RESEARCH CONFERENCES

ESF-LFUI Research Conference

Modes of Variability in the Climate System: Past-Present-Future

Universitätszentrum Obergurgl• Ötztal• Austria,
27 May – 1 June 2012

Chaired by: **Hubertus Fischer**, Climate and Environmental Physics, Physics Institute & Oeschger Centre for Climate Change Research, University of Bern, CH
Co-Chaired by: **Eric. W. Wolff**, British Antarctic Survey, Cambridge, UK

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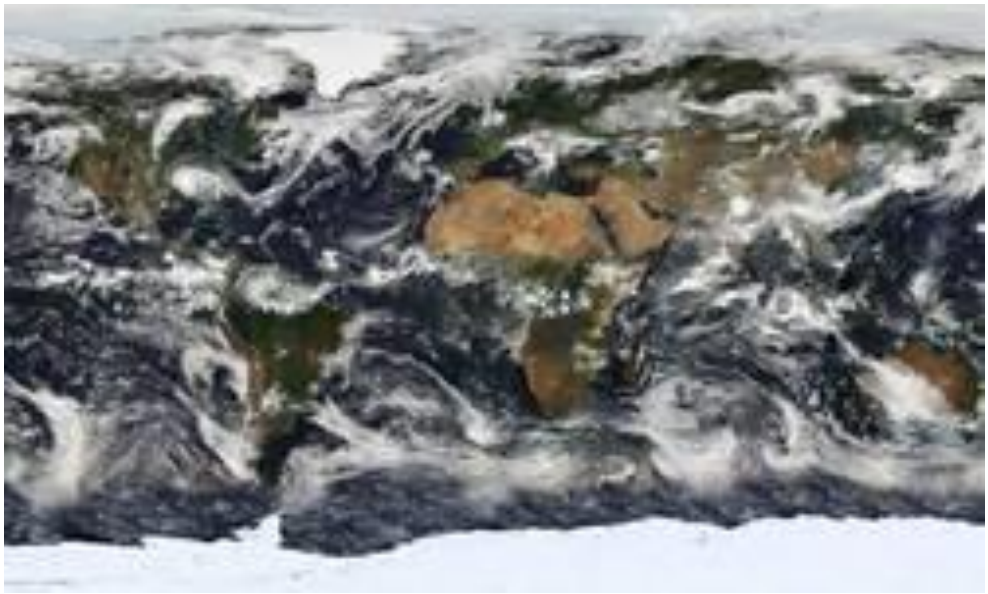
Highlights & Scientific Report



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Conference Highlights

Please provide a brief summary of the conference and its highlights in non-specialist terms (especially for highly technical subjects) for communication and publicity purposes. (ca. 400-500 words)

The ongoing climate warming requires a detailed understanding of global and regional climate variations and forecasting of their future changes using climate models. These changes pertain not only to the average global warming but especially to changes in regional climate, circulation patterns and their temporal variability, which have direct impact on individual welfare and societies. Moreover, to decrease the uncertainty in model predictions, climate models have to be validated using paleoclimate data as provided by natural climate archives. Spatially representative climate modes and teleconnection patterns and their temporal variability allow for this validation and represent the vehicles to contrast rather coarsely resolved climate models to point-wise paleoclimate data.

Accordingly, the Conference “Modes of Variability in the Climate System: Past-Present-Future” aimed at putting together the world`s most renowned scientists in the field of past and current global change and in particular experts in the current operation of modes in the climate system and their past variability. The conference presentations characterized the state-of-the-art knowledge on the mechanisms behind the most important modes and teleconnection patterns in the ocean, atmosphere and on land at all latitudes. This included past and current changes of modes and climate variability as well as feedbacks of those changes in climate modes on biogeochemical cycles that may lead to amplification of climate change.he scientific highlights of the ESF-FWF Conference were

- outstanding presentations on the state-of-the-art of our knowledge on the operation and impact of climate modes and teleconnections. The viewpoint from the past was taken to make predictions for the future and to investigate the stability of modes and teleconnections for different climate boundary conditions. The presentations comprised the interpretation of observational data, paleoclimate reconstructions from corals, speleothems, sediment records and ice cores as well as coupled climate model studies. Both, comprehensive invited lectures were given by senior experts in the field as well as exciting short talks given by selected participants adding latest results from active research projects. The scientific program was completed by two poster sessions allowing in-depth discussion of new results.
- Two group discussions were included in the four-day program identifying the major gaps in our understanding of the El Nino Southern Oscillation (ENSO) phenomenon, monsoon and the North Atlantic Oscillation (NAO) and consecutively developing ideas how to fill these gaps. In a plenary discussion the overall funding structure in which this research is embedded was discussed and how we can better inform the public and policy makers to support a sustainable development in the future using the paleoclimate expertise. These interactive discussions were especially designed to activate the whole group of young and senior scientist alike.

Last but not least this conference provided a unique opportunity for early stage researchers to be exposed to a topic of paramount importance for the society of tomorrow in a stimulating international environment and to establish networks with renowned senior researchers. Accordingly, the event will help educating a new generation of (paleo-)scientists and to ensure a prominent position of Europe in the field of climate research.

☒ I hereby authorize ESF – and the conference partners to use the information contained in the above section on ‘Conference Highlights’ in their communication on the scheme.

Scientific Report

Executive Summary

(2 pages max)

The ESF-FWF Conference in partnership with LFUI on “Modes of Variability in the Climate System: Past - Present – Future” has taken place in Obergurgl (Ötztal, Austria) from 27th of May to 1st of June 2012. It represents the 2nd conference in a series on “Mechanisms of Quaternary Climate Change”, where the first conference in 2009 (chaired by C. Barbante and co-chaired by H. Fischer) focused on the “Stability of warm phases in the Past and Future”, and thus, mainly on the long-term trends in the global climate system. In contrast the conference “Modes of Variability in the Climate System: Past - Present – Future” focused on higher-frequency climate variability and its regional imprint as characterized by climate modes and teleconnection patterns.

In the longer perspective this conference is part of a sequence of conference series on “Polar Regions and Quaternary Climate” over the last 15 years that had been initiated by the European Project for Ice Coring in Antarctica (EPICA), but developed from more ice core centered topics to an integrative view of paleoclimate changes and their implications for the ongoing global warming.

Following these earlier initiatives the subject of this ESF Conference has moved toward a topic of great relevance for current and past climate change, i.e. the understanding of climate modes and teleconnection patterns today and their prevalence/changes in the past as well as their feedback to regional climate and biogeochemical cycles**.**

In this context, climate modes may represent either distinct climate states (such as states in the overturning circulation, vegetation, cryosphere etc.) or spatial climate patterns that are strong enough to be imprinted in local climate archives, while being of large enough spatial extent to be reliably resolved in coupled Earth System models. At the same time changes in such circulation patterns strongly affect regional climate change and their effect on human societies. Modes and teleconnection patterns are also characterized by specific time-scales of climate variability that can be resolved both in observations and models. These time scales may vary from centennial, decadal to multiannual, their variability being influenced by the changing background climate conditions.

To cover the wide spread of aspects of modes and teleconnection patterns the conference was organized in 6 sessions comprising:

1. Introduction to past and future modes of variability
2. Tropical Teleconnections
3. Orbitally Changing Boundary Conditions of Climate Modes
4. Extratropical Teleconnections
5. Climatic Impacts of Ocean Circulation Changes
6. Modes and their Biogeochemical Feedbacks

In each session invited lectures were given by the top researchers in the field covering observational evidence over the full spectrum of climate archives as well as climate modeling studies. The invited lectures were complemented by short talks on specific subjects presenting latest results in ongoing research as well as by 2 poster sessions. The intense scientific discussion fuelled by these sessions was deepened and enhanced in specific group and plenary discussion sessions.

Based on the feedback by young and senior scientists present at the conference, this setup together with the great venue and perfect organisation by the ESF was most successful in teaching and inspiring all the participants of the conference, leading to new networks in climate mode research and redefining research topics for the future.

Scientific Content of the Conference

(1 page min.)

- *Summary of the conference sessions focusing on the scientific highlights*
- *Assessment of the results and their potential impact on future research or applications*

The main objective of the ESF Conference was to improve our understanding of the past variability in climate modes and teleconnection patterns, the processes leading to these changes and their implications for future changes. These modes and teleconnection patterns have the potential to change both in intensity and frequency as well as in their spatial pattern as illustrated in Fig. 1. An improved understanding in this field can only be gained by integrating researchers working on observational data, high-resolution climate archives and climate modelers. Accordingly, 21 renowned scientist with outstanding experience in the field as well the necessary capacity to transfer their enthusiasm to young researchers gave invited presentations summarizing the state-of-the-art knowledge on modes and teleconnection patterns and presenting latest results. In addition 8 young scientists were selected by the Scientific Committee to give short talks on their research. This formula was highly appreciated by both early stage and senior scientists, because it gave the possibility to participants to show their results to a highly competent audience and to the invited speakers to interact with the new generation of scientists with stimulating questions.

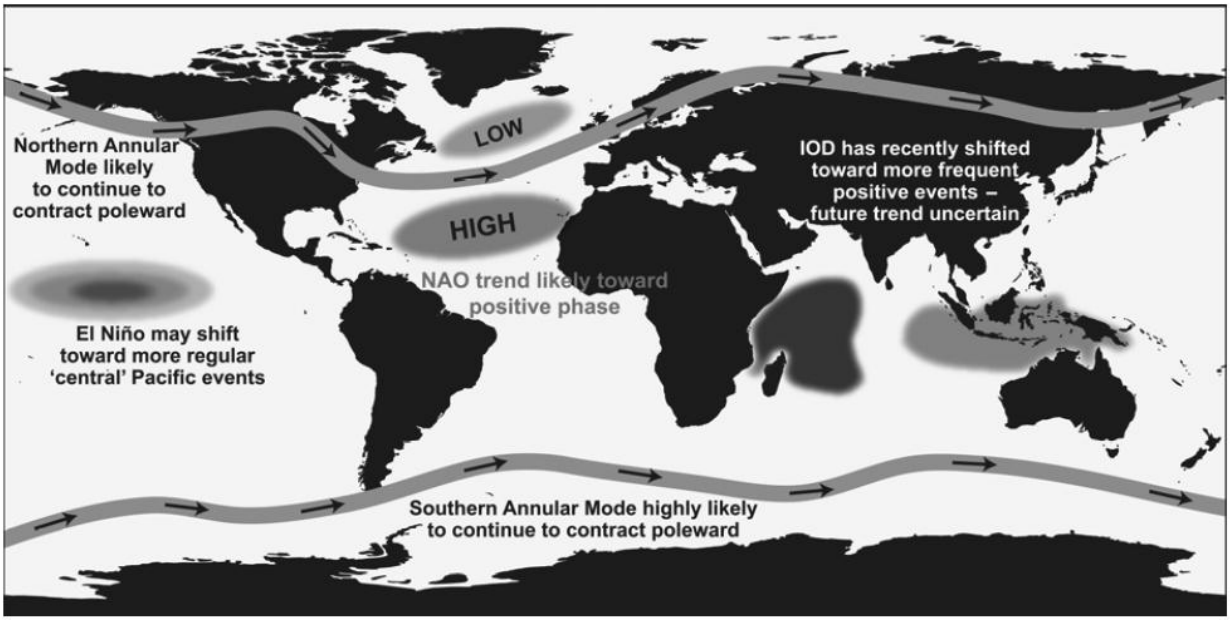

Fig. 1: Schematic diagram showing the major modes of climate variability and how they may change in the future. The high latitude modes have already undergone significant change over the past century. Trends in the tropical modes have been detected in the more recent climatological record. (figure provided by invited speaker Matthew England)

The Conference was divided in 6 sessions covering the whole spectrum of modes and teleconnections and their feedbacks in the climate system. In the following the content and highlights of the 6 sessions will be briefly described:

1. Introduction to past and future modes of variability: The first session set the scene by providing the background for the definition of modes and teleconnection patterns based on observational evidence. Moreover the physical background of atmospheric and oceanic teleconnections by advection and wave propagation was provided. This encompassed the whole spectrum of atmospheric, oceanic and coupled teleconnections.

2. Tropical Teleconnections: Tropical climate variability is largely controlled by changes in monsoon and the El Nino Southern Oscillation (ENSO) phenomenon. The latter is a prime example for a coupled atmosphere/ocean system and past evidence clearly illustrates that its strength can change over time. Latest results also show that its impact is not confined to the tropical Pacific but that hydrological changes as well as wave propagation transfer energy from the tropical Pacific to other ocean basins as well as extratropical regions. However, representation of ENSO in global climate models is still not satisfactory, hampering the progress in its prediction for the future. Also the monsoon system has been subject to strong changes in the past. In contrast to ENSO, monsoon intensity in different regions appears to be highly controlled by deep water formation in the North Atlantic and concurrent changes in the Intertropical Convergence Zone (ITCZ). Despite a clear imprint of Heinrich and DO events for example in Chinese speleothems, the causal link of speleothem signal formation to monsoon variations and ITCZ shifts is still a matter of debate and justifies further research.

3. Orbitally Changing Boundary Conditions of Climate Modes: While for the Holocene and the ongoing climate warming, climate boundary conditions are still similar, completely different conditions prevailed during the last glacial and the consecutive glacial/interglacial transition. The effect of large northern hemisphere ice sheets and their slow retreat over the transition have been the focus of the third session. Model studies show that the topography of ice sheets has a strong control on the teleconnection patterns in the North Atlantic and likely also in the Southern Ocean. Moreover the phase relationship between ice sheet retreat, greenhouse gases and ocean circulation over the orbitally driven transition have been discussed, showing that climate changes in the Southern Ocean slightly preceded the CO_2 increase over the transition (see also comments on CO_2 wind coupling in the Southern Ocean below). In return, increasing CO_2 accelerated ice sheet loss in the northern hemisphere and led climate changes in the North.

4. Extratropical Teleconnections: The North Atlantic Oscillation (NAO) is one of the best studied teleconnection patterns on the globe. Both observational evidence as well as detailed data from tree rings, corals and ice cores exist that allow for a reconstruction of the strength of the NAO in the past. Reconstructions show that the NAO is not only restricted to the North Atlantic, but has far-field connections to adjacent regions. The discussion showed that although the NAO can be reconstructed from climate archives with sufficient skill over the last centuries, field reconstructions are superior to two-points indices traditionally used to quantify the NAO. In addition to the high frequency variability in the NAO also (multi-)decadal variations exist both in the Atlantic and the Pacific, that can be reconstructed and which are connected to sea surface temperature modulation. For the Southern Ocean the Southern Annular Mode (SAM) is the most important teleconnection pattern reflecting the radial-symmetric structure of the Antarctic and the adjacent Southern Ocean. However, also ENSO is capable of energizing atmospheric circulation in the Amundsen Sea. Latest results show that both ozone as well as greenhouse gases can change the location of the southern jet stream, the Southern Ocean westerlies and in response also the Antarctic Circumpolar Current (ACC). The lack of a sufficient representation of the stratosphere/troposphere

coupling has been identified as a major caveat in reliably representing the response of the SAM to climate changes in models. However, latest model developments suggest that this will be improved in the future.

5. Climatic Impacts of Ocean Circulation Changes: Changes in the Atlantic Meridional Overturning Circulation (AMOC) as well as in the ACC and, thus, the connected Southern Ocean Overturning Circulation (SOMOC) are capable of strong changes in the interhemispheric heat transport and exert control on natural atmospheric CO_2 levels. Using tracers for water bodies and circulation it can be shown that during the glacial a less ventilated, carbon enriched water mass prevailed in the Southern Ocean extending into the deep North Atlantic as well as into the intermediate waters in the southern hemisphere. Both, changes in southern westerly winds as well as in the AMOC are able to disrupt this water mass bringing old CO_2 back to the surface. AMOC changes are most likely initiated by freshwater inputs into the North Atlantic (e.g. from ice berg discharge, glacier melt, or proglacial lakes), however, also the wind driven ACC may feed back on the AMOC. Model studies show that changes in the AMOC lead to rapid hemispheric responses in climate and the hydrological cycle, which are essentially synchronous in time with the shut-off of the AMOC. Also the simplified concept of the AMOC as a continuous conveyor belt has been discussed. While the true drivers of ocean circulation are mainly wind-driven currents, their net effect on global circulation together with the sinking of cold and/or salty waters to the ocean floor at high latitudes lead to a net AMOC that is well represented in climate models and resembles the cartoon of the conveyor belt very well. Latest models allow to track water parcels on their way along this conveyor belt showing that the mean overturning time is approximately 1000 years, but that individual water parcels may require several thousand years to complete the loop.

6. Modes and their Biogeochemical Feedbacks. Finally the sixth session illuminated the influence of changing modes and teleconnection patterns on biogeochemical cycles. E.g. dust mobilization and transport in the Southern ocean is highly dependent on the westerly wind belt. The latter may also drive the ACC and, thus, the SOMOC and the capacity of the ocean to store CO_2, although different models still differ widely in the response of the southern westerly wind belt. The changing dust input in the Southern Ocean due to changes in the SAM has also strong impacts on the marine bioproductivity in the Southern Ocean, again impacting carbon storage in the ocean. Ecological studies testing iron fertilization show that export production can be significantly enhanced by iron fertilization. However this is not always the case related to the complex ecological interaction within the trophic chain and the competition between calcareous and silicious plankton groups. The anthropogenic influence on the food web in the Southern Ocean is not only limited to changing atmospheric CO_2 but due to the decrease in whale population in the Southern Ocean, representing the upper trophic level, also krill stocks in the Southern Ocean have permanently decreased. Finally, changes in the AMOC have also strong impacts on tropical and boreal wetlands and, thus, methane emissions. Latest developments in isotopic ice core research will allow to better quantify the related changes in the hydrological cycle, the bioproducitvity on land and in the coean and the response of different methane sources on slow and rapid changes.

The panel presentations and poster session were efficiently supported by discussion groups on specific topics, where both young and senior scientists actively participated. The high level of interaction was especially reflected in ad hoc gatherings of small groups in the evening to deepen specific science issues or to prepare joint publications.

Forward Look

(1 page min.)

- *Assessment of the results*
- *Contribution to the future direction of the field – identification of issues in the 5-10 years & timeframe*
- *Identification of emerging topics*

A Forward Look Plenary Discussion has been organised at the end of the Conference with early stage career researchers and senior scientists actively participated in the discussion. The aims of this plenary discussion were

1. to identify themes for a future ESF conference and options to improve the conference series (for more details on this part of the discussion see section business meeting below)
2. to identify the gaps in our research on modes and teleconnections but also climate change in general
3. to envisage how we can develop the natural science based climate research into a more integrative solution oriented research in the future.

The discussion on point 2) was fuelled by the question, where the foci in the research on modes and teleconnections will lie after the IPCC Assessment Report 5 (AR5). The discussion showed clearly that there still exist gaps both on the modeling as well as on the data side. As had been already discussed during the course of the conference, the reconstruction of modes and teleconnection patterns using individual records may be flawed, because the spatial expression of the patterns may change in time. Accordingly, field reconstructions of climate parameters (such as temperature, precipitation or preferably atmospheric pressure) are desirable. First steps into this direction have been taken especially from tree ring studies in Europe. However, the need for quantitative climate data from other terrestrial archives has been stressed, especially to get independent data on climate variability on interannual but also on multidecadal and centennial time scales. The PAGES2k working group, initiated by the IGBP core project Past Global Changes (PAGES) assembled and synthesized climate records over the last 2000 years from all regions of the globe. This comprehensive data set could be used to attempt such a field reconstruction for past temperature variability.

Besides variations in the spatial expression of climate patterns also the occurrence of temporal non-stationarity in the modes represents an unsolved problem and asks for more paleodata from new sites but also for improvements in data quality and resolution on already existing sites and introducing new proxies. Apart from the need for more and better data, however, also model development has to be pushed forward. Although higher supercomputer power may improve some aspects, not all processes will be better represented by better model resolution. The discussion on ENSO and the SAM in the course of the conference has shown that some processes are either unsatisfactorily represented in the models or that even the physics behind them is not entirely understood. An even closer collaboration between paleoscientists and climate modelers has been asked for from both sides to improve on reconstruction and prediction, to gain further insight into the processes by model/data interaction, to allow for data assimilation in models as well as to include forward modeling of “synthetic proxies” in models that allow for more direct data/model comparison.

To fuel the discussion of question 3 an overview of the current changes in the strategic research programs and funding schemes has been presented. This included the presentation of the Future Earth program, which will replace the current ICSU programs IGBP (International Geosphere Biosphere Program), Diversitas and IHDP (International Human

Dimension Program) and by introducing the new joint funding opportunities within the Future Earth Initiative provided by the so called Belmont Forum (a group of some of the most important funding agencies worldwide). This process is oriented to integrate natural and social science research on sustainability issues. Despite considerably uncertainty how this will be implemented in reality, this initiative has been largely welcome in the discussion and the need to incorporate policy makers into the research strategy process has been recognized in order to warrant that researchers know, what policy makers have to know.

The discussion also identified major areas where integrated paleoscience can contribute to the urgent questions to be addressed in the Future Earth program. Among others, these topics comprise

- the sensitivity of glaciers and ice sheets and the prediction of sea level rise, that can be reconstructed from geological and glaciological evidence and quantified in climate models
- changes in rainfall and the risk of flood and droughts as well as other extreme events, with their probability only documented in the extended paleorecord
- tipping points in the Earth System, documented in paleodata and their processes being represented in climate models
- the long-term effect of climate changes on biogeochemical cycles and their effect on the foodweb that cannot be assessed using the short instrumental record
- the potential of geo-engineering for and its impact on the Earth System, that can be assessed from previous “natural experiments” in the distant past and quantified using coupled climate models.

Implementation of the recommendations of this Forward Look should also lead to form the new generations of researchers on climate sciences that will allow Europe to maintain its leading position in this field.

▪ Is there a need for a foresight-type initiative?

It was discussed whether the open questions raised above should be tackled in a specific PAGES working group on “Modes in the Climate System”, focusing on synoptic teleconnection patterns and their influence on regional climate and societies. Such an initiative has to be adjusted with the goals of the already existing PAGES/CLIVAR intersection, representing the interface between the IGBP project PAGES and the WMO project CLIVAR.

Business Meeting Outcomes

▪ Election of the Organising Committee of the next conference
▪ Identified Topics
▪ Next Steps

All participants felt that the open questions identified in the course of the project and outlined during the discussion clearly justify another conference in this long-term series. Potential topics that could be addressed by such a conference have been identified as

- feedbacks in the Earth System
- biogeochemical cycles

- data-model comparison

A Scientific Committee has not been appointed yet, however Eric Wolff has been elected as chair of the next conference and has been tasked with setting up the theme and scientific committee. The targeted date for this conference is summer 2015.

Atmosphere and Infrastructure

▪ *The reaction of the participants to the location and the organization, including networking, and any other relevant comments*

We have greatly enjoyed the warm Tyrolean hospitality at the Universitätszentrum Obergurgl (Ötztal, Austria). All the participants appreciated the atmosphere of a mountain hut, while at the same time providing the amenities of a Three Star Hotel. The food has been recurrently praised by many of the participants and the conference center was very flexible in accommodating special dietary wishes on short notice. The only negative practical note pertains the technical equipment in the lecture hall, where the brightness of the projector is still not powerful enough, the blinds were partly damaged and the wireless connection was not sufficiently stable to allow for uninterrupted video-conferencing.

Special thanks go to the event organizer at the ESF, Ms Nsenda, who was very responsive to all our questions and wishes before and during the conference and who contributed significantly to the success of the conference.

Most important for the great success of the conference was its format, which besides very intense sessions also allowed for a lot of time for informal discussion and exchange of ideas. A very appreciated feature in this respect was the possibility for the early stage career researchers to be in close touch with the world`s most renowned scientists in the field of past global change in an informal atmosphere during discussion, dinner and in the lounge until late in the evening. This stimulated the discussion and was in the end very productive also for senior scientists. A conference size of up to 90 participants including invited speakers appear to be most conducive for that kind of informal discussion.

It has to be pointed out that currently there exists no other equivalent conference scheme on the European level that would allow for such intense and fruitful exchange and that the ESF conference scheme should be continued by all means. From a practical side the restriction of the Earth Science conferences within this ESF scheme to the Universitätszentrum Obergurgl may be a disadvantage in the long run. Although participants were very pleased with the venue, there may be a long-term saturation to go to the same venue place over and over again.

Finally, it should also be pointed out that the success was only possible due to the extensive sponsorship by the ESF, the FWF together with the University of Innsbruck and the considerable co-sponsorship provided by the EPICA Descartes Prize, by PAGES, the Oeschger Center at the University of Bern and the German focus program INTERDYNAMIK which in total provided about € 70,000. Such a substantial amount of money is required to invite both speakers as well as early stage researchers from all continents and especially from developing countries, which otherwise would not be immersed into such a high-level scientific event.

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none

Date & Author: 13.06.2012 Hubertus Fischer