MEETING

Challenges to Understanding Past and Future Climate in Africa

MARUM Workshop: Response of North African Ecosystems to Abrupt Climate Change; Bremen, Germany, 14–16 November 2007

PAGE 196

The future response of African ecosystems to global change is highly uncertain. North Africa is one of the regions where many state-of-the-art climate models fail to reproduce major features of the monsoonal precipitation system, and consequently, projections of future changes are not coherent among different models. A 3-day workshop brought together 50 international experts in atmosphere physics, African paleoclimate, and archaeology. The workshop aimed to explore the role of Africa in global climate change throughout the geological past, the present, and the future. The following principal recommendations resulted from the workshop:

1. The Intertropical Convergence Zone is effectively independent of the system that produces most of the rainfall over West Africa. Recent meteorological observations show that the rainfall belt is produced by a deep core of rising air that lies between the axes of the midtropospheric African easterly jet and the upper tropospheric tropical easterly jet. While the location and intensity of the African easterly jet has long been implicated as a major factor in interannual rainfall variability, the role of the tropical easterly jet has been largely ignored until recently. Future research should focus on mechanisms that control the dynamics of the two jets in order to improve predictions of West African precipitation.

2. Marine and terrestrial paleoclimatic records from all around and throughout the African continent show pronounced dry spells between the Mediterranean and about 10°S that are associated with slowdowns of the Atlantic meridional overturning circulation during known millennial-scale periods of the Pleistocene (1.8 million to about 10,000 years ago) when anomalously cold conditions prevailed in the North Atlantic realm (so-called Heinrich events and Dansgaard-Oeschger stadials). It is still an open question as to whether this drying was due to an overall drying in tropical Africa or whether these events represent southward shifts of the tropical rain belt. Because a slowing of the overturning circulation is to be expected for the future, further studies should address this question by extending the paleoclimatic archive.

3. Another open question concerns the abruptness of environmental changes in North Africa during the Holocene (the past 10,000 years). Although the early Holocene's rapid change to humid conditions is now widely accepted, increasing support speaks for a gradual rather than abrupt decline of precipitation along with a decrease of summer insolation. Climate models show contradictory results. While one model suggests an abrupt collapse in vegetation and precipitation caused by a strong positive vegetation-climate feedback, another model shows a gradual retreat of rainfall. To resolve this discrepancy, independent paleobotanic and paleoclimatic estimates of Holocene changes in Saharan vegetation and rainfall are sorely needed.

4. Modeling of climate-dust feedbacks is still in its infancy. Besides tremendous uncertainties regarding dust radiative forcing, simulating the global dust cycle is still a challenge, in particular due to uncertainties in the dust emission term. So far, there is no consensus as to whether mineral dust aerosols will increase or decrease in the future and what their impact on climate will be. Implementing and improving dust feedbacks in climate models should be on the top priority list of model developers.

The workshop agenda and more details can be found at http://www.marum.de/african-workshop.html.

The full text of this meeting report can be found in the electronic supplement to this *Eos* issue (http://www.agu.org/eos_elec).

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BOOK REVIEW

Fundamental Astronomy, Fifth Edition

Hannu Karttunen, Pekka Kröger, Heikki Oja, Markku Poutanen, and Karl J. Donner, Editors
Springer; 2007; 510 pp.; ISBN 978-3-540-34143-7; $69.95

PAGE 197

Writing a spectacular astronomy book is relatively easy these days. The impressive images of the latest observations of the celestial world capture the attention even of those who may not be interested in anything else in the world. In the bookstores, one can find a wide variety of beautifully illustrated books that display all of the known members of the celestial realm. The books present us with the planets and their moons, the Sun, some spectacular stars and constellations, the Milky Way, other galaxies, and the incomprehensible dimensions and depths of space. Undoubtedly, all of us—regardless of age or social or academic background—need these books, simply because we would like to know where we actually live.

This book is not simply one of those types of astronomy books. Showing a number of shiny astronomical objects cannot satisfy the book's editors. This is evident for the reader even without opening the book. The title, *Fundamental Astronomy*, already places the level of our expectations high. And the cover photo does not show any magnificent solar prominence before a violent eruption or the lofty Horsehead Nebula in Orion or any astonishing infrared view of the Andromeda Spiral Galaxy. Instead, the photo displays the massive James Clerk Maxwell Telescope, in Hawaii. The picture expresses the desire of the editors, and of eager amateur and professional astronomers, to explore the universe and discover the laws governing it.

More than two decades ago, the book's editors—a handful of Finnish astronomy teachers, solar physicists, and astronomers—decided to provide a textbook for astronomy students and, at the same time, a handbook for serious amateurs. In this book, the editors have proven their claim that the reader needs only standard high-school knowledge of mathematics and physics to digest the chapters, which, one by one, cover every field of astronomy.

The reader can learn basic observational techniques first. This leads to the detailed description of the solar system, various classes of stars, interstellar medium, star clusters, and galaxies. These various subjects of astronomy follow upon each other in a carefully structured order.

In addition to presenting the fundamentals of astronomy, the editors have been working hard to include the latest discoveries and an up-to-date understanding of astronomical questions. For example, the editors take into account the redefinition of a planet by the International Astronomical

Supplementary material to “Challenges to Understanding Past and Future Climate in Africa”

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Response of North African ecosystems to abrupt climate change (Supplement)

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North African climate is dictated by a monsoonal circulation system. During summer, the southwesterly monsoon surface winds penetrate as far north as 20ºN, transporting moisture onto the African continent across the Guinea coast. The monsoon flow converges with northeasterly Saharan trade winds (“Harmattan” winds) at the monsoon trough which is also referred to as the “Intertropical Front” (ITF) or the “Intertropical Convergence Zone” (ITCZ). At higher levels, two easterly jets characterize the tropospheric circulation over North Africa: the mid-level African Easterly Jet (AEJ) with its maximum near 600 hPa and the Tropical Easterly Jet (TEJ) with its maximum near 150 hPa in the upper troposphere. The average summer position of the AEJ is about 15ºN, while the TEJ is located around 5ºN. In winter, North African climate is dominated by the dry Harmattan winds penetrating almost as far south as the Guinea coast.

Over West Africa the summer rainfall maximum is some ten degrees of latitude south of the ITCZ and it is important to realize that the ITCZ is effectively independent of the system that produces most of the rainfall. Sharon Nicholson (Florida State University) pointed out that the tropical rainbelt – which is often confused with the ITCZ – is in fact produced by a deep core of ascent lying between the axes of the AEJ and the TEJ. The seasonal precipitation cycle is related to seasonal changes in these jet streams. While the location and intensity of the AEJ has long been implicated as a major factor in interannual rainfall variability, the role of the TEJ has been largely ignored until recently.

On average, more than 80% of annual precipitation over the semi-arid Sahel region (ca. 10ºN–20ºN) occurs during the summer months June–September. Andreas Fink (University Cologne) reported that the most important rain-bearing weather systems in the Sahel are organized mesoscale convective systems, mostly squall lines, which contribute to about 80–90% of the local rainfall. Towards the moister Guinea coast unorganized convection types (e.g., "afternoon instabilities") become more important.

Jost Heintzenberg (Leibniz-Institute for Tropospheric Research, Leipzig) summarized the influence of mineral dust on the energy balance of the Earth system. Dust aerosols modify the transfer of solar radiation through the atmosphere by scattering and absorption processes. Through absorption, dust particles also interact with long wave radiation fluxes. Moreover, acting as cloud condensation nuclei and ice nuclei, dust particles may modify the albedo and lifetime of clouds. On the other hand, it has also been observed that Saharan dust may act to inhibit precipitation: clouds forming within desert dust contain relatively small droplets and produce little precipitation by drop coalescence. Peter Knippertz (University Mainz) reported that meteorological systems relevant for Saharan dust mobilization range from microscale dust devils and convective dust plumes (which are estimated to contribute ca. 35% to the global dust budget) over mesoscale cold fronts and moist convective outflow boundaries to synoptic-scale wintertime low pressure systems.

The radiative forcing of airborne mineral dust also affects African climate via vegetation dynamics. Andrea Sealy (NCAR, Boulder) presented preliminary results from the Community Atmosphere Model coupled to a dynamic vegetation model and a dust transport module which takes direct radiative feedbacks into account. The simulations suggest the existence of a strong response of precipitation and dust to dynamic vegetation.

New results from both marine and terrestrial paleoclimatic archives were presented from all around the African continent ranging from the eastern Mediterranean to the Indian and Atlantic Oceans, as well as several African lakes. John Peck (University Akron) presented a 1 Ma sediment record from Lake Bosumtwi, Ghana. On orbital time scales, this record indicates an elevated aerosol dust export from arid Sahel sources during glacial lake-level lowstands. Two drill sites in Lake Malawi (East Africa) presented by Chris Scholz (Syracuse University) and Tom Johnson (University Minnesota) show periods of severe aridity between 135 and 75 ka ago, when the lake's water volume was reduced by at least 95%. At this site drought has been strongly influenced by high-amplitude precessional variability of Southern Hemisphere insolation. A feature present in nearly all records (both lake and marine) between the Mediterranean and about 10ºS are pronounced dry spells associated with a slowdown of the Atlantic meridional overturning circulation (AMOC) during Heinrich Stadials and, to a lesser extent, during Dansgaard-Oeschger Stadials. Henry Lamb (Aberystwyth University) and Dirk Verschuren (Ghent University) presented paleoecological data from East African Lakes. These data show that dry conditions prevailed during Heinrich Stadials. Further evidence for dry conditions during Heinrich Stadials was presented by Stefan Mulitza (MARUM Bremen) who showed two sediment cores from the continental slope off Senegal and Mauretania where dust deposition was increased. It is still an open question as to whether this drying was due to an overall drying in tropical Africa, or whether these events represent southward shifts of the tropical rainbelt. A sediment core studied by Holger Kuhlmann and Jürgen Pätzold (MARUM Bremen) in the southwestern Indian Ocean indeed seems to suggest higher fluvial sediment input related to increased precipitation during Heinrich Event 1 and the Younger Dryas. By contrast, a marine pollen record from the southern rim of the tropical rain belt presented by Lydie Dupont (MARUM Bremen) in the eastern Atlantic indicates a northward shift of atmospheric (Congola Air Boundary) and oceanic (Angola Benguela Front) fronts during Heinrich Event 1.

Several records documented a more gradual decline of precipitation along with the Holocene decrease of summer insolation. Syee Weldeab (Kiel University) presented paired measurements of Mg/Ca and oxygen isotopes in a core from the Gulf of Guinea that show a gradual runoff decline. A relatively gradual change toward more arid conditions is also evident from a northern Red Sea sediment core studied by Helge Arz (GFZ Potsdam). However, many records also indicate the presence of abrupt multi-centennial droughts during the Holocene. Gerhard Schmiedl (Hamburg University) presented a core from the Mediterranean that reveals multi-centennial fluctuations in Nile discharge during the middle to late Holocene, including severe droughts at 8.2 and 4.2 ka. Holocene fluctuations in Sahel precipitation have been documented in a sediment core from Retba Lake presented by Raphaël Sarr (Dakar University).

Matthias Prange (MARUM Bremen) presented a detailed analysis of the West African rainfall response to a weakening of the AMOC in the Community Climate System Model. The model simulates the observed drying of West Africa (both in the Sahel and in the Guinea coastal region) which can be explained by enhanced northerly low-level inflow of dry Saharan air into the Sahel region (induced by a high-pressure anomaly over the Mediterranean Sea and northern North Africa associated with surface cooling) in conjunction with an intensification and southward expansion of the mid-tropospheric AEJ.

Drier conditions in the West African Sahel were also found in climate model simulations of the Last Glacial Maximum as reported by Ute Merkel (Bremen University) and Bette Otto-Bliesner (NCAR, Boulder). Climate models also simulate wetter North African conditions during the early/mid Holocene, although the scatter in rainfall magnitude is considerable and the predicted patterns of Saharan greening are rather different. Presentations by Martin Claussen (MPI Hamburg), Zhengyu Liu (University of Wisconsin-Madison) and Victor Brovkin (PIK, Potsdam) showed that coupled climate-vegetation models are capable of simulating the expansion of the Sahara during the mid/late Holocene due to precession-forced insolation changes. In these models, the biogeophysical feedback exhibits complex dynamics including multiple steady states and bifurcations. The presented models, however, show strong differences in the abruptness of the climate transition and the role of vegetation feedbacks.

Stefan Kröpelin (University Cologne) presented terrestrial evidence for climate change in sub-Saharan Africa, mostly based on archaeological findings. Around 9.5 ka ago there was an abrupt extension of monsoonal rainfall leading to widespread human occupation of most likely savanna-type areas that are nowadays sand seas. Subsurface drainage systems indicate widespread runoff by rivers and ample evidence of regional cattle pastoralism suggests prevalent grasslands at those times. The dry centre of the desert was located at about 25ºN, yet still receiving about 150 mm rain per year. The abrupt change to relatively wet conditions was followed by a gradual drying of the Sahara starting at about 8 ka BP, leading to a steady expansion of the desert in both northern and southern directions and resulting in a southward migration of the 150 mm isohyets to about 17ºN at present. More evidence of large-scale reorganisations in climate, leading to spatial variability in vegetation was presented by Katharina Neumann (University Cologne) who deduced seasonality changes from population movements. In particular the spread of the

Bantu Language by savanna specialists through areas that are now impenetrable rainforests was taken as proof for several rainforest crises centered around 2.4 ka BP. Effects of modern climate change on conflicts were presented by Cullen Hendrix (San Diego University). He emphasised that there is a tight coupling between aridity, land degradation, and conflict likelihood in Africa. Heiko Paeth (University Würzburg) investigated the influence of climate change on the future dissemination of malaria. From his study it appears that there will be strong regional differences in the spread of this disease between West and East Africa.

The workshop agenda and more details can be found at http://www.marum.de.

References

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