

EUG XI



Symposium CC06

Holocene Palaeoclimate Records over Europe and the North-Atlantic

Convenors

Kay Emeis
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Wednesday PO Session

CC06 : WEpo01 : PO

Tephrochronology and Holocene Climate Changes as Identified in the Klockamyren Mire; Mid-Central Sweden

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Details of the Holocene climatic development in the southern part of the Scandes Mountains are relatively poorly known. A PhD thesis is directed at investigating the climatic variations and related vegetation change in the Sylarna area, mid-central Sweden. In order to reconstruct regional Holocene climate changes with a good chronology, a peat record has been obtained from the Klockamyren mire (63°18.5' N, 12°29.0' E) situated 528 m a-s-l. The sampled site is a large mixed mire with a sequence of 2.4 m of peat with varying vegetative content. The peat sequence which spans the past 9000 years has been analyzed for degree of humification, loss-on-ignition and tephra content. The results indicate four distinct marker horizons containing rhyolitic tephra, which described and geochemically identified enable an absolute chronology to be established, based on tephrochronology and ¹⁴C-dating. The four tephra horizons recorded correlate well with the eruptions of Askja A1875 (AD 1875), Kebister Tephra H-S (3500 cal BP), Hekla H4 (3830 cal BP) and Hekla H5 (6100 cal BP). These results will be compared to detailed stratigraphic studies of lake sediments at various altitudes in the vicinity, in order to clarify aspects of treeline dynamics and other environmental changes in the region related to climate changes during the Holocene.

CC06 : WEpo02 : PO

Climatic Variations in Holocene Sediments from Skagerrak and their Correlation to Historical Records

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Holocene sediments from Skagerrak have stored the paleoceanographic evolution of this border region between the open ocean conditions of the North Sea and the land-locked epicontinental brackish conditions of the Baltic Sea. From well dated and high resolution sediments (up to 1 cm/a) we extract informations on natural changes of the environment caused by cyclic and acyclic variations of the climate with long (> 100 y) and medium (> 10 y) periods over the last 2000 y. For this we use physical properties as evidence of the intensity of bottom currents. Isotopic and organo-geochemical signals in the sediments ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ of foraminifera, alkenone pattern) reflect the near surface conditions of temperature and salinity in the Skagerrak area.

Here we will present our first sedimentological and geochemical results on six long (5.75 m) and six short (40 cm) cores recovered in May 2000. We will show the climatic variations of SST (as derived by the UK '37-method) for the last 2000 y in different areas of the Skagerrak region and correlate these variations with environmental changes known from historical records.

CC06 : WEpo03 : PO

Isotopic Climatic Records of Modern and Subfossil Scots Pine Trees from North-western Russia

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The goal of this work is to contribute to the study of climatic changes during late and middle Holocene on the Kola Peninsula (north-western Russia). This region, adjacent to relatively well investigated Scandinavian areas, is climatically affected not only by the Gulfstream and the North Atlantic but also from the Eurasian continent. Modern and subfossil pine trees from different locations on the Kola Peninsula were analysed for tree-ring width and for carbon, oxygen and hydrogen isotopic composition.

A collection of 90 radiocarbon-dated subfossil pine trees (*Pinus sylvestris* L.) were sampled from several sites in the Khibiny low mountains (ca. 67-68°N; 33-34°E) in the tundra belt above the modern upper (pine) tree line as well as from small lakes in the lowland near the Norwegian border beyond the modern northern conifer tree-line (> 69°N; ca. 31-32°E). Most wood samples from the Khibiny mountainous regions fall into a rather narrow age range of ca. 800-1000 ¹⁴C BP, indicating calibrated age ranges of about cal AD 1000-1300. This corresponds to the well known Medieval warm period. Dendrochronological investigations on 18 subfossil scots pines, yielded a floating tree-ring chronology of 556 years (953-1508 AD), which was synchronised with the established pine tree-ring chronology from Finnish Lapland (M.Timonen, METLA tree-ring research laboratory, Rovaniemi, Finland). The distribution of the ¹⁴C ages from lowland lakes pines is between ca. 4000 and 7000 ¹⁴C BP with a distinct maximum between c. 5500 to 6500 ¹⁴C BP. Stable carbon and oxygen isotope ratios of modern late wood cellulose correlate well with both mean annual temperature and precipitation. $\delta^{13}\text{C}$ - and $\delta^{18}\text{O}$ -values are sensitive in particular to changes in the temperature of July-August and to precipitation of November of the previous year, respectively. On average, a-cellulose of pine trees from Medieval time is enriched in ¹³C compared to modern trees from this region. This points to a distinctly warmer summer climate in Medieval times than recently observed. $\delta^2\text{H}$ -values of the nonexchangeable hydrogen of tree cellulose (cellulose nitrate) from mid-Holocene subfossil wood seem to be somewhat increased compared to those from the Medieval period and from present time. This probably suggests drier conditions during the mid-Holocene climatic optimum. Stable isotope data obtained will be discussed in detail.

CC06 : WEpo04 : PO

High Mountain Lakes Sediment Records: Evidence for Multi-Decennial Oscillations of Climate and Anthropogenic Impact during the Last Millennium

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Subsurface studies of lakes from the "Massif des Aiguilles Rouges" (French alps) have been investigated in order to test the possible climatic influences (solar activity and atmospheric fluctuations) and the role of anthropic pollution in the vicinity of the "Massif du Mont Blanc". The sedimentary infill of lake Cornu consists of non-carbonate slightly varved sequences enriched in organic matter; the characteristics (especially the presence of vegetation and the input of nitrates and phosphates induced by sheep population) of the catchment area control i) the primary production of water column and ii) the mass accumulation rate of organic matter.

Age-depth models were established for the last century with ¹³⁷Cs (Chernobyl contamination and thermonuclear tests) and ²¹⁰Pb (produced at steady rate in the atmosphere. Half-life : 20.4 years) and extrapolated up to the bottom cores. These radionuclide dates provide sedimentation rate ranging from 0.672 mm/yr for Lake Cornu to 1.3 mm/yr for lake Brévent.

Total Organic Carbon measurements of the sediment have been done every 5 mm from the top to the bottom of cores representing approximately a thousand years of archive. The "TOC" signal compared to the atmospheric temperature of the Northern Hemisphere over the last 7 centuries (Mann et al., 1998) exhibits evidence of a global control. Both signals are correlated until 1850 AD and decorrelated for the last 150 years due to the anthropic impact; the minimum of primary production corresponds to the coldest stage of the Little Ice Age. Terrigenous extraction using the protocol of Rea et al. (1986) corroborates these hypothesis. The hydrodynamic evolution of the drainage basin of both lakes recorded by terrigenous Mass Accumulation Rate, (MAR) are linked to the precipitation conditions estimated for the last millennium. The short-term cyclicity of terrigenous "MAR" could reflect the "North Atlantic Oscillation" influence.

CC06 : WEpo05 : PO

Human Impact on the Vegetation of the Upper Engadine (Central Swiss Alps)

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A palynological, palynofacies and macrofossil study of sediment cores from lakes St. Moritz and Champfer (South-eastern Swiss Alps; 1800 m asl) provides a continuous well dated record of environmental changes for the last 12000 years. Both sites show a distinctive change ca. 4000 cal. yrs. BP. Despite the lack of corresponding archaeological evidence, our data point towards human impact as the dominant cause of this change.

Larch (*Larix decidua*) and Swiss stone pine (*Pinus cembra*) are the main forest components during the early Holocene. Around 7500 cal. yrs. BP spruce (*Picea abies*) characterized the forests together with larch and Swiss stone pine. Ca. 4000 cal. yrs. BP the so far dominating conifers show decreasing pollen values with the exception of *Larix decidua*. It is also observed a contemporaneous increase of pollen of grasses, *Plantago lanceolata*, *Rumex acetosa*, *Ranunculaceae*, and other herbaceous indicators for grazing. Green alder shrubs (*Alnus viridis*) also became more important. Thus the pollen records show a continuum of open larch forests until today.

The change in the pollen record ca. 4000 cal. yrs. BP is accompanied by a reduction in the concentrations of the most prominent phytoclasts (degraded wood and fungi), while charcoal becomes a major component in the palynofacies record.

Changes in the inferred vegetation and the related variations in palynofacies are interpreted as a result of an extensive pastoral farming since the early Bronze Age. Thus, these results suggest that early human impact on the vegetation of the Upper Engadine has been so far underestimated, probably due to the sparse available archaeological data. Our results provide evidence for massive and continuous land-use since 4000 years.

Although the data presented here show clear signals of human activity in the catchment area, there are global evidence indicating major changes in the climate system ca. 4000 cal. yrs. BP (Ariztegui et al., 2001 and references herein). Thus, further work is necessary to identify proxies that will allow to clearly disentangle climate and human impacts on the environment.

Ariztegui et al, *Journal of Paleolimnology*, (2001).

CC06 Holocene Palaeoclimate Records

CC06 : WEpo06 : PO Geochemical Changes of the Aral Sea Water during the Regressive Events from the Last 11000 Years

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The Aral sea is currently drying since the expansion of intensive irrigation for cotton cultures in the Turan plain (Central Asia), in the 1960 years. The withdrawal of water from its tributary rivers (Amu Daria and Syr Daria) has led to significant falls of the level of the lake and an important increase in salinity. It is not the first regression recorded in the basin sediments. Several natural events (climate or/and tectonic) and anthropogenic actions (from the Bronze Age) have induced transgressions and regressions (Létolle and Mainguet, 1997). The sea has been an endorheic basin since the development of the Amu Daria delta around 7000 yr BP. This event is related to important detrital sedimentation and vertical tectonic movements. It has led to the closure of the Aral exurgence toward the Caspian sea via the Uzboy channel in the South part of the basin (Létolle 2000). A multidisciplinary study (geochemistry: trace elements and stable isotopes from the carbonated phase; mineralogy, pollen and diatoms) of the regressive levels from the core 48 (central part of the Bolchoie More - Large Sea) have been performed. The studied levels have been dated by lithological correlations with sediments from the nearest core 15 which were dated by ¹⁴C (Létolle and Mainguet, 1997). These regressive levels record changes of the geochemical composition of water and diatoms assemblages related to the fluctuations of the tributaries. If the Syr Daria seems to have been a continuous tributary of the Aral Sea during the Quaternary, the Amu Daria has been sometimes diverted to the Sary Kamish and the Uzboi channel (Kes, 1995). Some studied levels show minor inflow of the Amu Daria. The Syr Daria was the major tributary around 8000 yr BP and 4956 yr BP. During these periods, the deposits are enriched in gypsum, aragonite and calcite. Diatoms are hardly observed. On the contrary, between 6500 yr BP and 5800 yr BP, inflow from the Amu Daria was more important. Then, the sediments are characterized by aragonite and Mg-calcite precipitation and high Fe and Mn carbonate contents. Planktonic taxa *Stephanodiscus* is observed in particular around 6500 yr BP. At other times, two main different diatoms assemblages are observed around 1590 yr BP showing a major decrease of salinity and pH change related to a well recorded peat level in the basin observed earlier by Rubanov (1982).

Kes AS, *Geojournal*, **35**, 1, 7-10, (1995).

Létolle R & Mainguet M, *Bull. Soc. Géol. France*, **168**, 3, 387-398, (1997).

Rubanov IV, *Doklady Akad. Nauk SSSR*, **264**, 4, 927-929, (1982).

CC06 : WEpo07 : PO A Paleoclimatic Reconstruction of the Last Deglaciation in the Central Mediterranean: A Multidisciplinary Approach

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A multidisciplinary study has been performed on a 3.3 m long gravity core (AD 91-17) collected in the Southern Adriatic Sea (40°52'.17N-18°38'.15E). The muddy sediment contains two thin turbiditic levels and a 60 cm dark layer corresponding to the sapropel S1. The core has been sampled every 5 cm with increasing resolution (1 - 2 cm) in the sapropel. AMS ¹⁴C measurements, micropaleontological (foraminifera, pollens, dinoflagellate cysts and nanofossils) analyses and oxygen isotope record provide a time interval spanning the Last Deglaciation and most of the Holocene. During the last deglaciation, micropaleontological records allow to characterize the most important paleoceanographic changes related to global climatic oscillations (Oldest Dryas, Bölling/Allerød and Younger Dryas). In agreement with the other mediterranean records, our data show the classic succession of taxa marking the beginning of the Holocene (succession of temperate trees, increase in warm water microfauna) related to improvement of the climatic conditions. The sapropel layer is characterised by high concentrations of microfossils (planktic foraminifera, pollen and dinoflagellate cysts) implying an increase in productivity and a better conservation of the organic material. Magnetic concentration exhibits minimum values as an effect of the diagenetic dissolution related to the anoxic conditions. The S1 sapropel layer consists of two distinct intervals characterized by several phases separated by a short return to oxic conditions that might have been caused by a temporary climatic deterioration.

CC06 : WEpo08 : PO A Record of High Resolution Ocean Variability from the Skagerrak over the Past 500 Years

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We analysed sediment core material from the high sedimentation area in the Skagerrak, which is located in the NE corner of the North Sea. The core is located in the area where the Norwegian coastal current starts, an area of intensive mixing of water masses. The region is also characterised by high positive correlation between SSTs and the NAO-index, implying that the Skagerrak SSTs are strongly influenced by NAO dynamics. A 2.5 m long sediment core reflects a time interval at a proximally 500 yr. The sampling resolution is 1 cm every 3 cm, which approximately equals 2.5 yr per sample, and 5 yrs between the samples. ²¹⁰Pb and AMS dating is used to establish the chronological control. The high resolution makes it possible to look at rapid climatic changes, even at a decadal scale. The sediment contains almost homogeneous silty clay, 80% <10µm. Grain size measurements and the proxy sortable silt (mean 10 - 63 µm) are interpreted in terms of current strength variability. Other data sets are magnetic susceptibility and carbonate content. These show small amplitude, but there is distinct variation. Oxygen isotope ratios of benthic

foraminifera are used for ocean temperature analyses. The values indicate temperature fluctuations on the order of 2 degrees. A detailed record will be presented and data from the period which overlap with instrumental records, will be used to assess the fidelity of the longer term record.

CC06 : WEpo09 : PO Determination of Climatic Changes by Speleothem Analysis

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Cave calcites known as speleothems formed in limestone caves have been found to be an excellent repository of paleoclimatic data for terrestrial environments. Combined radiometric and stable isotope methods have been used on calcite obtained from speleothems to reconstruct the paleoclimate. The isotopic composition of carbon and oxygen in the calcium carbonate of cave concretions may vary under different climatic conditions, according to the isotopic variations of water and CO₂ participating in the CaCO₃ solution-deposition chemical reactions. Such variations are determined by the isotopic composition of CO₂ in rain water, which changed under glacial and interglacial conditions. Differences in the carbon isotopic composition of CO₂ in percolating water reflect different amounts of humic matter of the soil. Furthermore, the isotopic composition of the deposited calcium carbonate depends on the deposition temperature, which equals, in general, the yearly averaged temperature of the region. These various factors stimulate interest in the idea of looking for continuous isotopic record of climatic variations in the cave concretions.

CC06 Holocene Palaeoclimate Records

Thursday AM Session

CC06 : THam02 : G2 The Climate of 6000 Years BP in Near-Equilibrium Simulations with a Coupled AOGCM

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One focus point for application of complex models in paleoclimate studies is the time slice 6000 years before present. Most of these studies have been performed using uncoupled atmosphere general circulation models (AGCMs) forced with insolation and CO₂ concentration of the mid-Holocene and prescribing present-day sea surface temperatures (SSTs) and sea-ice distributions. First results from coupled atmosphere-ocean general circulation models (AOGCMs) with identical CO₂ and insolation forcing, however, show a marked effect of resulting SST changes on the atmospheric circulation. We have performed a set of coupled AOGCM simulations to investigate the impact of insolation and CO₂ changes including a control run with present-day forcing. In one simulation, both, insolation and CO₂ forcing were applied. In a second run the mid-Holocene CO₂ forcing and modern insolation were prescribed. The periodically-synchronously coupled ECHAM3/LSG AOGCM has been employed for integrations of 1000 years length each to permit the ocean circulation to adjust to the changes in forcing. In order to derive an estimate of the error induced by the use of present-day SST fields, corresponding uncoupled AGCM experiments have been performed. In the coupled runs the insolation and CO₂ changes lead to an decrease of the global mean near surface temperature of 0.3 K after 1000 years. Regarding only the CO₂ changes the cooling is 0.5 K. Whereas the cooling dominates in most regions, the high northern latitudes show a warming in connection with a reduced ice coverage and intensified thermohaline circulation of the Atlantic. Cooler tropical SSTs lead to a weaker monsoon response compared to the uncoupled simulations.

CC06 : THam03 : G2 Holocene Climate Variability as Evidenced from Lacustrine Sediments from Southern Greenland

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Holocene lacustrine sediments from the southern tip of Greenland have been investigated for magnetic susceptibility and content of organic material, sulphur and biogenic silica. The choice of study area is optimal for recording even minor fluctuations in the strength of the East Greenland and Irminger Current and in the position of the polar front system. It is possibly also sensitive for changes in the high-pressure cell of the Greenland Ice Sheet. A high deposition rate along with a very dense dating series have allowed to create a fairly secure time scale of possibly decadal resolution.

As a consequence of isostatic uplift, following deglaciation, the lake emerged out of the ocean at c. 13,800 cal yr BP (Bennike & Björck 2000), and as such it is the oldest Late-Glacial lacustrine record from Greenland. The sediments consists of clayey gyttja with varying content of moss. The amount of biogenic silica rises stepwise during the early Holocene, is nearly constant throughout mid-Holocene and decreases, with fluctuations, in the late Holocene. As a first approximation high values are possibly associated with mild climate since it signals high aquatic productivity. The amount of sulphur shows an inverse relationship with biogenic silica. This may indicate that sulphur could be interpreted as a paleoclimatic indicator - most likely sea salt spray. Normally salts migrate in the sediment column and should therefore be taken with caution as a paleosalinity indicator, but if the sulphur has undergone bacterial reduction it may be a true recorder of changes in sea salt fluxes. Sulphur isotopic studies will be conducted

to test this hypothesis. The combined data reveal that the Holocene was characterized by a climatic optimum between 8000 to 4000 calendar years BP, followed by a cooling trend, likely due to long-term changes in insolation. Superimposed on this trend is shorter duration climate shifts - possibly on millennial scale. These low frequency shifts experienced far larger amplitude during the early and late Holocene than during the Holocene optimum which may indicate the importance of a close-by ice sheet as a climatic amplifier. Eventually these results will be synchronized to marine sediments from the Denmark Strait in an attempt to analyze atmospheric-marine lead and lag relationships.

Bennike, O & Björck, S. *Geology of Greenland Survey Bulletin*, 186, 60-64, (2000).

CC06 : THam04 : G2 Paleoclimatic and Paleceanographic Changes in the Norwegian Sea Through the Holocene

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Holocene oxygen isotopes and foraminifera abundance and SST records from core MD95-2011 (66°58.19'N, 07°38.36'E, 1040 m water depth) are presented. High resolution records (measurements every 15-27 year for the isotopes) document that the Holocene is a period where the natural state of high latitude climate has changed on several occasions, considering both relatively large and small scale of variability. For the earliest parts, the Holocene climate is still influenced by the transition from a glacial to an interglacial state. The 8.2 ka BP event is very well represented, both in the planktic oxygen isotope and the foraminifera records. This event also marks the initiation of a more stable state of climate lasting to ~4-3 ka BP. Through this period there is a small gradual increase in the planktic isotope values, indicating slightly colder temperatures through time. There is no sign of an early Holocene thermal optimum. A situation with a pervasive high gradient between the Icelandic low and the Azores high pressure systems with concomitant stronger westerlies may have increased the eastward influence of Arctic intermediate and near-surface water. Thereby a colder imprint will be seen on the foraminifera living at intermediate depth in the eastern Norwegian Sea. At about 3-4 ka BP this situation changed and another mode of climate variability developed. The influence of Arctic water was not of less importance for the intermediate water masses on the Vøring Plateau. Atlantic water became the major factor of determining the planktic oxygen isotope signal. The variability which is superimposed on the generally lower planktic isotope values during the last 4 ka BP is related to changes in the strength and distribution of Atlantic water entering the Norwegian Sea and varying influence of Arctic subsurface water. Although climate is changing throughout the Holocene there seems to be no single uniform pervasive periodic system represented in all the records.

CC06 : THam05 : G2 Geochemical Analysis of Terrestrial Carbonates: Do Holocene Tufas Record Reliable Climatic Signals?

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It has been established that modern terrestrial carbonates, including microbial crusts, tufas, lacustrine, cave and soil deposits, record information about local environmental conditions. A number of British Holocene tufas have had detailed study, including sites in Derbyshire, Kent and North Wales, UK. In an attempt to validate the climate signal recorded at these sites, a multi-proxy and comparative study is underway. Work that concentrated on the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ of riverine and paludal tufa is now being expanded

to include stable isotope analysis of ostracods, and trace element analysis of both the tufa carbonate and the ostracod valve carbonate.

Mg/Ca and Sr/Ca molar ratios of ostracods collected from tufa deposits could give new insights to riverine or spring systems. In addition, stable isotope analyses of ostracods will provide a direct comparison to the tufa data, and so reproducibility at a site can be determined. Geochemistry of ostracods from tufa deposits has not been attempted before and it will hopefully provide a new proxy to decipher palaeoenvironmental conditions of terrestrial Britain during the Holocene.

Elemental analyses (Ca, Mg, Sr, Mn, Fe and K) have been taken from bulk tufa carbonate from Alport (Derbyshire) in order to establish whether they contain a climatic signal comparable to the stable isotopes. Results to date suggest that elemental variability reflects palaeohydrological change, and/or leaching of the non-carbonate residue. This is directly relevant to establishing whether distribution coefficients of Mg/Ca molar ratios contain a valid temperature signal.

A site at Wateringbury (Kent) has a well understood molluscan biostratigraphy, supported by 7 radiocarbon dates, making this tufa deposit one of the best dated in Britain. At about 7700 radiocarbon years BP, the Wateringbury $\delta^{18}\text{O}$ values show minima, suggesting a marked cooling. This cooling corresponds to the globally significant 8.2 ka cold event (7500 radiocarbon years BP). It is important to establish if this event is corroborated by the ostracod data.

The Caerwys site (North Wales) is the only site in the UK that is suspected to contain tufa deposited during the Younger Dryas. These samples are being analysed to see if they contain a distinct isotopically negative $\delta^{18}\text{O}$ colder climate signal. In younger deposits at this site, excellent examples of reed stem encrustations at the edge of fine carbonate 'flour' pool deposits make it possible to determine if there are any discrepancies of $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ within the carbonate deposits in these micro-environments.

CC06 : THam06 : G2 Palaeomagnetism and Tephrochronology of two Holocene Varved Lake Sediment Sequences in West Central Sweden

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Annually laminated lake sediments (or varved lake sediments) are ideal geological archives since they provide calendar year chronologies and the advantage to present palaeoclimate and palaeoenvironmental data at a high temporal resolution (Renberg and Segerström, 1981; Saarnisto, 1986). Two new annually laminated Holocene lake sediment sequences, which extend from the present day to c. 9500 cal. BP, have been located in the province of Värmland, west central Sweden (i.e. Furskogstjärnet and Mötterudstjärnet). The Furskogstjärnet sequence is thus the longest continuous geological archive in Sweden with an annual resolution. Regional Holocene palaeomagnetic master curves on calendar year time-scales can be constructed by palaeomagnetic secular variation measurements (PSV) of varved lake sediments and used for dating (Saarnisto, 1999). Natural Remanent Magnetisation (NRM) measurements were performed on the two varved sequences in Värmland, where eleven reproducible inclination/declination features have been recorded. The PSV curves are almost identical to the Finnish data and curves obtained from varved lake sediments in northern Sweden. Regional marker horizons, such as volcanic ash layers (tephra), can be used for objective correlation between geological records. Boyley (1998) identified and radiocarbon dated 3 tephra in the province of Värmland, which originated from Icelandic eruptions (Hekla volcano). The same tephra layers (i.e. Hekla 4, Kebister and Hekla 3) have been identified (i.e. by geochemical analysis) and dated in the varved lake sediment sequence in Värmland. Hekla 4, Kebister and Hekla 3 were distinguished by calculating MgO/CaO and FeO/TiO ratios of the relative concentration of these elements (Boyley, 1998). To improve the knowledge about the temporal leads and lags in climate change (e.g. between the North Atlantic region and terrestrial Europe) high-resolution palaeoclimate and palaeoecology studies with good chronological control are

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essential. Such chronological control can be archived by linking geological records with palaeomagnetic time-scales and tephrachronology obtained from annually laminated lake sediments.

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CC06 : THam09 : G2 Undulation of Sea-Level Rise Recorded in Holocene Coastal Sequences of NW Germany

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Lithofacies and biofacies in Holocene coastal sequences of NW Germany indicate temporarily vigorous alternations between terrestrial and marine environmental conditions. Most incisive was the contact between early Holocene terrestrial environments and the transgressive North Sea, as reflected at the top of organic basal units. Extensive environmental changes due to the early transgression are indicated by (i) enrichments of pyrite in the topmost peat layers of the organic basal sequence indicating that the peat received seawater sulphate, probably from short-term flooding events, (ii) microfossil records of diatoms and foraminifera: oligohaline species being abundant in the top of the basal peat as well as in the overlying lagoonal sediments, polyhaline species in the succeeding sediments of the lower clastic unit point to open marine conditions.

When the sea-level rise gradually slowed-down, continuous deposition and accumulation caused the progradation of the coastline, as indicated by an increasing intermixing of terrestrial components with marine material, and finally by clear facies changes towards supratidal and ultimately semiterrestrial lagoonal depositional environments. Distinct features of continuous progradation are terminations of clastic strata by peat layers. These, however, are usually intercalated between clastic sediments which indicate a proximate shoreline and a marine influence by storm-driven floods. The intercalated peats contain planktonic microfossils indicative of brackish conditions. Also increasing numbers of fragile diatoms indicate the change towards nonmarine palaeoenvironments. Foraminifera, in marine strata dominated by euryhaline tidal flat species, change towards brackish water forms mainly belonging to agglutinating species.

In one of the sequences studied, upper sedentary sequences change from Phragmites to raised bog peat. This terminates a complete progradation cycle. At contacts between two different peat types, e.g., Phragmites and raised bog peat, clastic layers repeatedly are intercalated, which originate from marine floods, as indicated by marine diatoms. These presumably are secondary intercalations deposited when the sea reached the outcropping peat and led to its partial floatation at weak transition zones. These events record contacts between the rising sea and a peat-dominated coastal area. The uppermost peat layer dates to 1,300 years BP. A subsequent transgression is indicated by clayey and silty sediments overlying the raised bog peat, which in its upper part is eroded. This again suggests a strong transgression.

In conclusion, the sediments studied document both the response of the sea-level to Holocene climate changes as well as numerous local, e.g., morphological features of the coastal area. As long as no dikes existed in this area, the coastline was shifting across an enormously wide coastal zone with the phases of rapid and slower rise of the sea-level, providing lateral and vertical facies changes between the former shoreline and the outcropping Pleistocene.

CC06 : THam10 : G2 Lake Sediment Signatures of Climate and Human Induced Environmental Changes in the Central Swiss Alps

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The occurrence of steep climatic gradients over short geographical distance is a characteristic feature of mountainous regions. Hence, lakes located at an ecotonal boundary in such regions may experience large environmental changes through time. These can be climatically or human induced changes in their catchment or in the lake itself. In the framework of the project *AQUAREAL* we studied the Holocene sedimentary record of lakes that are situated on an altitudinal gradient, between 1514 and 2265 m a.s.l. across present day timberline. We focus on Sägistalsee (1935 m a.s.l.) that is located at today's timberline. Its 13.50 m of continuously laminated sediments encompass the last 9045 cal. BP and were analyzed for their calcite, organic carbon, biogenic silica (BSi) contents, their grainsize distribution and their mineralogical composition. In the catchment of Sägistalsee almost pure limestones on the steep northwestern and southeastern slopes contrast with carbonaceous, quartz bearing marls and schists in the flatter northeastern and southwestern catchment. Variations in the calcite/quartz-ratio (Cc/Qz) therefore are considered to represent changes in the dominant erosion mode. Cc/Qz-ratios and for some levels also grainsize parameters reveal that distinct changes occurred around AD 1850 and at 1900, 3500 and 6400 cal. BP. These are interpreted as erosion events which are associated to climate and/or human induced changes in the vegetation cover. The immigration of *Picea* that started at 6400 cal. BP caused a stabilization of the catchment that manifests itself in a gradual decrease of Cc/Qz-ratios. This decrease is part of a sawtooth pattern that is a characteristic feature in the upper section of the core and is interpreted as stabilization/erosion cycles. According to very low Ca/Qz-ratios most stable catchment conditions were reached just before 3500 cal. BP. After 3500 cal. BP deforestation of the catchment as evidenced by the occurrence of charcoal in the sediments caused the erosion of unweathered soils and rocks leading to an abrupt increase of Cc/Qz-ratios and sediment coarsening. Peak Cc/Qz-ratios were reached 250 years later, due to the enhanced erosional input of unweathered calcite presumably from the steeper part of the catchment. During the following period of recovery that lasted until 1900 cal. BP, elevated BSi concentrations indicate higher lake internal productivity in response to higher nutrient levels. The beginning of pasturing seems to be the reason for this. Towards the top the core at least two other erosion events were detected that might mark roman forest clearings and recent intensification of human activity in the catchment after AD 1850.

CC06 : THam11 : G2 Short-Term Climatic Variations in the Holocene (2-10 kyr) Mediterranean Basin: Data and Models

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High-resolution isotopic, faunal and organic geochemical records have been generated from the ODP Leg 160 Hole 963D sediments (central Mediterranean area) for the 2-10 kyr time interval. The adopted sampling rate, one sample each 2 cm corresponding to a time slice of about 30 years, allowed us to identify very short climatic and oceanographic fluctuations. Planktonic foraminiferal distribution throughout the studied core enabled us to identify the sequence of ecobiozone boundaries previously calibrated by 14°C AMS and considered synchronous throughout the central Mediterranean area. A new set of 14°C AMS radiometric ages refined the time framework of the studied sedimentary record. Such a detailed time resolution allowed us to apply spectral methodologies to the studied core in order to identify the dominant periodicity characterising the collected signals. A strong influence of a 200 years cyclicity has been recognized in the planktonic $\delta^{18}O$ record and in alkenone signals with a variability range of about $\pm 1\%$ and $\pm 0.5^\circ C$ for the isotopic data and temperature, respectively. A box model is presented to simulate these short-term coupled temperature and humidity changes for the past 10 kyr. Results suggest that the cyclic variations of mean temperature in a range of about $\pm 0.5^\circ C$ are coupled to relative humidity oscillations (range of about $\pm 7\%$) which modulate the isotopic signal.

CC06 : THam12 : G2 A Late Holocene Paleoclimatic Record: Speleothem from Aven de la Salamandre, South of France (High Precision U/Th Dating, ¹⁴C Dating and Stable Isotopes)

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While paleoclimatic variations are well defined for marine regions, recent continental climatic changes are little documented owing to the few available proxies. Caves favor long term conservation of the continental paleoclimatic variations record and therefore offer opportunity to observe past climate transitions. In south of France, where pollen records are influenced by anthropogenic activities for the past 10 ky (farming and deforestation), speleothems could provide precise paleoclimatic records for this period. Here we present the results from a 50 cm long speleothem collected in the Aven de la Salamandre, south of France. This stalagmite grew from the basis of an older broken speleothem. It is made of well laminated, compact yellow and white calcite except in two non laminated porous levels. High precision U/Th analysis by Thermo-ionisation mass spectrometry (TIMS) were performed on calcite sampled along the growth axis of the stalagmite and on a core from the broken speleothem. The samples contain little detrital thorium (²³²Th range from 10 to 0.02 ppb). The uranium content displays small variations in all of the samples (about 0.2 ppm) and the ²³⁴U/²³⁸U ratio is close to isotopic equilibrium. The high resolution chronology of the

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stalagmite shows two growth periods from 0.5 to 3 ky and 5.5 to 8.5 ky and a hiatus between 3 and 5.5 ky. The origin of this hiatus may be climatic as it is correlated with the warm and dry period in Europe (the Sub-boreal period). U/Th results are compared with ¹⁴C dating in order to estimate the past dead carbon proportion in some laminated levels. $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ profile were generated along the stalagmite. We will describe the correlation between these proxies and attempt to link them with paleoenvironmental conditions.

CC06 : THam13 : G2

Evolution of the North Atlantic Oscillation in the NW Alps as Evidenced by 600 Years of Terrigenous Sedimentation in Lake le Bourget (France)

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Cores recovered from periglacial lake Le Bourget deep basin (NW Alps) were investigated to examine the influence of the Little Ice Age (LIA) on terrigenous lacustrine sedimentation. Growing glaciers in the regional watershed induced catastrophic Rh(t)m³ river floods and major underflow deposits in the deep basin during the early 15th, the 16th and the mid-18th century. The LIA is characterised by a decrease in deposition from interflows from AD ~1550 to 1740 and an increase in deposition from underflows from AD ~1550 to 1800. On one hand, spectral analyses of the laminations in interflow deposits reveal 4-5 yrs cyclicities from AD ~1440 to 1550, as well as 7-8 and 13-14 yrs cyclicities from AD ~1740 to 1870 ; on the other hand, spectral analyses of a clay mineral ratio reflecting underflow deposits highlight 45-50 yrs cyclicities from AD ~1550 to 1800. These pluriannual, decadal and pluridecadal periods, are typical of the North Atlantic Oscillation (NAO). A NAO-like period in our data would be a consequence of periodical variations in rainfall and snow accumulation during late fall and winter over lake Le Bourget's watershed (Chapron et al. in press).

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CC06 : THam14 : G2

The Climatic Response of Siberia to Changes of Thermohaline Circulation in the North Atlantic According to High Resolution Record from Lake Baikal during LGM-Holocene Transition

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The high resolution sedimentary record of Lake Baikal reveals details about the response of the lake's watershed and lacustrine ecosystem to the Younger Dryas cooling. The LGM-Holocene transition of Baikal is characterized by an increase in diatom productivity from zero during LGM to high levels in Holocene. The first significant increase in diatom productivity in Baikal occurred at ca. 13 Ka (¹⁴C age) during the Bølling-Allerød warming. Diatom abundance and biogenic silica contents increased abruptly in approximately hundred years to reach the Holocene levels. However, the diatom assemblages were different and less diverse as compared with the Holocene.

This diatom bloom was abruptly interrupted about 11.5 Ka ago (¹⁴C age) with the beginning of the Younger Dryas. As a result, diatom productivity drastically reduced to almost

LGM levels. From this time forward glacial clay with ice rafted detritus (similar to LGM) began to accumulate again in Baikal. These data indicate that mountain glaciers advanced in the Lake Baikal watershed during the Younger Dryas. However, the Baikal diatom productivity did not rebound with the end of Younger Dryas at 10 Ka (¹⁴C age), but instead remained depressed until ca. 8 Ka (¹⁴C age). The total duration of the diatom productivity depression in Baikal exceeds 3 Ka. We believe that this long period of diatom absence in Baikal resulted from discharge of cold and nutrient poor melt water from melting mountain glaciers in the Baikal watershed, which is supported by accumulation of glacial clay in the lake.

The Baikal sedimentary record exhibits a linkage between the climate of the North Atlantic region and Siberia. The cooling of the North Atlantic region led the cooling and glacial advance in mountain areas of Siberia as reflected in the environmental changes of terrestrial and lacustrine systems. However, the environmental/climatic changes that are recorded in Baikal are different from those observed in marine and maritime environments of the North Atlantic region. These differences possibly represent the inner continental response to climatic changes influenced by changes of thermohaline circulation in the North Atlantic. Many Siberian paleoclimate records also exhibit a deep cooling episode during Boreal time around 9-8 Ka (¹⁴C age) (Khotinskiy, 1984; Vorobieva, 1994; Volkova, 1989) suggesting that cooling during Boreal time was not restricted just to the Lake Baikal area but was more widespread in Siberia.

Another peculiar feature of the Lake Baikal records is the indication that the Holocene climatic optimum in this part of the world occurred during the Subboreal period, unlike in Europe and northern Eurasia, where the climatic optimum corresponds to the Atlantic period of the Holocene (Karabanov et al., 2000). The Baikal records show close correlation with paleoclimate reconstructions from Mongolia, where similar climatic responses are observed (Khotinskiy, 1989).

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Thursday PM Session

CC06 : THpm21 : G2

Carbon-13 Tracing of Organic Matter Dynamics and Fluctuations of the Sea Level during the Last 7,000 Years in Southern Benin (West Africa)

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The Ouémé-S(tm) valley formed in an ancient deep bay incised into "Continental Terminal", which are mainly Mio-Pliocene fluvial and palustrine formations. The lower Ouémé-S(tm) valley presently consists of broad open-water and wetland bodies infilled by fluvio-deltaic progradation. On the northern shores of Lake Nokoué, these formations overlie Holocene beach sand-ridges deposited during the eustatic Nouakchottian transgression between 6000 and 5000 years BP. They generally consist of basal beds of moderately to poorly sorted sands intercalated with layers of rich organic mud or peat. Sedimentological and geochemical studies of the Ouémé-S(tm) Delta (Benin) show changes in organic matter content and related changes in the paleoenvironment of the West African coast since 7000 yr B.P. The Ouémé-S(tm) rivers feed into Lake Nokoué, north of Cotonou. The fluvial deposits grade northward into the post-Eocene to pre-Quaternary ferrallitic sandstones of the "Continental terminal". A series of samples was collected by drilling to depths of three to six meters. Sedimentological facies reveal alternating continental and marine influences. Several stages of organic matter accumulation are observed in each boring, reflecting a transition from marine to continental facies. Correlation between variations in $\delta^{13}\text{C}$ and in C/N ratios suggest a mangrove swamp type paleoenvironment. These variations are also correlated with the presence of neofossiliferous minerals such as pyrite, which are common in mangrove derived soils. Pedological studies and botanical inventories confirm the existence of plant residues from the mangrove swamp and inherited soils. Carbon dating reveals that these levels of organic matter were laid down about 6000 years BP, and this study indicates a major transition in the sedimentary record.

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CC06 : THpm22 : G2

Late Holocene Climate and the Evolution of the Baltic Sea Environment

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The Baltic Sea is a land-locked epicontinental brackish water body that has pronounced horizontal and vertical salinity gradients. It is subject to a strong climatic influence originating in the atmospheric circulation of the North Atlantic Ocean, which governs the water budget and wind fields and thus the two climatic influences on the salinity of the Baltic Sea. Depositional basins along the salinity gradient show alternations of laminated and homogeneous sediments during the late Holocene. Occurrence of laminations and changes in salinity proxies suggest variable stratification density between upper and deep water bodies, and are expressions of changed salinity contrast. The Baltic Sea had a salinity maximum and highest incidence of anoxic conditions around 4,500 calendar years. After that time and

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until 2,700 years, a trend to less saline surface waters is indicated by decreasing $\delta^{13}\text{C}$ of organic carbon in the sediments, by increasing amounts of freshwater-tolerant diatoms and decreasing lamination frequency. The trend to decreasing salinity ends and reverses at 2,600 years, but the decrease is less pronounced than at 6,000 years and the sediment continues to be banded and dark. A comparison of $\delta^{18}\text{O}$ in GISP2 ice with the Baltic Sea records shows a surprisingly good correspondence between cold conditions over Greenland and anoxia in the Gotland Deep since 5,000 years. Likewise, the less resolved curve of salinity traces the envelope of minimum temperatures in Greenland well. In analogy to the atmospheric circulation patterns underlying the North Atlantic Oscillation (operating on decadal time scales), we propose that low salinity phases and homogeneous sediment intervals coincide with intensified heat flux from the North Atlantic Ocean to the atmosphere, caused a deepened low-pressure zone during winter near Iceland and caused warmer winters and wetter conditions in the Baltic Sea catchment. Conversely, reduced advection of salty and warm water to the Greenland Sea caused higher pressures in the wintertime Iceland Low, and a more meridional air flow that was deflected by wintertime blocking situations (high-pressure areas) over Scandinavia and the British Isles. This constellation caused reduced moisture advection and was conducive to frequent inflow of cold and dry arctic air masses from the Northeast to the Baltic Sea region. In our records, these were periods of enhanced salinity in the Baltic Sea. To explain the frequent periods of anoxia during the Atlantic climatic period, we propose that continental summer high pressure zones were more frequent over the Baltic Sea: while conducive to salt water inflow, the inflowing salt water was oxygen depleted.

CC06 : THpm23 : G2 Climatic Significance of the $^{18}\text{O}/^{16}\text{O}$ Variations in Organic Matter: Calibration in Modern Plants and Application to the Paleoclimate Analysis of the Last 3000 Years in Europe

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The $^{18}\text{O}/^{16}\text{O}$ -values of plant cellulose are determined by (1) isotopic composition of waters used by plants, (2) alteration of this isotopic signature by evapotranspiration in leaves and (3) biochemical isotopic fractionation occurring during the synthesis of organic compounds. While the later process is thought to remain constant with temperature, the first two factors are influenced by humidity and temperature.

The accumulation of organic matter, well preserved in peat deposits, constitutes a potential climatic archive in the continental realm. Past peat-based paleoclimate studies, however, have generally relied on analysis of bulk peat material or on the cellulose fraction extracted from bulk peat material and have not been well calibrated through modern climate- $\delta^{18}\text{O}$ relationships. We present here results of such a calibration and its application to paleoclimate analysis by studying individual species in a peat core and its isotopic compositions and. Representative species of vascular plants and mosses were sampled along an altitude gradient in the Swiss Alps, which provides a substantial environmental gradient. Oxygen isotopic ratios were measured by EA-IRMS on the α -cellulose fraction.

The response of plant $\delta^{18}\text{O}$ to the climatic changes encountered along the altitudinal gradient varies from species to species. With increasing altitude, the $\delta^{18}\text{O}$ -values of cellulose from vascular plants and from emergent mosses generally decrease, following the trend of isotopic composition of precipitation described by Siegenthaler and Oeschger (1980). The environmental parameters, well constrained along the transect, allow us to test the hypothesis of different models proposed to predict the isotopic composition of terrestrial plant cellulose (i.e. Burk and Stuiver, 1981, Edwards et al., 1985).

A second part of this study investigates the isotopic response of peat species to climatic changes during the last 3000 years. A peat core was collected at 1200 masl in the Swiss Alps, precisely dated (^{14}C and ^{210}Pb) and subsampled at high-resolution for identification of individual plant species. The bottom of the core has a radiocarbon age of 3148 ± 71 years. Two peat species are present throughout the entire core: *Eriophorum vaginatum* and *Sphagnum magellanicum*. Oxygen isotope measurements were performed on the α -cellulose fraction of the species. Similarly to the modern plants, $\delta^{18}\text{O}$ measured for *E. vaginatum* are higher than those measured in *S. magellanicum*.

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CC06 : THpm24 : G2 Elemental, Sr and U Isotopic Compositions as Records of Sedimentation Variations in the Caspian Sea: A Climatic or a Tectonic Monitoring?

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The Caspian Sea, which is the world's largest internal sea, was subjected to important sea-level fluctuations during the recent Quaternary. The origin of these fluctuations is still matter of debate: records of either climatic or tectonic-related changes? The aim of the present study is a geochemical study of the sedimentary records. A 10-m long core containing Late Pleistocene and Holocene records, was drilled in the southern basin of the Caspian Sea. It consists in three units: (1) a homogenous U1 unit from bottom to 98 cm, characterised by low carbonate contents (20-25%), (2) an intermediate U2 unit up to 17 cm, with dominant carbonate contents (about 75%), and (3) an upper U3 unit with less carbonates (55%). The Sr isotopic compositions of the whole sediments, the biogenic carbonates, the clay fractions and the interstitial waters from U1 unit yield low variations, whereas they decrease significantly from the U1/U2 transition to the top of the core. The sediments of unit U2 yield a more important $^{234}\text{U}/^{238}\text{U}$ disequilibrium than those of the lower U1 unit. The upper values are close to the present-day Caspian water disequilibrium, probably because of the high amount of biogenic carbonates in equilibrium with the sea water. In the lower unit, the $^{234}\text{U}/^{238}\text{U}$ activity ratio represents a mixture between carbonates and an important supply of old detrital minerals probably in secular equilibrium. The transition at 98 cm depth shows a strong variation in the sedimentation regime with a decrease of the detrital part in comparison with the biogenic flux. The 98-cm deep U1/U2 transition at 98 cm has not yet been precisely dated, but it records an important change in the sedimentation with an important decrease of the detrital input, as well as in the origin of the detrital input, the clays from both units yielding different $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{234}\text{U}/^{238}\text{U}$ signatures. This major change may be related to either a dramatic modification of the hydrodynamic regime or even to a change in the shape of the drainage basin. Influence of a climatic monitoring on the sea-level fluctuations cannot be discarded, but Clauer et al. (in press) showed that equilibration of the geochemical and hydrological budgets of the Caspian sea-water definitely needs a contribution of subterranean thermal waters (6 to 9%) to the sea-water budget. This supply which may explain the recent sea-level fluctuations, seems also to have been recorded by varied Eu/Eu* ratios in the sediments, the carbonates and the Fe-oxides. It seems also to be recorded in the Sr isotopic compositions of the interstitial waters: the uppermost ones are not in isotopic equilibrium with those of the Caspian sea-water. In summary, the recent sea level changes seem to record indirectly on-going tectonic activities beneath the Caspian Sea.

CC06 : THpm25 : G2 The Terrestrial Biosphere as a Net CO₂ Source during Abrupt Climate Change Events

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Abrupt climate changes occurred several times in the past, leading to modifications in the vegetation patterns and therefore having an important influence on the global carbon cycle. The net terrestrial carbon flux into the atmosphere is therefore not only controlled by the plant productivity but also by shifts in the vegetation distribution due to climate change.

Dynamic global vegetation models (DGVM) are the most advanced tools for reconstructing past or predicting future shifts in vegetation distributions in response to climate change events on a global scale. The Lund-Potsdam-Jena (LPJ) model is a DGVM that includes a complete description of terrestrial-vegetation carbon cycling.

We use the LPJ for a long time integration simulating such an abrupt climate change event. Thereby, LPJ is driven with output from a climate change simulation with the ECHAM3/LSG AOGCM. Thus, data from a 850 year long model experiment representing a highly idealized Younger Dryas (ca.13,000 years bp) like event are used to study the reactions of the vegetation arrangement and changes in the terrestrial carbon storage. The modeled net biospheric CO₂ flux to the atmosphere is constrained by a simple ocean carbon model.

The main feature of this meltwater experiment is the suppression of the Atlantic thermohaline circulation leading, apart from a significant cooling of the northern hemisphere, also to different climate variability pattern. The transient behaviour and also the response time of the various plant functional types included in LPJ will be identified for such a climate change event. Finally we comment on the use of $\delta^{13}\text{C}$ to validate the modelled ecosystem fluxes.

CC06 : THpm26 : G2 High Resolution Palaeoproductivity Fluctuations Since the Last Glacial Maximum as Indicated by Benthic Foraminifera in the Marginal Arctic Ocean

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Foraminiferal analyses from three sediment cores off the Yermak Plateau (PS2837), the northern Barents Sea continental slope (PS2138) and the Laptev Sea (PS2458) reveal significant fluctuations in glacial palaeoproductivity. In coincidence to the maximum extension of the Spitsbergen Barents Sea Ice Sheet palaeoproductivities off Spitsbergen and the Barents Sea were significantly lower than today. In contrast, extraordinary high palaeoproductivities coincide with initial deglaciations following peak ice sheet extent. The Laptev Sea shelf was exposed during the Last Glacial Maximum. Therefore, palaeoproductivity fluctuations at core site PS2458 (Laptev Sea continental slope) were not or only slightly affected by the changes in the continental ice sheet extent. Here peak glacial palaeoproductivities coincide with the opening of the Lena river. Because the Arctic shelves were either exposed or covered by ice-sheets during the Last Glacial Maximum (LGM), nutrients were not diminished by primary production on the continental shelves. During initial deglaciations, shear-stress between wind-induced sea-ice drift and the waning ice-sheets might by chance have led to leads or polynyas along the continental slope. Similarly, the draining of the Lena river may have significantly reduced the local sea ice coverage. In these glacial seasonally ice-free areas upwelling processes, nutrient influx by melting sea-ice, calving ice-sheets, and draining rivers, may additionally have nourished algae growth. Peak glacial palaeoproductivities may have been as high as two to three times modern production at the core site. At the Spitsbergen Barents Sea continental margin, peak glacial palaeoproductivities are usually found subsequent to peak abundances of Atlantic species. This indicates that the initial Spitsbergen Barents Sea ice sheet retreat is often attended by an enhanced advection of warm Atlantic derived water. We propose that the glacial Arctic Ocean was preconditioned for enhanced palaeoproductivities. Nutrients were not consumed by shelf production, but replenished by upwelling effects at the ice edge, melting icebergs or even atmospheric transport.

