuft valley border respectively the east and the west fringes of the Tadrart Acacus mountains and similarly to this area, well known for the rock art galleries, they were densely populated all over the Saharan Prehistory. Due to their specific physiographic characteristics, these areas reacted in a different way to the Holocene climatic changes and the human groups settled in them gave rise to complex models of adaptation to the drying environment. The erg Uan Kasa enjoyed a large water supply during the Early and Middle Holocene, both by intensified monsoon rain and for the improved discharge of watercourses flowing from Acacus. Consequently shallow lakes were formed in the interdune corridors, together with extensive marshes and deep soils on the dune slopes. A large number of Epi-Palaeolithic sites were found along the fringes of the dunes and mainly in the interdune lakes, where they are buried below peat deposits radiocarbon dated to the IX millennium BP. The shores indicating the highest lake stand dating back to the VI millennium BP, are dotted with hundreds of pastoral Neolithic sites, composed of cluster of fireplaces, storage pits, faunal remains and grinding equipment. The erg Uan Kasa dried out at about 5000 years ago, while in the following millennia the area was not completely abandoned as it is indicated by clusters of tethering stones on the surfaces of desiccated lakes. During the wet Holocene the wadi Tanezzuft was a large meandering river, with high discharge .A secondary branch of the river fed a large lake (Gara Houda). Hundred of pastoral Neolithic sites have been found along its margins in which fishing activities are also recorded. At about 5000 y BP also this area dried out and wadi Tanezzuft was not exhausted by this dry episode but changed its pattern, and a silty alluvial valley originated in the upper reach of its former course. In this way a large oasis was originated and from the fourth to the second millennium BP it was intensively settled by Late Neolithic communities and later by the Garamantes. More than four hundred of archaeological sites were recorded, buried inside the alluvial deposits.

Occurrence of large grinding equipment, gouges, and lithic hoes, may indicate the introduction of agricultural practice, further supported by the pedological evidence indicative of soil management. As an effect of increasing desiccation the Tanezzuft oasis suffered a drastic reduction in size during the first centuries A.D, in coincidence with the abandonment of the local Garamantian settlements.

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COPING WITH UNCERTAINTY: NEOLITHIC LIFE IN THE DHAR TICHITT-WALATA, CA 3800 – 2400 BP

Augustin F.C. Holl

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The sandstone escarpment of the Dhar Tichitt-Walata in south-central Mauritania was inhabited by Neolithic agro-pastoral communities for approximately one and half millennium during the Late Holocene, from ca 3800 to 2400 BP. The absence of prior evidence of human settlement points to the influx of mobile herders moving away from the “drying” Sahara toward more humid lower latitudes. These herders took advantage of the peculiarities of the local geology and environment and succeeded in domesticating bulrush millet – *Pennisetum sp.* -. The emerging agro-pastoral subsistence complex had conflicting and/or complementary requirements depending on circumstances. In the long run, the social adjustment to the new subsistence complex, shifting site location strategies, nested settlement patterns, and the rise of more encompassing polities appear to have been used to cope with climatic hazards in these relatively circumscribed areas. An intense arid spell in the middle of the first millennium BC triggered the collapse of the whole Neolithic agro-pastoral system and the abandonment of the areas. These regions, re-settled by sparse oasis-dwellers populations and iron-using communities starting from the first half of the first millennium AD, became part of the famous Ghana “empire”, the earliest state in West African history.

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SCARCITY CONSTRAINTS AND PATHWAYS OF ACCUMULATION IN PREHISTORIC MIDDLE ASIA

Maurizio Tosi

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During Middle Holocene times the scattered Neolithic communities that occupied the alluvial lowlands in the vast arid landmass north of the Arabian Sea, encased between the Iranian Plateau and the tectonic corrugations of Baluchistan carving the NW borderlands of the Indian Subcontinent, experienced an impressive forward drive towards socio-political complexity and wealth accumulation hardly relatable to the available stocks of natural resources. By 3000 BCE even the smallest alluvial enclaves fed by water flows cutting through desert and steppe had attained levels of proto-urban nucleation comparable for size and complexity with the contemporary conditions along the river corridors of Egypt, Mesopotamia and the Indus.

Around 5000 BCE all these land-locked basins were settled all year round by village networks of farmers combining cereal cultivation with the mixed herding of cattle and ovicaprids. These enclaves incorporate alluvial basins ranging from 1000 sq. km. around minor streams of piedmont discharge to vast of endoreic deltas of 15-20,000 sq. km., like the Helmand in Sistan, the Gorgan in NE Iran, the Tejen and Murghab in SE Turkmenistan. Agricultural production depended from irrigation and water and it had to be supplied by combining natural and artificial drainage channels. The balance among population, farmland and resources remained extremely delicate, with little surplus stocks to count on. At the end of the Early Holocene, in the 6^{th} millennium BCE, and for most of the Middle Holocene, there is substantial evidence that large water bodies, like interdunal ponds, shallow swamps and terminal lakes, were still wide enough to ensure additional food from the gathering of fish, fowl and a variety of mammals in good supply in order to buffer periods of lower productivity. Their integrative exploitation is rather well documented by bio-archaeological remains. However since basic food stocks were built on wheat, barley, cattle, sheep and goats any increase in population density would have required a comparable growth in food production.

Irrigation water would have remained critically scarce and this is evident by the construction of artificial waterworks as early as 4000 BCE, when canals 3-5 km long were dugon a sub-fossil delta of the Tejen to increase the water supply around the central settlement of Geoksyur 1. Such massive earth moving construction works required large labor investments that involved the populations of several villages in combined efforts. It was a desert economy maintained by an oasis society based on labor division, mutuality, cooperation and exchanges.

Hence we suggest that the adaptive response came from political strategies of social condivision. This assumption is further indicated across the archaeological record for increasing craft specialization at household level there is in all manufacturing sectors. The integration increases during the 5^{th} millennium BCE along with dependency from interregional circuit of exchange several raw materials.

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MODALITIES AND CHARACTERISTICS OF HUMAN OCCUPATIONS IN YEMEN DURING THE EARLY/MID-HOLOCENE

Rémy Crassard

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The study of the Late prehistory (Early/Mid-Holocene) of Yemen profits from multiple approaches, on various geographical scales and through various research orientations, which allows proposal of a preliminary definition of Southwest Arabian prehistory. It is thus possible to determine, with more precision than before, the particular place Yemen could occupy during the Early/Mid-Holocene. Technological studies of lithic industries are on this subject particularly interesting, since the lithic assemblages constitute relevant comparative data.

Still few sites of reference are known in Yemen, but those found until now gave good but preliminary chrono-stratigraphic sequences presenting different types of lithic industries. The region of Hadramawt, eastern Yemen, is a particularly rich zone in Early/Mid-Holocene sites, and wadis such Wâdî Wa'shah (site HDOR 419 for instance) or Wâdî Sanâ are places where sites in stratigraphy were found. The site of Manayzah in Wâdî Sanâ represents for the moment the most concrete example and most promising of a stratified site which revealed at the same time a very rich and varied lithic industry through more than two meters of vertical stratigraphy, but also of the important faunal remains which will allow proposing a better definition of a possible Yemeni "Neolithic".

The Post-Paleolithic period is characterized, as soon as the Early Holocene, by the appearance of probably laminar lithic industries (blades production with the "Wa'shah method") but especially bifacial industries, with an important production of flat and symmetrical arrowheads and one, probably of later age, of arrowheads with triangular section. The distribution of the latter through South Arabia suggests a technical tradition well anchored at the beginning of the Middle Holocene and particular to this area. The presence of the fluting technique reinforces this impression that a true "endemic development area" was constituted through time, without any particular external influences interfering within a "trihedral tradition" in Arabia. The transition towards societies with production economy from the Bronze Age remains very poorly known.

The Holocene occupations are also better understood through Yemen's diverse geographical entities. Climate and geography probably contributed to certain types of settling modalities and, consequently, influenced diffusions, relations and movements of populations.

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ASSESSMENT OF HOLOCENE SURFACE HYDROLOGICAL CONNECTIONS FOR THE OUNIANGA LAKE CATCHMENT ZONE (CHAD)

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The reconstruction of a quantified evolution of drying in the Sahara during the Holocene remains a challenging task. One reason is that high quality records of former climate are scarce at such latitudes, mainly due to the difficulties in maintaining for instance lakes bearing sedimentary archives in this hyper-arid environment. Another reason is that such records still require confrontation with other sources of information to reconstruct the landscape and its evolution.

Climate reconstruction for the last 6000 years was carried out recently from lake sediments at Ounianga Serir lake (20°30'E, 19°N) in NE Chad within the ACACIA project. The present-day lake maintains in a hyper-arid environment (roughly 5 m/y evaporation and scarce precipitations) due to inflow from groundwater corresponding to the lower SW end of the Nubian Sandstone Aquifer. This exceptional continuous and accurately dated record (Kröpelin et al. 2008) uses multi-proxy indicator approach for a finely laminated lake-sequence: sedimentary data, geochemical data, biological indicators (pollen, spores, aquatic biota). Three major phases in drying are observed, (1) evolution of the lake from a freshwater habitat to the present-day hyper-saline oasis (around 3900 cal yr BP), (2) establishment of today's terrestrial desert ecosystem as the result of continuous vegetation succession (5600 to 2700 cal yr BP), (3) evolution in regional wind regime with onsets of major dust mobilization at roughly 4300 cal yr BP and establishment of modern, near continuous northeasternly winds around 2700 cal yr BP.

We propose here a hydrological view to the regional surface water system with the objective of reconstructing the conditions for the more humid period around 5000 yr BP. This reconstruction relies upon the sedimentary records from Ounianga Serir, climatic modeling results and topographical and hydrological analysis and modeling.

We first identify the surface water network from topographical data and the catchment area associated with the Ounianga Serir lake including sensitivity to lake levels. Basically STRM 90 m data is considered, at some locations complemented by SRTM 30 m data made available from NASA and photographical databases. ArcGis tools serve to analyse the topographical rasters. Results show that the Ounianga lake catchement area is at regional scale (approx. 2.104km2) mainly including the Erdi plateaus (north from lake) and showing a relation with the Tibesti massif (west from lake) for high lake levels coherent with the fact that high altitude vegetation taxa are recorded in the lake sediments.

Moreover for lower lake levels, the system becomes endorrheic and in a second step, we estimate the major components of the water balances for the same humid period including precipitations and evapo-transpiration resulting from literature models, pollinic records and hydrological information obtained formerly. All pieces of information appear coherent with a progressive drying of the zone but still imply large uncertainties leading to various vegetation repartition scenarii. Some of the sources of uncertainty pertinent for this model are discussed (mainly the impact of eolian erosion on the landscape evolution). More precision is required considering the water inputs from the aquifer. This term is, for present-day situation, dominant for surface water balance and can be easily estimated but for time periods back in Mid-Holocene, a regional and local modeling of the drainage of the Nubian Aquifer units starting from the African Humid Period in Early Holocene is required. This will be our next step.

HYDROLOGICAL MODEL SENSITIVITY TO BASIN TOPOGRAPHY ON LAKE CHAD, AFRICA

Mathieu Le Coz[1,2], François Delclaux[1], Pierre Genthon[2], Guillaume Favreau[1]

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Lake Chad is characterized by a huge endorheic drainage basin (2.5 Mkm^2) and a particularly shallow bathymetry that result in a great sensitivity to climatic variability. An hydrological modelling was initiated in order to simulate changes in lake extent during Holocene and to reproduce, and then to predict, the hydrological responses of the basin to climatic forcing.

Digital Elevation Models (DEMs) are widely used in hydrological modelling to describe the geomorphological variability of watersheds. However, due to limited computational and memory resources, the resolution of the most precise available DEMs is often too fine to run models over regional scales. DEMs therefore need to be aggregated to coarser resolutions that affect the representation of the land surface. In the Lake Chad basin, six algorithms were assessed to aggregate the SRTM (Shuttle Radar Topography Mission) DEM from 3'' (~90 m), the resolution of the released product, to 5' (~10 km), a resolution directly usable by the hydrological model.

The results show that mean and median methods produce a smooth representation of the topography. Consequently, small depressions governing the floodplain dynamics are not represented. Other aggregation methods, especially the nearest neighbour, enable a more consistent representation of these depressions but result in anomalies on the drainage network. A blended aggregation procedure was therefore proposed: this consists of a preliminary median filtering of the 3'' DEM based on a variographic analysis, then of a resampling to 5' via the nearest neighbour method. With the resulting DEM, the simulated floodplain hydrology is consistent with observations (3% underestimation for simulated evaporation volumes). Moreover, there is no anomaly on the extracted drainage network and the Lake Chad bathymetric curves are close to those extracted from the 3'' DEM (RMS deviation < 3.5%).

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MAPPING PAST LANDSCAPES OF SAHARA USING ORBITAL RADAR

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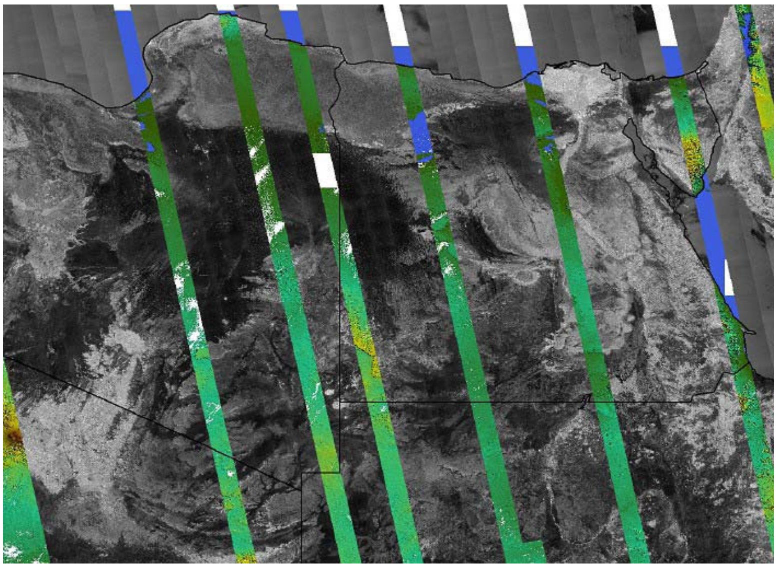
Orbital imaging radar has the capability to map the subsurface down to several meters in arid areas. It then presents a high potential for past landscape mapping in arid and semi-arid environments. One of the first results regarding subsurface imaging with orbital radar was obtained more than 20 years ago: the Shuttle Imaging Radar revealed buried and previously unknown paleo-drainage channels in south-western Egypt. While the geographical coverage of the Shuttle Imaging Radar missions were limited, a complete L-band radar coverage of the eastern Sahara by the Japanese JERS-1 satellite was used to realize the first regional-scale radar mosaic covering Egypt, northern Sudan, eastern Libya and northern Chad. This data set helped discovering numerous unknown geological structures, in particular paleo-drainage channels, faults and impact craters. In January 2006, the Japanese Aerospace Exploration Agency successfully launched the ALOS satellite. It includes high-performance imaging radar, PALSAR, that will map the entire Earth. First global acquisitions over North Africa took place between December 2006 and January 2007. Using several hundreds of PALSAR scenes, we produced a high-quality radar mosaic over the complete Sahara. This dataset that will be accessed through Google Earth will constitute a unique tool for the scientific community to study the paleo-environment and paleoclimate of North Africa.



The PALSAR radar mosaic over eastern Sahara, plotted on top of SRTM coverage.

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NEOGENE DESERTIFICATION OF AFRICA

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At present, desert covers approximately one third of the surface of Africa, the Sahara in the north extending over 9 million km², the Namib ca 135,00 km², the Kalahari some 260,000 km², with other smaller desert zones in Kenya, Somalia, Eritrea and Ethiopia and neighbouring Arabia. Geological and palaeontological studies in areas that, at present, are total desert, such as Gebel Bellorat in the Western Desert Egypt, Sahabi and Gebel Zelten in Libya, the rift valley deserts of Northern Kenya, Ethiopia and Eritrea, and the Namib Desert in Namibia, reveal that during the Neogene all these areas were for a time more humid than they are today.

Early Miocene sediments in the Namib Desert contain rich faunas indicating the presence of woodland to open forest conditions from 21 to 19 Ma, after which the fauna changes to steppic and arid types. Gebel Zelten (17.5 Ma) has yielded fossil bracket fungus along with tropical forest trees, and a woodland fauna. A suite of micromammals from a vast system of karstic deposits at Gebel Bellorat (10 Ma), includes several forest-adapted lineages such as tree porcupines, galagids and fruit bats. Fossils from Sahabi indicate the presence of wooded savannah in northern Libya some 7 Ma. Fossil piscivorous crocodiles from 12-10 Ma deposits in central Tunisia indicate the former presence of large and deep rivers flowing northwards across the country, an indication borne out by the presence of extremely thick (up to 30 metres) point bar deposits in the sedimentary successions of Central Tunisia.

In contrast, the Congo Basin is today covered in tropical forest which grows on Miocene and Pleistocene aeolian sand deposits up to 250 metres thick. These deposits cover much of Congo, Northern Angola and Gabon and even reach as far east as Western Uganda where Middle Miocene (13-12 Ma) sand deposits containing large gypsum crystals attest to arid conditions in what is now a very humid part of the Albertine Rift Valley.

Studies of the fossil records of these areas reveal a complex history of desertification, with different areas going arid at different times, and some areas going arid at the same time that neighbouring zones were becoming more humid. The geographic position of arid and humid areas appears to have changed throughout the Neogene.

The earliest evidence for hyper-arid conditions documented in the Cainozoic of Africa occurs in the Namib Desert, where thick aeolianites started accumulating ca 17-16 Ma in zones that had hitherto been well wooded and sub-humid. The Namib has been arid to hyper-arid ever since, with fluctuations in aridity indicated by changing faunas and the development of different kinds of palaeosols.

The earliest evidence for aridity in the Sahara is much younger than that in the Namib, certainly younger than 10 Ma, and likely to be in the region of 7-6 Ma. In East Africa, desertification progressed from the Late Pliocene (ca 3 Ma) into the Pleistocene and persists in parts of the region to this day.

A major consequence of the early development of hyper-arid environments in southern Africa, at the end of the Early Miocene, as far away from Eurasia as it is possible to go, is that plants and animals in the region had a considerable period of time to adapt to these conditions with minimal interference from plants and animals from Eurasia that may have been adapting to similar environments. The result was the evolution of a whole suite of autochthonous plant and animal lineages adapted to arid, climatically unstable environments. Lineages involved include crocodiles, ostriches, various rodent families (Pedetidae, Bathyergidae), macroscelidids (elephant shrews or senges), prohyracid hyracoids, tubulidentates, some carnivores and bovids among others. Plants were also involved in this evolutionary activity, but the details are less well known due to a paucity of palaeontological studies, but grasses came to dominate ecosystems in Namibia much earlier than they did in East Africa, and in several mammal lineages this led to the evolution of a wide range of dental strategies (hypsodonty, ptychodonty, cementodonty, pliocodonty, polylophy) to extend the life of cheek teeth that were experiencing excessive wear due to the presence of opal phytoliths in the grass that they were consuming.

Adaptation of animals and plants to arid environments continued unhindered in Namibia for up to 10 million years before the first signs of aridity became evident in the Sahara and some 14 million years before East Africa started going dry. When the environment in northern and eastern Africa began to open up due to increasing aridity, local plants and animals had no time to adapt before they were displaced by arid-adapted lineages spreading from South Africa on the one hand, and from arid zones in Eurasia on the other. The East African fossil record thus shows an interesting history of faunal changes implicating lineages from southern Africa (pedetids, bathyergids, some suids, some bovids, aardvarks, ostriches, and crocodiles, for example) and from Eurasia (porcupines, leporids, hyaenas, giraffes, some suids, some bovids, equids, and camels, among others). Many East African animal lineages either went extinct (the crocodiles *Euthecodon* and *Rimascuchus* for instance) or retreated west as the forest cover shrank (osteolamine and cataphractine crocodiles, and tragulids for example).

In contrast, fossil faunas from North Africa, such as those at Sahabi, Libya, tend to show much more evidence of faunal interchanges with Eurasia than do East African and South African faunas, although more fossil evidence is required from the Late Miocene of the latter regions to throw light on the details of the exchanges.

As a consequence of the complex history of desertification in Africa, it is essential to study the fossil record from all parts of the continent in order to obtain a holistic view of how desertification progressed, when it occurred, and what effects it had on the development of faunas and floras in the different regions of the continent. Only then can it be appreciated that the Namib Desert, even though it is tiny compared to the Sahara, had a considerable impact on the development of African plant and animal communities, simply because it has been arid for so much longer and was so far removed from other arid areas in Europe and Asia. The animals and plants that live in the Sahara, in contrast, show a great deal of influence from Eurasia ; indeed much of the northern Sahara (Maghreb, Libya, Egypt) is populated by plants and animals (deer, bears, various land snails) with Palaearctic affinities, although it is clear from the fossil record that there were periods when these same areas had a substantial presence of animals that had spread northwards from equatorial and southern Africa (gelada baboons, aardvarks, wildebeest, phacochoeres).

The history of desertification in Africa (indeed, throughout the world) is intimately linked with global climatic changes, in particular to the history of polar ice caps. The Antarctic Ice Sheet started to develop during the Oligocene, but it didn't expand to cover the entire continent until the end of the Early Miocene. It was this expansion that produced the conditions in the southern mid-latitudes for desertification to proceed on land, with the consequence that the Namib in Africa and the Atacama in South America became arid to hyper-arid some 17-16 Ma. At this time there was no counter-balancing Arctic Ice Cap, a consequence of which was the northward displacement of the world's ecoclimatic belts (temperate belt, sub-tropics, tropics). However, between 8 and 7 Ma the Arctic Ice Cap grew to immense proportions, first on Greenland and then onto the Arctic Ocean, and as a result the world's ecoclimatic belts were shifted back towards the south. Mid-latitude Europe, which had enjoyed a tropical to sub-tropical climate for most of the Middle and Late Miocene (16-8 Ma) became temperate and boreal. The septentrional arid zones which used to be located in mid-latitude Eurasia, also shifted southwards, and it is from this time that the Sahara, Arabian and Thar Deserts became arid.

An understanding of the processes and timing of desertification in Africa is thus greatly dependent on a proper understanding of the African fossil record, not just from one area, but from all latitudes of the continent.

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COULD MEGALAKE CHAD «FOSSIL» WATER REMAIN PRESERVED IN THE PHREATIC AQUIFER?

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Lake Chad is an endoreic Lake that was shown to be very sensitive to climate change. In the Middle Holocene, Megalake Chad covered the Quaternary aquifer over a surface area of about 340,000 km^2 (Leblanc et al., 2007). Considering the lack of recharge since that period for some parts of the aquifer, the geochemical signature of Megalake waters may still be preserved within the unconfined aquifer.

In the western part of the Lake Chad basin, the flat plains of Kadzell and Bornou are separated by the Komadougou River, that ends up into the Lake. Each of those two plains displays in its center a natural piezometric depression, interpreted as the result of a local deficit in the groundwater budget (no recharge) over several thousand years. Salinity gradients were shown to mimic these hydrodynamic patterns: fresh groundwaters occur nearby the river, whereas more saline (Cl/SO_4) waters were observed in the "hollow" part of the water table. Very similar chemical facies were observed in groundwaters recently infiltrated from the present Lake. Environmental, radio (C-14, H-3) and stable (O-18, D, C-13) isotope analyses were also performed for groundwater samples. Modern values were observed nearby the river and the Lake, whereas at a few tens of kilometres from surface waters, more depleted values were obtained, with the lowest values in the centre of the plains. Considering uncorrected C-14 values, the oldest recharge events would date back to the beginning of the Holocene (~ 10,000 BP). However, moderate dissolution of continental carbonates was suggested by complementary tracers (C^{13}, Sr^{87}/Sr^{86}), and this process may have lowered C-14 activity. Combined with piezometric data of the aquifer, these tracers consistently suggest that part of the phreatic groundwaters are indeed fossil waters infiltrated during Megalake Chad events, reported to have occurred at 10-8 ka BP (Schuster et al., 2005), and/or at 8-6 ka BP (Leblanc et al., 2007).

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PALYNOLOGICAL EVIDENCE FOR THE EMERGENCE OF THE PERSIAN CIVILIZATION IN SOUTHERN SECTION OF THE ZAGROS MOUNTAINS, SW IRAN

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A pollen diagram was obtained from a 150 cm-long core from the shallow hypersaline Lake Maharlou in the Zagros Mountains, SW Iran. It shows that *Quercus brantii* woodlands and *Pistacia-Amygdalus* scrubs dominated the area during the late Holocene. The record starts at around 5700 cal yr B.P. with a dry period during which both *Pistacia-Amygdalus* scrubs and *Quercus brantii* woodlands were in their minimum extent. This period was followed by the expansion of *Pistacia-Amygdalus* scrubs in the area and the spread of *Quercus brantii* woodlands in higher altitudes. Human activities became very intensive since 3700 cal yr B.P. An important occupation phase with the appearance of several cultivated trees including *Juglans*, *Olea*, *Vitis* and *Platanus*, started around 4700 cal yr B.P. coinciding with the onset of the Bronze Age in Jiroft civilization in Central Iran and reached its culmination between 3400-3200 cal yr B.P. Around 2700 cal yr B.P., extensive stands of *Pistacia-Amygdalus* scrubs became almost completely degraded presumably under strong human pressure coinciding with the beginning of the Persian empires. A very strong but short-lived dry period occured around 2100 cal yr B.P. followed by the maximum expansion of the *Quercus brantii* woodlands. The latter remains relatively stable until the end of the diagram at 400 cal yr B.P.

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MID-HOLOCENE VEGETATION IN CENTRAL AFRICA: RECONSTRUCTION FROM MODELS AND PROXIES

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The main objective of this study was to simulate the Mid-Holocene (6K BP) vegetation in Africa and to compare the simulation results with proxies such as pollen. We used climate data simulated by 3 General Circulation Models (GCM), ECHAM3, UKMO, and LMD5- IPSL. Climate anomalies were calculated between 6ka BP and the control (0ka) simulations for each GCM, and then applied to the CRU climate data sets (New et al., 2002). The resulting simulated climate data for the Mid-Holocene were then used as inputs in the LPJ Dynamic Global Vegetation Model (LPJ-DGVM, Sitch et al., 2003) to simulate the vegetation response.

The studied area covers from 20° N to the equator and between the Gulf of Guinea and 10° E, in order to include the forest-savanna limit that has been displaced several times in the past. Further, within the region, there is a broad variation in modern vegetation, from closed canopy tropical rainforests to open forests, savannas, and steppes. A comparison between a modern potential vegetation map (White, 1983) and modern vegetation simulated by LPJ-DGVM revealed that significantly better results were obtained when interannual climate variability was taken into account. Results obtained at 6ka BP show that the vegetation differed significantly to that of the present day, most notably the distribution of tropical deciduous forests and the savanna-steppe limit. This difference between Mid-Holocene and modern vegetation distributions was found with all GCMs (ECHAM3, UKMO, and LMD5-IPSL). The vegetation simulations obtained using the output of a fully coupled ocean-atmosphere GCM (IPSL) showed improvements over those based on the forced atmosphere GCM version of the same model (LMD5). The few available pollen assemblages show an overall agreement with the simulated changes in distribution. However, both pollen records and vegetation simulations indicate problems with the 6K BP simulated climate.

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ARE MODERN POLLEN DATA REPRESENTATIVE OF WEST AFRICAN DRY ECOSYSTEMS?

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Numerical simulations over northern Africa have confirmed Charney's hypothesis that increasing surface albedo could reduce precipitation (Charney et al., 1977). Vegetation changes and feedbacks to the atmosphere have been shown to amplify hydrological changes in the Sahel during the Holocene (e.g., Claussen,1997; Texier et al., 1997; Braconnot et al., 1999; Renssen et al., 2006), and particularly at the end of the African Humid Period, 5500 years ago (deMenocal et al., 2000). First attempts in North African biome reconstruction from pollen data by e.g. Jolly et al. (1998) have suggested that, during the Holocene, steppe expanded at low elevation in the Sahara while the desert itself was considerably reduced. Climate model experiments from PMIP (Joussaume et al., 1999) however are unable to reproduce such an environmental change and simulate the related penetration of monsoon fluxes over West Africa. In order to better constrain vegetation reconstructions and climate models in West Africa, we present here a large data set of modern pollen samples recovered from the Saharan desert to the north to the equatorial forest domain to the south, with a special focus on transition zones between tropical forests, savannahs and xeric regions currently poorly simulated by all Dynamic Global Vegetation Models (DGVM). This data set includes non-published samples allowing precise description and interpretation of the West African vegetation (White, 1983). Here, we use recent works carried out by Gajewski et al. (2002), Vincens et al. (2006, 2007), Hély et al. (2006) and Watrin et al. (2007) for quality control on taxonomy and model calibration - validation for vegetation composition and pollen-plant-climate relation to improve plant functional types (PFTs) and biome definitions in West Africa.

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SUB-GUINEAN ECOSYSTEM SURVIVAL IN THE SENEGALESE *NIAYES* DURING HOLOCENE UNDER HYDROGEOLOGICAL FORCING

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The Niayes of Senegal, western sahel, are interdunal fens located behind the Atlantic coastal strand between 15 and 16°N. The presence of a freshwater table near the surface of the interdunes allows humid gallery forests to thrive despite dry regional atmospheric conditions. The small watershed of each interdunal depression records variations in plant communities and water resources in relation to local climate conditions. Regional hydrogeology is slowing recovering from long-term drainage during Pleistocene, when sea water level was down to 120 m lower than actual (Delibrias 1974), as relic inland piezometric depressions (-80m) testify (Dieng et al. 1990). The actual littoral dunal band, set as soon as 6 000 BP (Nguer 1989), may have provided a barrier to sub-surface sea water intrusion. As elsewhere in the Sahel, and in contrast with past resilience of the ecosystem, recent droughts have led to significant drops in groundwater levels (-3,5 m between 1963 and 1984 [Aguiar et al. a, b]), and, in association with increasing anthropogenic pressure, to a reduction in natural vegetation.

The aim of this work is to understand how environmental conditions remained favourable to the subsistence of azonal sub-guinean vegetation, especially during the onset of actual climate conditions (between 6 000 and 3 000BP) (Lézine 1987; Lézine et al. 2005). Therefore, we focus on the hydraulic head obtained by numerical simulations with the Cast3M code, using modern data (hydrology and climate), along with paleo-simulations (climate and water table depth), as inputs. Simulations are performed at two scales: (i) *sectorial*, covering the whole coastal niaye area and part of inland up to the local recharge area, and (ii) *local*, comprising one synthetical niaye and its vicinity. Regional hydrology is used as boundary conditions to the sectorial model, which in turn gives indication to local boundary conditions.

[Temporary conclusion:] It is shown that both littoral proximity and high sea level maintained a favorable proximity of a freshwater table, despite decreasing pluviometry and stronger hydrogeological inland diversion.

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A PALAEOENVIRONMENTAL RECONSTRUCTION OF POZM BAY (OMAN SEA – EAST OF THE STRAIT OF HORMUZ) - A MULTIPROXY APPROACH

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Studying the environmental history of Pozm Bay and the surrounding coastal region (Oman Sea – east of the Strait of Hormuz) aims to produce a reconstruction of monsoon intensity fluctuations and to highlight the effects of past cyclones and tsunamis occurring during the last centuries. The regions crucial importance in world oil transportation makes studying past environmental change in the area essential for predicting future natural hazards and climatic events. The region of study is situated just north of the Makran Subduction Zone, which has generated large destructive tsunamis in the past (e.g. Makran tsunami, 1945). The northwestern Indian Ocean remains one of the least studied regions in the world in terms of tsunamigenesis despite of its large destructive potential (e.g. Sumatra tsunami, 2004). Strong cyclones also occur in the region (e.g. Cyclone Gonu, 2007). Studying past monsoon variability is beneficial to predict possible future monsoonal activity. This is crucial as the Asian monsoon system affects the earth system both locally and globally. Previous studies have suggested that the Asian monsoonal system responds to many different aspects of the climatic system, for example fluctuations in the El Niňo-Southern Oscillation (ENSO) and also the North Atlantic thermohaline circulation (e.g. Yang., 1996, Shukla and Paolino., 1983.; Overpeck *et al*., 1996). Some researchers have also speculated that fluctuations in the Asian monsoon can modify climate not just locally but elsewhere in the world, by generating changes in tropical methane production or in the transfer of water and energy (Liu *et al*., 2000, Kudrass *et al*., 2001, Gasse and Van Campo., 1994). The southern Iranian coast is being studied by analysis of cores retrieved by the Iranian National Centre of Oceanography (INCO). These cores form the focus of a multi-disciplinary study to clarify sea level, climate and environmental change in the region. Multiproxy analysis of sedimentary archive provides good land (pollen grains) - ocean (dinoflagellate cysts) palaeoclimatic connections. This poster contains the preliminary results from the sediment cores taken offshore southern Iran. An analysis of sedimentology, magnetic susceptibility, palynology and core photography were undertaken in order to reconstruct monsoon intensity and investigate the effects of past cyclones and tsunamis occurring in last centuries. Preliminary results indicate that the sedimentary record of these short cores reveal minimal facies change throughout the region and large variations in magnetic susceptibility, with the cores taken further to the east displaying higher magnetic susceptibility values. Core OSC55 in 170 m water depth had an unusually high amount of coarse, sandy and fragmented shelly beds, with large variations in magnetic susceptibility throughout the core. These are interpreted as event beds or beds generated by strong undercurrents due to their sharp erosive contacts with the underlying fine sediment. Core OSC53 situated closer to the shore directly in front of OSC55 strangely contains no coarse beds consisting of homogeneous fine clays and silts. Dating by radionuclides and radiocarbon is subject to ongoing investigation.

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AN EARLY HOLOCENE DRY PHASE RECORDED AT 8.2 KYR BP IN THE CENTRAL SAHARA. CONSEQUENCES ON LANDSCAPE AND HUMAN COMMUNITIES

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A recent palaeoenvironmental research in the hyperarid Central Sahara (SW Fezzan, Libya), focused the attention on continuous archives for isotopic proxy data. Several carbonatic tufa outcropping in the Acacus mountains, and thick carbonatic lake sediments from the Edeyen of Murzuq have been sampled and submitted to dating (U/Th and ^{14}C) and geochemical determination of C and O. The chronological extension of deposits covers almost the so-called "African Humid Period", and they represent the first high resolution archive for hydrological changes for the Early and Middle Holocene in an area crucial both for the SW African Monsoon dynamic and for human history.

According to U/Th datings, carbonatic tufa deposition occurred between 9.7 and 8 kyr BP; $\delta^{18}O$ in tufa range from -12 to -2‰; $\delta^{13}C$ values are from -4 to 2‰. Moreover, measured $\delta^{18}O$ in tufa formed between 9.7 and 9 kyr BP present the lowest $\delta^{18}O$ values (-12/-10‰), while in more recent samples $\delta^{18}O$ is from -8 to -2‰. Between the dunes of the Edeyen of Murzuq two different Holocene lacustrine phases have been identified. The older high stand occurred between 9.5 and 8.2 cal. kyr BP; sediments indicate in this phase deep, permanent water bodies, with high autogenic $CaCO_3$ precipitation ($CaCO_3$ content up to 95%), $\delta^{18}O$ around -5/-4‰, and a highly differentiated malacological content. After a dry phase, a new rise of levels happened between 7.8 and 5.5 kyr uncal. BP; this phase, with a lower $CaCO_3$ production (around 80%), $\delta^{18}O$ between -3 and -1‰, and less abundant shells, was probably characterized by seasonal oscillation in lakes level. The onset of severe arid conditions occurred at 5.5 cal. kyr BP; the lakes levels suddenly dropped and the area dried out: after that only a few short wet events are recorded.

In the Central Sahara carbonatic sedimentation is a consequence of the rise of the water-table, related to enhanced precipitation favoured by the northward migration of the SW African Monsoon. The first shift of the monsoon to Central Sahara took place between 9.7 and 8 kyr cal. BP, recharging water reservoirs, and allowing the activity of springs and lakes. A second shift happened between 7.8 and 5.5 kyr cal. BP, but precipitations were less intense. An abrupt dry period interrupted the water supply between 8.2 and 7.8 kyr cal. BP, as consequence of the 8.2 kyr cold-dry global event ; the Holocene hydrological and environmental changes documented in the Fezzan are synchronous with those recorded in different Saharan region.

The Early Holocene wet phase is coincident with the first intense exploitation of the area by hunter-gatherer groups (Mesolithic). The sudden drop in precipitation and the following environmental crisis recorded around 8.2 kyr BP, together with the decrease in rainfall during the Mid-Holocene wet phase, were the main factors driving to a change in adaptive strategies: from a hunter-gatherer economy to one mainly based on herding and food production (Pastoral-Neolithic groups).

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HIGH-RESOLUTION ANALYSIS OF FISH OTOLITHS AS INDICATORS OF MARINE ENVIRONMENT AND FISHING PRACTISES IN NORTH MAURITANIA AT 6730 BP

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The modern coast of Mauritania is characterized by continental arid conditions and productive marine waters due to the Canarian Current and coastal upwelling. An abundant ichthyofauna was recovered from the Epipaleolithic site of Cansado (radiocarbon dated to 6730 BP) located near Cap Blanc (Baie du Lévrier, 20°50' N). Meagre (*Argyrosomus regius*, Asso, 1801) is the dominant species, represented by thousands of otoliths (ear stones). It is a migrating benthopelagic fish, inhabiting coastal temperate waters from western Europe to North-West Africa, moving along shore or offshore-onshore in response to temperature change. Its predominance is likely to indicate fresh oceanic conditions and relatively strong upwelling activity at 6730 BP along Mauritanian coasts. The accretionary nature and geochemical composition of fish otoliths offer a unique opportunity to gain more insights into environmental conditions at high temporal resolution as well as into fishing activities. $\delta^{18}O_{oto}$ values are near physico-chemical equilibrium with the environment and provide a direct record of temperature and $\delta^{18}O$ values of the ambient water ($\delta^{18}O_w$). Otolith carbon is derived from diet and dissolved inorganic carbon and $\delta^{13}C_{oto}$ values are indicative of fish habitat through variations in $\delta^{13}C$ DIC values. Sequential micromilling techniques were used to recover high-resolution aragonite micro-samples along otolith growth axis of four archaeological specimens and four modern specimens collected in Nouadhibou (19°N). Individual intra-otolith isotope profiles were then generated at monthly scale. Modern and archaeological specimens exhibited similar life history patterns and reconstructed thermal histories based on cyclic variations in $\delta^{18}O_{oto}$ values during 'adult' life. These results confirm the presence of coastal upwelling at 6730 BP. Moreover, fishing occurred seasonally during the fresh season, suggesting that human groups exploiting marine resources had a good knowledge of fish population behaviour.

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A STUDY OF THE CLIMATIC CRISIS OF THE END OF THE THIRD MILLENNIUM BC IN SOUTHEASTERN IRAN THROUGH THE LENS OF GEOMORPHOLOGY AND ARCHAEOLOGY

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The geomorphological and archaeological background of southeastern Iran is a good illustration of the complex interaction between human occupancy and climatic variability. Such interaction is the object of study of two programmes : ANR SOPHOCLE (Coordinators : Serge Cleuziou, Anne-Marie Lézine & Eric Fouache) and MEDEE, a programme of the excavations commission of the French Ministry of Foreign Affairs (coordinator : Eric Fouache).

At the end of the Third millennium, the region shows a collapse of the urban societies of the Bronze Age and of the agricultural development of the land, especially irrigation. It tooks a whole millennium before agriculture was developed again, particularly thanks to a new irrigation technique, the Qanats (draining galleries), which makes up for the scarcity of running water.

Our study will be focused on three regions in particular : the Halil Rud Valley (sites of Konar Sandal North and South); the Helmand Basin (site of Shahr-i Sokhta) and the region of Bam.

The three regions are very different as far as water resources and vulnerability to long cycles of drought are concerned. The Halil Rud Valley has the most important resources and it is very unlikely that the archaeological sites of this area were abandoned due to climatic determinism. On the Helmand Basin, on the other hand, the sites around Shahr-i Sokhta were most certainly abandoned because the delta changed place. The region of Bam more clearly suggests that men had already settled there by the Neolithic and Chalcolitic, around the Fourth millennium BC, thanks to a favourable climate. At the beginning, the running water seems to have been abundant enough, and the level of the underground water sufficiently high to be collected by canals in both cases, but later water became scarcer and its level dropped. The Bam scarp may have played a role in the process of development of the new technology of underground tunnels called Qanats.

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THE ROLE OF EARTHQUAKES IN THE COLLAPSE OF ARBORICULTURE DURING THE ROMANO-BYZANTINE PERIOD IN THE DEAD SEA REGION

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The Dead Sea area has an ecosystem very sensitive to climatic change and to catastrophic events such as earthquakes. Ancient settlements have often survived there at the limit of their resources, at the boarder with the desert. The sea level of the Dead Sea has varied quite extensively in the Roman and early Byzantine times: wet climate, high sea levels and arboriculture/agriculture on the slope and hilltops and the reverse: dry climate, low sea levels and shift if agriculture away from the Dead Sea Rift.

A pollen record is presented from a 3.65 m long core taken in the North basin, off shore Ein Gedi (Heim et al., 2007). This record covers the last c. 2500 years. The subannual character of the laminites is confirmed by pollen analysis of individual laminae. This study presents new results of changes taking place after earthquakes.

Two seismites have been analysed in the Ze'elim outcrop: 31 yr BC and AD363 at a subannual timescale. Following the earthquakes, agriculture and arboriculture recovered only after 3 to 5 years, causing a temporary collapse only.

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EVOLUTION CLIMATIQUE DU SAHARA ET DE LA PENINSULE ARABIQUE : LES DEUX DERNIERS INTERGLACIAIRES

N. Petit-Maire

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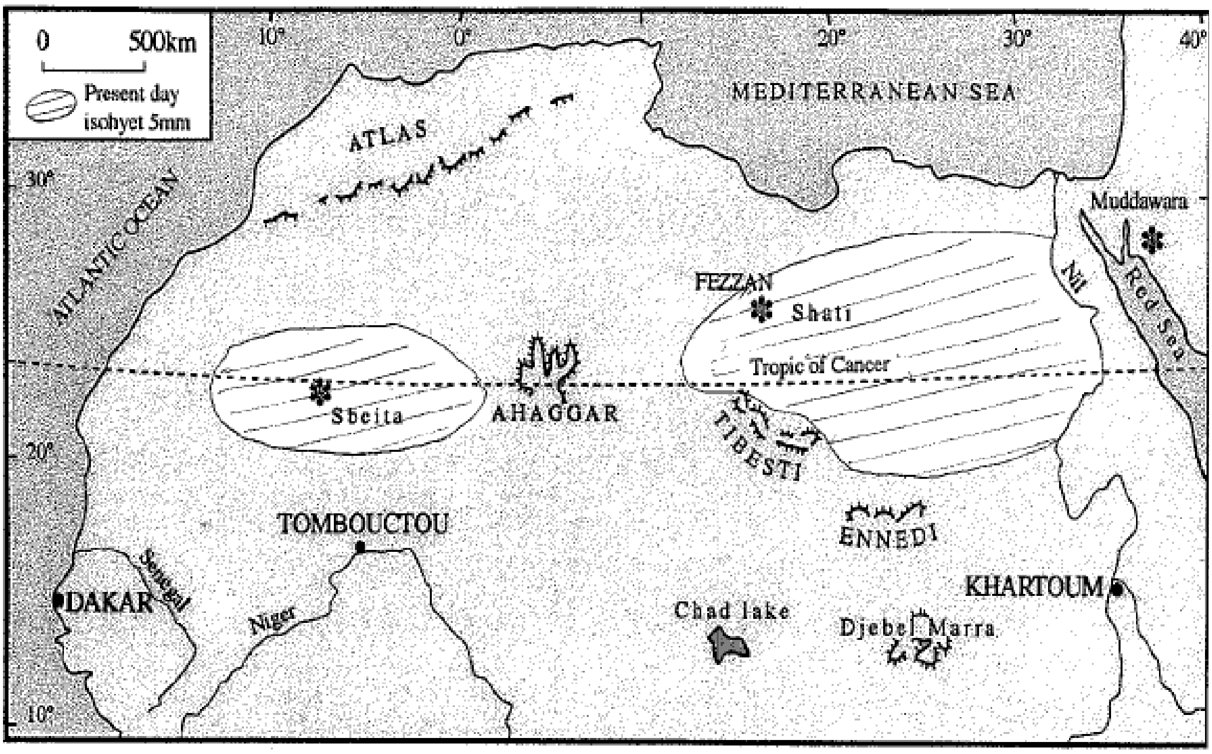
Des phases lacustres, bien datées par U/Th et ^{14} C, sont contemporaines des deux derniers optima climatiques de l'Eémien (01S 5^{e}) et de l'Holocène inférieur.

L'importance (surface, profondeur) de ces lacs pérennes est proportionnelle à l'intensité des réchauffements globaux respectifs (et aux hausses correspondantes du niveau marin).

Tous les paléolacs observés (Sbeita au Mali, Shati en Libye, Muddawara en Jordanie sont entourés de sites archéologiques moustéro-levalloisiens (voir carte de localisation).

Ainsi, chacun des deux derniers interglaciaires globaux a profondément modifié le climat de la zone hyperaride saharo-arabique.



Stage 5 paleolakes in the currently hyperarid desert areas.

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CHRONOLOGIE DES MONUMENTS A COULOIR ET ENCLOS D'EMI-LULU. DATATION CROISEE DE L'EMAIL DENTAIRE ET DES OS DES SQUELETTES DES HUMAINS INHUMES

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[3]*IRD Université d'Aix-en Provence*

La datation des monuments funéraires du Sahara pose un sérieux problème méthodologique. Le collagène des squelettes des humains inhumés est entièrement hydrolysé et les tombes sont généralement dépourvues de tout indice archéologique (céramique ou autre mobilier associé). La chronologie de ces tombes demeure un travail de pionnier qui ne peut être étayé que par de faibles arguments. Il était admis jusque dans les années 70 que les monuments à couloir et enclos étaient récents, post-néolithiques et attribués à la période des chars à galop volant et aux Garamantes.
La datation, par la méthode du carbone 14, de la bioapatite osseuse est la seule solution envisageable. Cependant, cette dernière, est sensible aux échanges isotopiques avec le carbone total inorganique dissous (CTID) de l'environnement. Les conditions arides du Ténéré du Tafassasset sont un facteur de préservation favorable, mais pour mieux contrôler une éventuelle interaction avec les carbonates de l'environnement, nous avons daté conjointement émail dentaire et os des squelettes.
Une première série de dates (sept) a déjà été publiée (Paris, 1996, Paris & Saliège,1996), mais cette nouvelle série (douze) obtenue à l'aide de la technique S.M .A. (Artemis, Saclay) permet d'une part de tester et comparer la datation sur email et os et d'autre part d'en améliorer la précision.
Grâce à la datation de la bioapatite, les monuments à couloir et enclos sont maintenant à classer vers le milieu du quatrième millénaire. En l'état actuel de nos connaissances, ce sont les plus anciens monuments funéraires du Sahara central.

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DATING THE FISHERMEN OF RA'S AL-HADD (SULTANATE OF OMAN)

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Ra's al-Hadd est un village de pêcheurs, situé sur le cap le plus extrême-oriental de la péninsule arabique, qui a joué très tôt un rôle dans les échanges internationaux.

Les recherches archéologiques conduites depuis près de 30 ans dans la région, ont permis de répertorier de nombreux sites allant du V^e^ au III^e^ millénaire avant notre ère. On connait plusieurs sites d'habitat, dont le principal, HD-6 est daté de la fin du IV^e^ à la première moitié du III^e^ millénaire BC. Ce complexe architectural comprend plusieurs ensembles de maisons en briques crues. Il représente un témoignage majeur de l'interaction entre les oasis de l'Intérieur et la côte océanique, et les relations culturelles et économiques qui prennent place au cours du III^e^ millénaire, au sein des routes commerciales de la Mésopotamie et de la Vallée de l'Indus. D'autres occupations, sont plus tardives, comme HD-5 et HD-99.

Les prospections et les recherches archéologiques ont également permis de recenser plusieurs nécropoles qui couvrent l'ensemble du III^e^ millénaire. Lorsqu'il s'agit de dater les hommes eux-mêmes, par la méthode du radiocarbone, la prise en compte de la diète des populations de pêcheurs est essentielle, puisqu'elle détermine l'influence de l'effet réservoir, et par ce biais, la calibration de la datation.

Les données archéologiques dont nous disposons (pratiques funéraires, typologie du mobilier, typologie des tombes, stratigraphie) permettent de proposer une fourchette chronologique probable dans laquelle peut se ranger l'échantillon osseux daté. En procédant par simulation et en modulant l'apport de nourriture marine, en fonction de cette fourchette attendue, on obtient une information sur la part probable de l'alimentation d'origine marine dans la diète. Les mesures des isotopes du carbone ($\delta^{13}C$) apportent un complément d'information.

Les données archéologiques fournissent ainsi un moyen de développer une stratégie pour connaitre la diète des pêcheurs, et calibrer les dates obtenues.

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ADAPTATION STRATEGIES IN THE III MILLENNIUM BC COASTAL OMAN

Valentina M. Azzarà

PhD Student, UMR 7041, Nanterre

The Italian-French "Joint Hadd Project" carried out several survey and excavation campaigns in the eastern province of the Oman Peninsula over the last three decades, showing a continuous occupation of the easternmost area of the Arabian Peninsula at least since the 6th millennium BC.

Nevertheless, critical changes have occurred in the region between the end of the 4th and the beginning of the 3rd millennium BC. Diminution of rainwater, together with the switch of precipitations from summer to winter, engendered a gradual desertification and notably the decrease of the species connected to mangrove, *Avicennia marina* and *Rhizophora mucronata*, and the simultaneous expansion of species like *Acacia* sp., *Zygophyllum* sp., *Commiphora* sp. This appears in the archaeological record of 3rd millennium BC both concerning organization and subsistence strategies.

The site of HD-6, represents so far the best example of the transition between the Late Stone Age and Early Bronze Age in coastal Oman. It yielded brand-new architectonical categories and commodities connected to a new social order and productive capacities.

The excavations have revealed several buildings installed directly on a sand dune between sea and lagoon surrounded by a stone wall. Dwellings were composed of various rectangular rooms constructed with mud-brick of standardized dimensions. The houses display rooms that might have functioned as storage facilities and spaces connected to luxury and domestic-goods processing.

Several features hint at specific organisation connected to food procurement and processing. Subsistence economy was mainly based on fishing, documented by net sinkers, copper fish hooks and thousands of fish-bones, with a emphasis on large pelagic species, *Scombridae* and *Carangidae*, associated to sea-mammal such as dolphin and green turtle. Wild and domestic land mammal had a limited role. Jujubes and dates provided the vitamin supply.
Besides daily subsistence, fish species were processed to constitute preserves for unforeseen situations. These included drying, salting, smoking and baking practised near or inside the settlement. Large hearths and clay ovens are generally located in cooking areas connected to the buildings.

The quantity of fish baked in the large ovens of HD-6 suggests that the production was not only aimed at local consumption. Most likely, the amount of fish baked in the ovens was sufficient to constitute a staple product traded to the inner oasis. Ethnography attests that few decades ago baked fish represented a luxury product for inland communities.

Hoarded-processed fish can be considered as a real surplus and it had the role of major staple-goods essential in the trade with inland oasis. Date stones attest the interactions between coastal and inland communities. This evidence suggests that the settlement was part of a network based on the exploitation and exchange of resources available in specific *terroirs*.

The social organisation and the subsistence economy revealed by the archaeological record of HD-6 constitute the expression of a successful strategy manipulating seasonality and unpredictability of the resources in a desert environment.

THE EVOLUTION OF SETTLEMENT PATTERNS IN THE EASTERN OMAN FROM THE NEOLITHIC TO THE EARLY BRONZE AGE (6000-2000 B.C.)

Jessica Giraud

(post-doctorante, UMR 7041, Nanterre).

Since 1985, surveys and excavations have been carried out in the Eastern Ja'alan, Sultanate of Oman. More than 4000 archeological structures are nowadays listed on an area of 3 000 km² encompassing various ecosystems in a restricted area: mountains, large dissected quaternary terraces, wide wadi beds, fossil or still active lagoons, rocky and flat sandy coasts along the Indian Ocean. The sites considered in the study are dated between the Early Holocene and the Middle Bronze Age.

The spatial distribution of these sites according to various periods follows various patterns evidenced through GIS study, reflecting the societies which generated and used them. The reconstitution of territorial dynamics on five millenniums allows us to have a direct access to social and cultural evolution of the populations. Powerful changes in the morphology of the region have been detected and can be matched with variations in sea levels and climatic change at millennial and even centennial scale also allowing various insights in resource distribution.

Although it was probably an important background, late early Holocene remains are poorly known, being partly buried under later sediments in the interior while coastal settlements are below present sea-levels. Many tethering stones on the surface of once herbaceous terraces now reduced to barren areas and poorly distinctive lithic concentrations attest of a rather intensive occupation.

The late 6th to 4th millennia are much better known mainly through the study of coastal zones were dozens of settlements have been identified and several partly excavated or tested. They generally associate the use of the resources of mangrove swamps and lagoons and that of coastal resources, with a growing importance of deep sea fishing. Seasonality of residence is questionable, although hunting-gathering continues aside fishing and restricted animal husbandry. Concentration of lithic artifacts in the interior may correspond to various seasonal camps, hunting parties as well as mineral resource exploitation (flint, red ochre, softstone, pyrolusite). Part at least of the dead are buried in coastal settlements. Identity landscapes may have followed major wadis between coast, lagoons and mountains, but necessary sharing of less common resources must also have acted in higher level social dynamics.

With the coming of Early Bronze age around 3200 BC, most aspects of the society experiment rapid and deep changes, that are visible by the construction of many tower-like collective burial on the rocky ridges overlooking settlements, fishing grounds, herding areas and even high visible in the landscape. The ancestors are used to enforce the structuration of territorial rights. Various configurations can be determined, according to the role of settlements or ecosystems: seasonal intensive fishing (in winter) on the coast, ports of trade such as Ra’s al-Hadd. Building of mudbrick houses indicate regularity year after year in the movements rather than permanent residence on the coast while in the interior and around the lagoons, smaller concentrations of graves have yield to the discovery of small settlements of palmtree gardens supplemented by animal husbandry; Such settlement that may have had an almost permanent component are probably a major discovery that will allow us to better understand the society and its structure, in addition to the large oases with permanent population in the South-western piedmonts of the main Omani mountains that probably heavily interacted economically at this time with territories like the Ja’alan, both for local exchange and international trade. When 500 years later, by 2700 BC, new and larger types of burials with increasingly complicated rituals abandon the highest elements of landscape to be be located closer to the settlements, probably filling new functions in social ideology; earlier monuments appear preserved and continue their role as territorial indicators. The unity of funeral, living space and oasis place seem to be organised in a dense network of complex sites within which a regional hierarchy is clearly expressed, where an instense relation exist with the coast and with the lagoons.