Dark Nature
Rapid natural Change and Human Responses

Workshop
How to Identify Mega-Floods in Palaeorecords
The Impact of Mega-Flood Events

Bobole - Mozambique
November: 1-5, 2004

Edited by:
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Workshop on Megafloods

The meeting "*Mega-floods: How to identify mega-floods in palaeorecords*", was arranged in Bobole, Mozambique November 1-5, 2004. It formed a part of the project "Dark Nature" and was funded by International Council for Science, International Union for Geological Sciences (Geoindicators), International Union for Quaternary Research and the Norwegian NUFU.

Throughout the geological history mega-floods have occurred in a great many places. The floods have had major impact on geomorphology, and during the Quaternary also on human societies. The cause of the floods varies, from drainage of ice-dammed lakes to the huge rainfalls associated with tropical cyclones.

In January 2000, coastal and lowland Mozambique experienced a period of catastrophic floods. Local settlements were destroyed, with disastrous consequences for the local population. Afterwards, many flood victims were offered new properties in safer localities. The experience has been, however, that many of them later preferred to move back to their old homesteads, which will be at risk during future flood events.

Many other parts of the world have experienced mega-floods during the past decades. Whether or not these are related to global warming is a question that is much debated. In order to understand this question it is important to look at palaeorecords: Have mega-floods been more frequent during warm than cool climate episodes, and if so, in which part of the world is this to be expected during a possible future global warming?

A mega-flood can result in major erosion along the river course, with a subsequent deposition of the eroded sediments. However, in parts of the river catchment it is not easy to trace the flood even a few years later. To understand the frequency and size of ancient floods it is therefore important to know where to look for the flood sequences and how to identify them. These important themes were presented and discussed at the meeting in Mozambique, where case studies of catastrophic floods events in Equatorial East Africa, southeast Africa, North America and Europe were presented, along with methods for flood assessments, remote sensing and studies of flood sediments. This booklet gives a declaration from the meeting, and abstracts of the presentations.

Maputo and Aas, Thursday 29 September 2005

Achimo Mussa Fatima Momade Sylvi Haldorsen

Fortunato Cuamba João Mugabe

Content

Programme
The Mega-Floods Meeting In Bobole, Maputo, Mozambique, Nov 1 – 5

1 November 2004

7.00: Departure from Maputo to Bobole
8.00: Arrival at Bobole
8.00 – 10.00: Registration of the participants & Coffee, Time to book into the rooms
10.00 – 11.30: Opening ceremony (welcome addresses)

- IUGS Vice-president: welcome address on behalf of the International Union for Geological Sciences
- President of INQUA Commission on Terrestrial Processes
- President of AGMM
- Representative of Faculty of Sciences, UEM
- Representative of Ministry of Mineral Resources and Energy (MIREME).

11.30 – 01.00: Lunch

Scientific programme:

01.30 – 14.00: Vasconcelos, Lopo: Floods in Mozambique, January – March 2000
14.00 – 14.30: Haldorsen, Sylvi: Dark Nature: environmental Catastrophes and recoveries in the Holocene.
14.30 – 15.15: Teller, Jim Catastrophic floods and abrupt global change: how glacial Lake Agassiz changed the world.

15.15 – 15.30: Coffee break

15.30 – 16.15: Ridgway, John: An introduction to geoindicators and their relevance to flood studies.
16:15 – 17.00: Abuodha, Pamela and Omenge, John: Modern mega floodings in Kenya especially Budalangi Division and Tana River Districts.
17.00 – 17.45: Bamutaze, Yazidhi: An analysis of the impact of floods on the urban poor in Kampala City.
19.30: Dinner

November 2

Scientific programme continued:

08.30 – 09.15: Kessarkar, Pratima M.: Record of abrupt climate change during Early Holocene on western continental margin of India.
09.15 – 10.00: Graniczny, Marek: Monitoring the catastrophic flood in Central Europe, in summer 1997 by means of modern cartographic techniques.

10.00 – 10.15: Coffee break

10.15 – 11.00: Haldorsen, Sylvi; Jakobsen, Leif; Jørgensen, Per; Strømme, Gaute: Geochemical flux from a mountain catchment is southeasten Norway during the 100 year flood in 1995.
11.00 – 12.00: Teller, Jim: Great floods of the Red River, Manitoba. Canada. The 1997 flood.
12.00 – 13.00: Video session: The 2000 floods, Mozambique

13.00 – 14.00: Lunch

14.00 – 14.30: Famba, Sebastião: The 2000 floods in the Limpopo River Basin, Gaza, Mozambique.
14.30 – 15.00: Tembe, César: The bases for the contingency plan (lecture in Portuguese).

15.00 – 15.15: Coffee break

Lectures related to the training course

15.15 – 16.15: Ridgway, John: Sediment geochemistry in the interpretation of flood plain sediments.

16.15 – 17.15: Teller, Jim: Great Floods of the Red River, Manitoba, Canada: Geoscientific insight into past floods.

17.15 – 17.20: Rhodes, Gwendolyn and Ely, Lisa l. (short communication): Combined palaeoflood and hydroclimatic analyses along some rivers in Idaho/Oregon

19.30: Dinner

November 3

Field programme

08.30 – 09.00: Achimo et al.: Introduction to the field trips.
09:30 – 17.00 Field trip to the Limpopo flood basin

18.30: workshop party

November 4

09.00 – 17.00: Field Trip
The Mkomati River flood plain: sampling and discussion
Maputo City: Erosion and rehabilitation
17.00 – 19.00: Discussion of the day in the field: For the training course participants: writing of The field report.

19.30: Dinner

November 5

Lecture connected to the training course (continued)

08.30 – 09.30: Graniczny, Marek: Ground – Motion Monitoring from the distance of 800 km TerraFirma Project

09.30 – 10.00: Discussion of the previous day in the field
10.00 – 13.00: Working with the samples

- Discussion about the sediment samples
- Preparation for analysis

13.00 – 14.00: Lunch

14.00 – Return to Maputo

Participant List (local organizers in bold)

Abuodha, Pamela, Kenya Marine and Fisheries Research Institute, Kenya

***Achimo, Mussa*,** Department of Geology, University of Eduardo Mondlane, Mozambique

Baloi, Aristides, Department of Geography, University of Eduardo Mondlane, Mozambique

Bamutaze, Yazidhi, Department of Geography, Makerere University, Uganda

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Daudi, Elias Xavier, Director, National Directorate of Geology, Mozambique

*Famba, Sebastião.*Faculdade de Agronomia e Engenharia Florestal, Mozambique

Fortunato, Cuamba, Department of Geology, University of Eduardo Mondlane, Mozambique

Graniczny, Marek, Polish Geological Institute, Poland

Haldorsen, Sylvi, Department of Environmental and Plant Sciences, Norwegian University of Life Sciences

Kessarkar, Pratima M.,Geological Oceanography Division, National Institute of Oceanography,, India

Levy, Albertina, National Directorate of Mining, Mozambique

Macaringue, Daniel, National Institute of Meteorology, Mozambique

Manhica, Vladmiro, National Directorate of Geology, Mozambique

Milisse, Dino, National Directorate of Geology, Mozambique

Momade, Fatima J., National Ministry of Mines, Mozambique

Mondlane, Salvador, Department of Geology, University of Eduardo Mondlane, Mozambique

Mucanhiwa, Tomás, Department of Biology, University of Eduardo Mondlane, Mozambique

Muchanga, Elónio, Dean, Faculty of Science, University of Eduardo Mondlane, Mozambique

Mugabe, João, Department of Geology, University of Eduardo Mondlane, Mozambique

Nogueira, Pedro, Department of Geology, University of Eduardo Mondlane, Mozambique

Ridgway, Jon, British Geological Survey, UK

Rhodes, Gwendolyn, Department of Geology, University of Maryland, USA

Sênvano, Adriano, National Directorate of Geology, Mozambique

Tauacale, Francisco, Department of Geography, University of Eduardo Mondlane, Mozambique

Teller, Jim, Department of Geological Sciences, University of Manitoba, Canada

Tembe, César: Instituto de Gestão de Calamidades, Mozambique

Towela, António Salvador, MICOA, Mozambique

Vasconcelos, Lopo, Department of Geology, University of Eduardo Mondlane, Mozambique

Declaration from the Dark Nature Workshop November 1 – 5, 2004 in Bobole, Mozambique: MEGA-FLOODS: The impact of megafloods - How to identify mega-floods in palaeorecords

The mega-flood meeting in Bobole focused chiefly on floods in Equatorial East Africa and Southeast Africa. This declaration is mainly based on the African experience:

FLOODS:
- Are the most frequent of all natural catastrophes
- Affect almost every part of the World
- Affect a great part of the World's population because so many people live along rivers and on flood-plains
- Have castastrophic effects that are closely linked to the man's manipulation of natural systems

During the history of humankind, the Earth's surface has experienced alternations between dry and wet periods. Floods and droughts along river floodplains and deltas have disrupted lives for the people living there. Catastrophic floods have recently occurred in almost all populated areas of the World. At the same time, many catchments are becoming drier, with reduced river flow. Climate models indicate that both floods and droughts may become more frequent and more severe during global warming. The mega-flood in Mozambique in 2000, as well as the recent catastrophic flooding along the coast of the Gulf of Mexico, showed that societies everywhere are unprepared to meet the challenge of such events.

CATASTROPHIC FLOODS ARE NUMEROUS IN EAST AND SOUTHEAST AFRICA:
Examples from Equatorial East Africa, Lake Victoria Basin:
- 1961: Famine and waterborne epidemics
- 1997/98: One of the worst floods ever recorded in Equatorial East Africa
- 2004: Floods displaced 24,000 people in Kenya

Examples from southeast Africa:
- 1984: Cyclone Domoina caused large floods on the coastal plain of Maputaland in northeast South Africa and southern Mozambique
- 1987: Large flood in eastern South Africa
- 2000: Cyclone Eline caused the largest recorded flood experienced in Mozambique, also large floods in Zimbabwe, Swaziland and South Africa. Nobody was prepared for it and the impact was catastrophic

UNDERSTANDING OF POSSIBLE FUTURE MEGA-FLOODS:
The listed floods in Equatorial East Africa were all related to El Niño events.
Some floods in Mozambique were related to El Niño events, while others were not. The mega-flood in 2000 was not related to any El Niño or La Niña event. Floods in South Africa during the past 50 years have not been related to El Niño events at all. Flood records dating back more than 50 years are almost non-existent in many African countries. This leads us to draw the following conclusions:
- Studies of the relation between climate cyclicity and floods are needed.
- Very little is known about the possible maximum magnitude of future mega-floods.
- Statistical analyses of long flood-records cannot be used to estimate such extremes. They may be orders of magnitude larger than registered floods.
- Sediment records from floodplains and deltas, and the geomorphology of river valleys indicate that pre-historic floods have been much larger than those experienced in historical times.

MANIPULATION OF RIVER SYSTEMS:

River systems are becoming more and more influenced by man:

- Dams
- Levees along artificially channelled river courses
- Bridges
- Extraction of groundwater from river plains
- Construction of heavy buildings and roads related to large cities
    - The recent flood in New Orleans has taught us that even highly developed countries are unprepared to cope with floods related to systems strongly altered by man.
    - In many African countries the rivers systems are still almost natural. There is a great need to know the impact of future man-made manipulation of these rivers.

ACTIONS NEEDED:

The Workshop in Bobole 2004 urges decision makers to:

- Improve research on past environmental change and its effect upon river systems. This knowledge is needed to understand what can be expected in the future. Societies must be prepared for catastrophic flood events larger than hitherto experienced
- Increase the expertise needed to study flood sediments in African countries. Training in sedimentology and past climate history are basic elements related to such expertise.
- Integrate with scientists to make assessment plans, in order to be prepared for mega-floods, to respond during the flood event and to act in the best possible way after the flood event itself.
- Make plans to allow existing data, collected by international researchers, to become available for national experts.

We call upon university and research funding agencies to ensure that:

- In coming to terms with rapid landscape changes, interdisciplinary research is strengthened.
- Funding agencies and the academic organisations increase their support for efforts to link different disciplines.
- More credit is given to young researchers who work with interdisciplinary teams and publish their work on the Internet and in non-specialist journals and books.
- Efforts are made to strengthen links between researchers and the media.
- Research that takes place in Africa is always carried out with the participation of local people, with the results communicated fully to them.

WORKSHOP CONCLUSIONS:

- Catastrophic floods are an integral part of the hydrological cycle – they are recurrent events and will occur again.
- Catastrophic floods cannot be accurately predicted or fully controlled anywhere in the world
- River plains are the most fertile areas. People will recolonise the same areas after floods. Local communities must be prepared for new floods. There is, therefore, a strong requirement for flood assessment plans in Africa.
- These plans must be based on realistic ideas about the largest possible flood.
- Therefore, knowledge about past mega-flood records is needed

Sponsors of the meeting:
-International Council for Science (ICSU)
-International Union of Geological Sciences (IUGS)
-IUGS Initiative on Geoindicators

-International Union for Quaternary Research (INQUA)
-Norwegian Universities Collaboration with Developing Countries (NUFU)

About 40 participants attended the Workshop, 23 of them participated in the Workshop training course. The participants were from First Nations, Developing Countries: governmental institutions and universities, and included decision makers, geologists, meteorologists, geographers and ecologists.

September 25, 2005

Sylvi Haldorsen John Ridgway

ABSTRACTS

Modern Mega Flooding in Kenya especially Budalangi Division and Tana River Districts

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Floods occasionally cause disaster in Kenya. Areas of Budalangi in Western Province and the lower parts of the Tana River are susceptible to floods. In 1997/98 the El Nino phenomenon affected many parts of Kenya causing damage worth millions of shillings, loss of lives, famine and waterborne disease epidemics. With inadequate preparation for the El Nino floods, national resources were over-stretched in the response phase. In 2002 floods affected Budalangi and Tana River resulting in the death of people and livestocks. The situation is aggravated by deforestation, rapid urbanization and weak enforcement of the physical planning Act, resulting in the location of human settlements in flood plains, steep hillsides, without observing building codes, design and standards.

Budalangi division lies to the north of Lake Victoria near the Kenya-Uganda border. Rainfall pattern in Budalangi is mainly bi-modal (two rainfall seasons in a year). The major season occurs in March to May (the long-rains season) while the other season (short-rains) occurs in October to December. Tana River district is in Coast Province of Kenya. The area may be considered a generally dry area. It also observes a bi-modal rainfall pattern (March-May and October-December) but the average rainfall peaks in both seasons fall below 100 mm. January-February and June-September are normally very dry.

Budalangi and Tana River areas have been identified with floods for decades. As a matter of fact, the flooding does not occur due to heavy rainfall in the areas. Annual rainfall analyses indicate that the amounts of rainfall in the areas alone may not be enough to cause such floods. Massive water in-flows emanating from the bursting of River Nzoia banks happens to be the main cause of the Budalangi floods. The River originates from two high-ground areas of Mt. Elgon and Cherengany Hills and drains into Lake Victoria. These two areas are known to have high rainfall amounts almost throughout the year. They receive average annual rainfall amounts of over 1250 mm while Budalangi area receives an average of about 1100 mm. The Nzoia River gathers strength as it flows downstream to an extent of bursting as it reaches the Budalangi areas. It all depends on the intensities of rainfall in the upstream regions Elgon, Cherengany and the surrounding areas. The displaced people usually damage some of the dykes, when they move with their belongings to higher areas that include the dykes, while others, whose homes have been submerged, use the dykes to bury their dead.

A lasting solution to the flooding problem has not yet been found. Every year the area floods, lives are lost, others are evacuated, relief assistance is sought, during dry seasons survivors go back to their land and rebuild their homes and with the next rains, they go through the same cycle. The study of the psychological and sociological attitude to floods reveals that there is remarkably little conscious human adjustment to this danger and that, even in places where action is taken to reduce the flood hazard, it may be ‘casual, improvised, ineffective and far from optimum’.

Meanwhile, some technical measures can help to control extreme floods;

- Reservoir systems for flood retention and control in the mountainous headwater areas.
- Construction of *levees* to increase the carrying capacity for flood flow, including canals parallel to the main stream.
- Real – time flood forecasting and early warning services must also be improved.

- Reforesting the upland regions (to reduce the proportion of run off).
- Dredging and cutting through meander loops.
- The government to improve the infrastructure during dry seasons in order to minimise the impact of renewed flooding.
- The government to build a strong dyke against the deluge, instead of "merely" repairing existing ones through its National Youth Service personnel.

In this paper, Budalangi and Tana River floods are described, causes and effects of flooding are mentioned and ways to eliminate the floods permanently are suggested.

Workshop: The impact of mega-floods
Excursion – field guide

Mussa Achimo, João Mugabe and Fortunato Cuamba
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One major concern in the recent discussion on global climate change is the prospective frequency and severity in the very near future of exstreme events such as heavy rainfall, flooding, drought etc. But estimating the return periods for ythese recent floods is difficult due to short instrumental records (rarely >100 years in most cases). In Maputo, the rainfall is recorded since the 1910s, but we only could get data from the 1950s. Floods are the most common type of natural disasters in Mozambique because of the climate irregularities and its unique drainage. In 2000 southern Mozambique experienced the worst floods in 50 years.

Two training areas were selected for the course of this workshop: Area 1 is within the Mkomati River meander bend north of Marracuene village, 25 km north of Maputo. The area was selected due to the fact that the Mkomati River floodplain areas are inudated periodically by the overbank floow, and the floodplain deposit here reflects the mechanism by which the sediments are transported and deposited. These include transfer from the main channel during overbank flow, and by slope wash from the red sand dunes of the Inland Dune Formation. The 2000 flood sediments are easily identified in cores close the Dune Formation.
Area 2 is located in the Maputo City and this was selected in order to show some of the impacts of the 2000 floods on the geomorphology. Large gullies were formed with a sedimentation on the lowland surface flats. This can be estimated by the heights of the buried houses. In the elevated areas the gullies have cut and/or removed houses and moved entire houses down to the lowland areas. Water supply systems have been cut off in many places.

Are Kampala's Floods driven by Geo-Physical Processes? An Assessment of the causes and Impacts to the Urban Population

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Flooding is one of the major environmental and planning problems in Kampala city. This is because the frequency and occurrence of floods in many parts of the city especially the suburbs has increased tremendously in the last 10 to 15 years. Kampala is largely experiencing flashfloods that occur mainly within the rainy seasons. Flooding in the city affects the population in different ways but is more severe to the urban poor who have mainly settled the flood prone areas that are converted wetlands. Thus even a slight down pour during the rainy seasons may have far reaching impacts to the people in Kampala. Land use changes associated with the geo-physical processes as well as the topographic setup of Kampala have played a significant role in the increase of floods. This paper derives from a compendium of studies (that have been undertaken from both the socio-economic and geomorpholigcal perspectives) to analyze interacting processes of human activity with the natural processes in increasing flooding in Kampala. The paper also analyses the social economic impacts of flooding especially on the urban poor who reside in informal settlements that occupy wetlands mostly. The paper presents an introduction of flooding problem in Kampala before briefly expounding on the drivers for flooding and an assessment of the impacts to the urban population. The paper concludes with a note on the way forward in management of floods in the city that comprehensively needs to consider the anthropogenic processes and geo-physical processes underlying flooding.

The 2000 flood in the lower Limpopo River basin

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The Limpopo catchment forms part of four countries: Botswana, Zimbabwe, South Africa (upper part of catchment) and Mozambique (17%: the whole lower part of the catchment). 13 mill people live in the catchment, with the densest population close to its mouth.

In recent years the river has experienced floods in 1955, 58, 67, 72, 75, 81 and 2000. Discharge measurements in Chókwe in Mozambique showed three times higher flood peak than during any of these earlier reported floods.

The main negative impacts of the 2000 flood in the Limpopo Valley are the following:

- More than 700 deaths and more than 250,000 displaced people
- Lost agricultural land and destroyed roads, railways
- The total cost of the floods damage and relief works is equivalent with about 20% of Mozambique´s GDP
- In addition to this, there became a shortage of drinking and sanitation water and insecurity in circulation of people, good and services.
- Environmental impacts include: Erosion and deposition, reduced vegetation cover (floods affected especially mangrove in the delta area), change in ecosystems and bio-diversity (e.g. occurrence of exotic commercial fish in the river after the flood)

Possible advantages of Floods:

- River ecology – flooding is part of the river nature
- •Fertilization of soils
- •Salt leaching in soils (ex. Chokwe Irrigation Scheam)
- •Increase fish production! After flood
- •Replenish groundwater
- •Rejuvenate wetlands, important for biodiversity

Flood mitigation strategies for the future include:

- Raise awareness of the flood risk in a community
- Establish a contingency plan (be proactive to floods): risk analysis scenarios vs. mitigation strategy.
- Ensure that a community responds effectively to a flood warning
- Ensure clean water is available during and after a flood
- Safe storage of food during a flood
- Evacuation plan
- Measures to be developed locally based on local needs and resources
- Construction of dams, dykes and flood storage areas

Floods are not necessarily disasters. Many positive ecological impacts of the river system are related to flooding cycle

Floods are recurrent events, will come again; - They are integral part of the hydrologic cycle – but each new food will differ in magnitude and characteristics to the previous.

There is a need to record the floods (flood history, flood height, inundated area, satellite images, video and photos) and to consolidate the data in a report.

Flood Hazard Mapping and Monitoring Using GIS and Remote Sensing

Marek Graniczny
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Severe rains affects the Earth almost every year and cause floods, bringing serious damages to towns, roads, agriculture and to the environment in general, sometimes with loss of human life's.

Polish Geological Institute and BGR (Geological Survey of Germany) started common studies in the Odra valley on the beginning of 90th. The multitemporal Landsat TM images, satellite radar data and aerial photos were widely used for geological, geomorphological and landuse mapping.

In the first half of July 1997, heavy rains falling on the border areas between Poland, the Czech Republic, Austria and Slovakia, swelled the water courses and caused floods in the southern part of this region. Within a 10-day period, over 100 people died in Poland and in Czech Republic.

On 15 July ERS-2 SAR data revealed consistent floods near Wrocław on the Odra river and westwards, along the river course. The extent of the flooding along the Odra river was revealed by ERS-2 SAR multitemporal images on 18 July. Additional SAR data, collected from ERS-2 on 21 July, provided, up-to-date information on the event. The flooding along the Odra reached the border between Germany and Poland with a high water pressure that seriously threatened the resistance of a 160-km dike along the Odra near Frankfurt. Threatened zones of the dike could be identified at the Landsat TM data, registered 22nd July. On 23 July a 160-km dike collapsed. Two days later, the residents in the Frankfurt neighbourhood had to be evacuated. In the Czech Republic, thousand of homes were destroyed and thousand of acres of farmlands badly affected. In Poland over 149 villages were submerged and almost as many were threatened by new floods. On 26 July about 15 000 citizens had to leave the Town of Słubice on the Odra. The Polish side of the Odra was more in danger than the German side, because of the height difference between the two river banks (1-3 m lower in Poland). In the night 27-28 July, the water level in Frankfurt reached a record height 6.75 m. The situation improved during the second half of August. Waters retreated, thus reducing the risk of further dike cracks, with the exception of the Oderbruck region. Here, the high water level was still threating villages and farmlands.

By using satellite information (optical and microwave), local authorities, civil protection entities and insurance and re-insurance companies are offered one more tool to monitor flood events and to assess damages. Furthermore, by combining the satellite information with topographic data (DTM), geological and hydrological data, an even more end-user-oriented products can be obtained for direct utilization by entities in charge of risk management and hazard prevention.

Applications of SAR remote sensing in landslide and subsidence studies
Kraków , 29 October 2004
Ground – Motion Monitoring from the distance of 800 km, TerraFirma Project

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The SAR is an active, coherent acquisition system: both amplitude and **phase information** are recorded. Phase values contains information about the **distance between the sensor and the target** on ground. Data are available **since 1992**. The method has been used in Poland.

•Today 3 SAR platforms are available for civil applications, and can be applied to measure small ground displacements. In Poland the method has been used to estimate ground subsidence. However, the method can also be used to look estimate flood water levels.

Preliminary conclusions:

1. The measuring data shows subsidence of the area limited to few millimetres per year 1 – 2 mm. Such small values suggest that these subsidences has not relation to underground exploitation. Only, about 1% of measurements show values extending from 1 to 2 cm, which could be indication of the hard coal exploitation. From other sources (geodetic measurements, precise levelling etc.) the recorded subsidence reach 10 – 20 cm per year and even more.
2. The strong correlation between the recorded negative values and structural pattern of Carboniferous strata is out of question. It is difficult to determine character of this correlation and its genesis, at this moment. The measurement's results indicate that subsidence is present at the areas of synclinal structures and the areas of the dropped wings of the two big regional faults (Będzin and Kłodnica). Undoubtedly, the two above mentioned faults of the Variscan origin were rejuvenated during the Alpine Orogeny (the Triassic deposits were found in the dropped wings of faults). It could be indication of the active tectonic movements, too. The further studies are needed to prove that hypothesis.

Dark Nature: Environmental Catastrophes and recoveries in the Holocene

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Environmental catastrophes become a task of increasing interest during the last years. In 2003 a group of scientists, lead by Prof. Suzanne Leroy at the Brunel University in London took the initiative to establish a project on natural catastrophes. The project was launched in 1994, with funding from ICSU, IGCP, IUGS and INQUA. The purpose of the project is to focus on historical and pre-historical catastrophes and to see which effect these have had on societies. The project will mainly be run as workshops, each of them dealing with one particular kind of natural hazards. The following themes will be addressed in the workshops:

1. Desertification and sever droughts (Mauritania 2004)
2. Mega-floods (Mozambique 2004)
3. Landslides (Argentina 2005)
4. Earth quakes (Black Sea 2005)
5. Melting of permafrost (Canada 2005)
6. Final meeting, with field trips to areas of neotectonics (Italy 2005)

Most of the catastrophic events listed above are driven by climate. In global change prognoses one will very often meet the prediction that climate extremes will become more frequent during a global warming. One of the main aims of the Dark Nature project is to look at past events, in order to see how they are linked to wet and dry, warm and cold climate episodes. Another aim has been to analyse historical data to understand how societies and ecosystems in an area exposed to natural catastrophes responded during the different events.

When we analyse data for example for mega-droughts, we often see that the relation between climate and the catastrophic events is not necessary linked in the way predicted by climate modellers. For example, in several areas climate prognoses link "warm and dry" while data from the past indicate that "warm" has been associated with "wet". In other areas a climate prognosis may say that large floods will become more frequent, while data from the past may tell us that the most catastrophic mega-flood events may have occurred during dry climate periods. It is necessary to understand what causes a catastrophic event, how it develops over time. This requires an integrated knowledge about climate, landscape, vegetation and land use in the area where it happens.

This meeting will in particular focus on recent mega-floods. The main focus will be on the interplay between nature and people.

Geochemical flux from a mountain catchment in southeastern Norway during the 200 year flood in 1995

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In 1995 eastern Norway experienced the largest flood ever recorded. The flood was caused by a snow-rich winter, along with a late and sudden melting period. The flood was in particular severe along the two large rivers of Glåma and Lågen with their tributaries. The discharges are normally controlled via a series of hydroelectrical dams, but the flood was too large to be managed by opening and closing of the dams. Our study was done in a sub-catchment of the largest tributary of Glåma, the Godlidalen, situated on the mountain plateau between Glåma and Lågen. The sub-catchment is natural and not manipulated by any dams. Discharge and geochemical flux were measured during the whole flood event, and was compared with the flux during the rest of the year 2005 and with the snow melt flood in 2004. In 1995 about 50 % of the annual ion flux out of the valley occurred during the first week of July. The discharge was the twice the discharge of the snow-melt flood in the same catchment in 2004, and the cation flux was 20 % higher. During the first month after the flood, the electrical conductivity of the river water was the lowest we have ever measured during the period 1985 – 1996. The lowest electrical conductivity was measured after the flood peak. This shows that ions are removed from the groundwater zone during the whole flood event from the start of the flood until its end. The geochemical flux during the 1995 flood is equivalent to the ion reservoir in the upper 2 m of the groundwater zone in the whole catchment.

Mega-floods in southeast Norway were considerably more frequent during the sold climate period from 1800 to 1880 than they have been during the warm period 1920 – 2000. Predicted climate changes in the region indicate that the amounts of lsnow in the studied catchment will decrease. The risk of mega-floods will most likely be reduced if the climate prognoses prove to be correct.

Record of Abrupt climate change during Early Holocene on the western continental margin of India

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Flood is one of the natural hazards that affect most of the countries in the world. The developing countries, particularly those in the tropics, with high and seasonal precipitation are subjected to widespread flooding. These floods are often related to deforestation, Industrialization etc. For the purpose of detecting the effects of human activities on climate change, it is important to document natural change in past climate.

India is monsoon influenced country, the Western Ghats provides a principal geographical barrier in the path of the Arabian Sea. Southwest monsoon season (june to september) is the principal rainy season, over 90 % of annual rainfall is realised in this period. The southwest coast of India is directly influenced by SW monsoons with high annual rainfall of 3,107 mm (national average is 1,197mm) in Kerala.

To check the influence of monsoon induced flooding in the marine environment, three sediment cores collected from the southwestern margin of India were studied for various sedimentological parameters (organic carbon, $CaCO_3$ content, grain size, coarse fraction constituents) and the results compared from the northwestern margin of India which is less monsoon affected. Our cores are located off Thiruvananthapuram, Mangalore and Goa and were collected from water depths of 1420 (core 1), 1940 (core 2) and 2650 (core 3) m respectively. Silty clays are the predominant sediment type in all the cores. The organic carbon (OC) content in the core-tops decreases from 4.4% (core 1) through 2.4% (core 2) to 0.6% (core 3). The $CaCO_3$ content is 38%, 26% and 43% in cores 1, 2 and 3 respectively. Down-core variations reveal two intervals of high OC associated with sediments of late Holocene and the Last Glacial Maximum (LGM), and an interval of low OC during early Holocene. Increased terrigenous clay content coincides with low OC and $CaCO_3$. Although high OC corresponds with high $CaCO_3$ in late Holocene sediments, there is no such relation in some early Holocene and LGM sediments. Down-core variations in OC are similar in southwestern margin cores. In contrast, a sediment core from the northwestern margin of India (at 1900 m water depth) exhibits low OC associated with LGM sediments. A gentle increase in organic carbon in late Holocene sediments is documented in all the cores.

An increase or decrease of OC in the LGM sediments of the southwestern / northwestern margin of India may be related to the presence / absence of convective mixing associated with the NE monsoon in these regions. The decreased OC and $CaCO_3$ and increased clay content evidence an intensified SW monsoon during early Holocene. Dilution by terrigenous matter and a stronger near-surface stratification during periods of intensified monsoons may have led to lower productivity. These features observed in the most of the cores on western margin of India suggest possibility of megaflood during this period. Increased OC in late Holocene sediments again suggests increased productivity and commencement of present day condition.

GEOINDICATORS: An introduction and their relevance to flood studies

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In 1992, the International Union of Geological Sciences (IUGS) established, through its Commission on Geological Sciences for Environmental Planning (COGEOENVIRONMENT), a working group to develop geological indicators of rapid environmental change. With the assistance of specialists in a variety of geoscience disciplines, the working group compiled a Geoindicator Checklist. This was designed to provide decision-makers, managers and planners with a series of Earth science related tools to aid in the assessment and monitoring of Earth system processes and changes that are important to the way man lives in, uses and manages urban, agricultural and wilderness environments along with their mineral and biological resources. The Geoindicators Initiative (GEOIN) has developed from this to encourage the application of geoscience to environmental concerns through monitoring and assessing rapid geological change. GEOIN operates via the Internet (www.geoindicator.org) as a medium for the exchange of data, information and experiences and is involved in the organisation of conferences, workshops, training courses, publications and other activities. The website provides an up-to-date list of activities and publications on geoindicators.

Geoindicators are measures (magnitudes, frequencies, rates and trends) of geological processes and phenomena occurring at or near the Earth's surface and subject to changes that are significant for understanding environmental change over periods of 100 years or less. They are applicable to both catastrophic events and those that take place more gradually, but which are evident within a human lifespan. Typically, they are high-resolution measures of dominantly abiotic, short-term changes in the geological environment, many of which can result in irreversible ecosystem disturbances at a variety of scales. Standard techniques in geology, geochemistry, geophysics, geomorphology, hydrology, physical geography and other Earth sciences form the basis for the development of geoindicators. Some measure simple observable changes that are easily represented on maps (e.g. shoreline position or the areal extent of a lake), whilst others (e.g. soil or groundwater quality) require measurements of chemical, physical, or biological parameters.

Twenty-seven geoindicators have been identified that are applicable to monitoring and assessing geological changes in fluvial, coastal, desert, mountain and other terrestrial areas. Examples of typical geoindicators are given and the twelve indicators that provide tools of relevance to the study of floods, their causes and effects, are briefly described.

Geochemistry in the Interpretation of Floodplain Sediments

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River floodplains provide a history of the their development through the preservation in their deposits of sedimentary features, fossil plant and animal life, and both physical and geochemical records. Together these features provide information on the fluvial environment in which the sediments were deposited, their age, the prevailing climate and land use at the time, and the origin of the materials. The interpretation of these features, however, is complex and multi-disciplinary studies are required in order to achieve a proper understanding of floodplain evolution.

The geochemistry of floodplain sediments is one of the tools that can be used, in conjunction with archaeological and industrial records and knowledge of the regional geology, geomorphology and geochemistry, to help decipher the age and origin of deposits and the processes of floodplain development.

Floodplain deposits can be sampled in natural riverbank and terrace exposures, by hand digging, the use of industrial excavators, or with a variety of drilling and coring techniques. The design of sampling programmes, wherever possible, should be based on an understanding of the geomorphology of the floodplain. Sampling intervals and the analytical programme depend to some extent on the aims of the study, but the possibility of post-depositional chemical movement under the influence of, for instance, changing water tables, must not be overlooked.

In drainage basins subject to mining or industrial activity, the geochemistry of floodplain sediments can be linked to records of contaminant output to help date flood events and cast light on how sediment moves through the system.

In general, the use of geochemistry in the interpretation of floodplain deposits depends on the close link between the geology of an area and the geochemistry of the sediments derived through erosion of that area. Regional geochemistry can be used to model inputs to a fluvial system from different parts of the drainage basin and to remove the effects of mining and industrial contamination. Even where regional geochemical data are not available, if the geology is known, limited sampling programmes can provide sufficient information to develop useful models.

Combined palaeoflood and hydroclimatic analyses along some rivers in Idaho/Oregon

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Combined paleoflood and hydroclimatic analysis can be used to suggest the timing of modern and ancient extreme floods and causal mechanisms associated with their occurrence. Flood terrace stratigraphy at the Tin Shed and China Rapid sites along the Hells Canyon reach of the Snake River, Idaho/Oregon were examined to chronicle flood-related sedimentary deposition. Further, to associate climatic and meteorological conditions to the extreme floods (>10 yr recurrence interval) in the central and lower Snake River basin composite maps of geopotential height anomalies over the North Pacific Ocean were constructed based on historical stream gauge and precipitation records.

Flood terrace stratigraphy at Tin Shed and China Rapids suggests 25 extreme floods have occurred over approximately 5,000 years. A set of younger flood layers, which are <1 m below the surface yield samples with radiocarbon ages between 0-2 cal yr B.P. and 573-462 cal yr B.P. Some of these layers were probably deposited during extreme floods that occurred between 1894 and 1964. An older set of layers >1m below the surface yield samples with ages between 1269-1045 cal yr B.P. and 8661-8451 cal yr B.P. Younger and older sets of layers are separated by 0-2 units, which suggests a temporal gap.

Seventy percent of the daily composite maps constructed for dates prior to winter (DJF) extreme floods in the historical record show a high-pressure anomaly near the Aleutian Islands and Bering Strait. In contrast, only 35% of daily composite maps based on extreme precipitation (90th percentile) show high-pressure anomalies over the Aleutians Islands and Bering Strait. High-pressure anomalies in this area are associated with snowmelt, rain-on-snow events or extended periods of extreme precipitation. The difference in mapped anomalies and extreme stream flow and precipitation is probably due to stream flow response lag time and the complexity of flood-generating meteorological conditions.

Catastrophic floods and abrupt global change: how glacial Lake Agassiz changed the world

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During the last glacial period, nortward-draining rivers in North America were dammed by Pleistocene ice, forming an extensive although discontinuous fringe of lakes across Canada that extended from the Mackenzie River basin across the Prairies to the Great Lakes and into the St. Lawrence Valley. This vast network of lakes was episodically connected as glaciers retreated, and overflow from them influenced most major hydrological systems east of the Rocky Mountains, as well as the oceans into which the lakes drained. Glacial Lake Agassiz was the largest of these lakes, covering large areas in Manitoba, Saskatchewan, Ontario, and western Quebec, as well as the largest lake in the world, and its geological record extends over more than 1.5 million km^2. Lake Agassiz influenced the climate, vegetation, and people of this vast region, and its overflow played a role in the evolution of the Great Lakes, St. Lawrence Valley, Mackenzie River Valley, and Mississippi River Valley systems. Overflow from Lake Agassiz entered 3 different oceans during its 5000-year life span, and periodic catastrophic outbursts of thousands of cubic kilometres of water altered global ocean circulation and brought about at least 3 episodes of global cooling during a period when the earth was warming. The record of overflow from this lake is being used to model potential impact of large fluxes of freshwater on global ocean circulation and climate.

Although none of the outbursts from Lake Agassiz resulted in ea level rises of more than 0.5 m, some caused rapid *transgressions* of the ocean across shallow continental shelves and marine basins. For example, the final outburst from Lake Agassiz 8400 years ago (163,000 km^3) would have caused an abrupt transgression of 0.7 km in one year across the floor of a gentle continental shelf with a slope of 1 in 1500, like that of the Mississippi River delta. On the nearly flat floor of the Persian Gulf (1:25,000 slope), which was dry during the last glacial maximum, the final outburst from Lake Agassiz resulted in a transgression of 12 km in only one year. Thus, in the Persian Gulf basin, not only did melting ice sheets produce a continuing ocean transgression of 140 m every year for 7000 years, but there was also an abrupt transgressive flood of 12 km about 8400 years ago. Generation after generation of humans living on the floor of the Persian Gulf would have been forced to move to higher and higher land: on at least one occasion, they would have had to move quickly. This must have prompted stories about a “flood”, such as that recorded in Babylonian history as the Epic of Gilmamesh (in the first cuneiform script on clay tablets, which were buried in the NW end of the Persian Gulf) and, perhaps, in the Bible as Noah’s Flood.

Identifying Past Great Floods of the Red River, Canada and the U.S.

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The Red River has a history of spring flooding, with large historic floods in 1826, 1852, 1861, 1950, 1979, and 1997. The most recent flood in 1997 formed a lake in the Red River Valley that was up to 120 km long and 38 km wide, which progressed northward (downslope) over a period of more than a month, reaching a maximum size of 2000 km^2. Although the economic impact of this flood exceeded $5 billion, only 3 lives were lost because waters rose slowly and were generally < 2 m deep; as well, many towns and cities were protected by ring dikes and diversion channels, and hydrological forecasting allowed evacuation and further reinforcement of engineering structures. The Red River meanders for 880 km across a wide (~50-120 km) very flat plain on the floor of former glacial Lake Agassiz, extending from the North Dakota-South Dakota border (U.S.A.) north to Manitoba (Canada). The main reasons leading to historic spring floods are: (1) high soil moisture content before winter, (2) deep freezing of the surface prior to spring runoff, (3) heavy winter snowfall that does not melt and/or heavy spring rains, and (4) a late and rapid spring thaw. This is all superposed on the low river gradient (0.0001), impermeable clay substrate of the drainage basin, and recent construction of agricultural drainage ditches that rapidly carry spring runoff to the main river. In 1997, an unexpected problem developed in the flooded area when wind generated waves >0.5 m high and also caused the “lake” surface to be set up by ~0.4 m, eroding protective earthen barriers around towns and cities.

To better predict future floods and design protective structures, geologists are studying the past record of flooding in the Red River Valley. Historic documents since 1800 are very helpful. Surprisingly, alluvium along the river and at its mouth have not provided a good record of flooding, perhaps because (1) the record is discontinuous, (2) bioturbation (roots, animals, agricultural plow layer) and freeze-thaw mixing have disturbed the record, (3) chronological resolution is poor, and (4) sediment accumulation is mainly silt and clay during floods as well as during normal flow. The isotopic record of cellulose in sediments at the mouth of the river studied by Bill Buhay provides some insight, such as “wet” vs “dry” periods, but it is not fully synchronous with the historic record.

The tree ring record provides the best insight into flooding along the Red River and its main tributary, the Assiniboine River, and has been studied by Scott St. George and Erik Nielsen. The overlapping chronology of >400 oak trees—some living, some in buildings, and some buried in alluvium—provide an annually-constrained record of large floods along the river since 1648; this record is cross-referenced during the period of historical records. Anatomical anomalies in tree ring growth identified by St. George and Nielsen (2000, 2002, 2003), such as reduction in mean vessel size and absence or reduction of spring and summer growth, are key in reconstructing the history of large floods. Seven major floods were identified over the past 350 years; there seems to be no regular recurrence interval nor trend in flood magnitude. Tree-ring widths have been used to reconstruct a record of annual precipitation for the past 600 years, and several prolonged dry and wet periods have been identified; these are consistent with other hydroclimatic records outside of this region.

Research by Scott St. George (Geological Survey of Canada), Erik Nielsen (Manitoba Geological Survey), and W. Buhay (University of Winnipeg) provided most of the data for the analyses presented; much of this has been published.

The basis for the contingency plan in Mozambique after the 2000 flood

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Documento orientador para as accoes a realizar antes, durante e depois da ocorrencia da calamidade.
Elaboracao numa base anual desde 1996
Contexto:
  Previsao meteorologica;
  Avaliacao hidrologica
  Populacao em risco;
  Estrategias de accao antes durante e depois da ocorrencia da calamidade;
  Recursos disponiveis e necessario;
  Resumo financeiro por provincia e sectores.
Reduzir o risco de calamidades
Antever os cenarios possiveis durante a epoca chuvosa e de ciclones;
Sistematizar os recursos disponiveis e necessarios;
Garantir a coordenacao intersectorial das accoes de prevencao e prontidao.
Metodologia:
Participativa: Planos provinciais esectorial

Existem 7 grupos(ver composicao no PC 2003/4) de trabalho para a execucao, monitoria e avaliacao especifica das actividades em de ocorrencia de calamidades, nomeadamente:

- Cooredenacao;
- Alerta e aviso;
- Educacao Civica e Sensibilizacao;
- Busca e salvamento;
- Logistica;
- Abrigo e Saneamento;
- Seguranca alimentar e Agricultura.

The impact of mega-floods
How to identify mega-floods in palaeorecords
Introduction to the workshop

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This lecture will give an overview of the geology and geography of Mozambique, as a background to understanding of the flooding in the country.

Northern Mozambique is dominated by Precambrian rocks, with a belt of sedimentary rocks along the coast in the east and Karoo age rocks in the northwestern corner, along the border to Tanzania and Malawi. The Zambezi River forms the boundary to Central Mozambique.

In central Mozambique there are two areas of Precambrian rocks to the west, surrounded by a belt of sedimentary rocks, with the main occurrence in the central part of this region.

Southern Mozambique is dominated by sedimentary rocks, with volcanic Karoo age rocks along the border to South Africa. These form the Lebombo mountains.

Quaternary unconsolidated sediments cover most of Southern Mozambique and the coastal zone of Central Mozambique.

A great part of land is a lowlying coastal plain, especially in southern Mozambique, with altitudes below 200 m a.s.l. In these areas the typical flood-plains occur. Areas influenced only by precipitation falling in Mozambique seldom experience floods. For areas influenced by precipitation in neighbouring countries, there is a high risk of flooding. There are very few dams in Mozambique.

Topics of this workshop will be:

- How to identify flood events in palaeorecords from several environments
- The catastrophic effect of historic and modern mega-floods
- The impact of historic and pre-historic floods on human societies

Floods in Mozambique

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As it was world-wide broadcasted, Mozambique faced the most severe floods of the last 50 years, due to heavy rains and 2 cyclones. The floods affected the southern provinces of Mozambique: Maputo, Gaza, Inhambane, Manica and Sofala. The cyclones affected Inhambane, Sofala, Manica Zambézia, Nampula and Cabo Delgado Provinces

In February 2000, the precipitation system produced rainfall at a rate exceeding 500mm a month in the damaged area. Heavy rain fell intermittently for three weeks from Feb. 26. This rate is several times the normal yearly rates.

As a result, rainwater flowed into the valley of the Limpopo River and caused a flood.
The hypsometric map of Mozambique shows that in the Limpopo area, altitudes do not reach 200m The Limpopo River is usually 10 km wide, but reached a maximum width of 125km.

Risks of flood:

- In areas influenced by precipitation only in Mozambique, floods rarely occur.
- Areas influenced by precipitation in neighbouring countries are high risk flooding areas.
- The high risk flooding areas are the low-lying areas found along the coast

Because of the large areas with low-lying coasts along river mouths, Mozambique is a highly vulnerable country in terms of water control.