UNFCCC Nairobi Work Programme:
WCRP Response to Climate modelling, scenarios and downscaling

Executive Summary

Adaptation of natural and human systems to the impacts of natural climate variability and human-induced climate change is not an option. Climate change is inevitable and so therefore are mitigation and adaptation. The costs of reducing and coping with a changing climate will be minimized and, hopefully, more manageable if anticipatory actions are taken based on adequate knowledge. Climate models have effectively demonstrated their role in systematically encapsulating our rapidly growing understanding of the climate processes, and catering to the climate information needs of adaptation strategies on a variety of time and space scales. *At the present time, the quality of regionalized model projection is often inadequate to support the specific and detailed information needed for adaptation purposes. In order to meet adaptation needs, the underlying climate science and models will need to be improved; regionalization techniques evaluated and improved; a global framework of regionalization be developed to guide the generation of appropriate regional climate projections for all the regions of the world; the capacities of the regional stakeholders, particularly those in the developing countries, need to be enhanced to use and evaluate the regionalization techniques on their own; and access and interpretative skills will need to be strengthened, especially in vulnerable areas.*

If adaptation is to be based on deliberate planning, then reliable projections of future climate are essential. The chief tools enabling projection of future climate are climate models. Global models are important because they enable researchers to simulate the full global climate system and capture the crucial global-regional linkages. They are also essential for setting the lateral boundary conditions that drive regionalisation/downscaling of global climate projections for the domain of interest. Such regionalized projections are indispensable because they are able to capture regional feedbacks, which are missing in coarse resolution climate models and provide much higher resolution information about changes at the regional, national and local scales of direct relevance to societal impacts, at which adaptation responses are required. Both global and regionalized climate model products require appropriate depiction of confidence measures (i.e., of the current skills), as uncertainty is an unavoidable facet of all climate model projections that need to be adequately integrated into decision making for adaptation. At the same time, concerted efforts are needed to pursue improved strategies through which the accuracy of the models themselves will be increased to produce more reliable results (i.e. developing future capability). As noted in more detail in the companion paper submitted by GCOS, adaptation strategies also need improved networks of observations (which also underpin model evaluation and impact assessment) and better operational production and delivery of climate information products of direct relevance to climate impacts developed on the basis of end-user liaison. Appropriate climate simulations are, of course, equally essential in enabling adaptation to the prevailing climate and to supporting many aspects of environmental sustainability, for example air quality, conservation of precious water resources and hydro meteorological disaster warnings.

The research programme proposed here by WCRP jointly with GCOS and WMO/WCP on climate observations, climate data management and generation and delivery of climate information products including capacity building in developing and least developed countries would enable regions to assess the adequacy of regionalised model projections, investigate likely regional climate trends, evaluate observational needs, and improve their capacity to use regional climate models and their products in the design of effective adaptation policies. The suggested series of regional workshops would use available observation records and global and regional climate projections (1) to assess how well regionalised model simulations of current climate for each region represent the available climate record, (2) to determine the reliability of regionalized projections of future climate change, (3) to establish the adequacy of available access routes and interpretive skills (4) to support improved use of regionalized projections for adaptation purposes. To help meet these aims and ensure improved climate advice for decision-making purposes, the workshop programme would also encourage needed improvements in designing effective regional adaptation strategies.

The Need for Climate Modelling Improvement for Adaptation

The objectives of the WCRP are to determine the predictability of climate and to determine the effect of human activities on climate. These two objectives directly address the needs of the UNFCCC and contribute to many other international policy instruments. The World Climate Research Programme (WCRP), a joint body of WMO/IOC/ICSU, has a central role in promoting and coordinating climate model development for the Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change (NWP), including downscaling to provide regional/national/local specific climate information. WCRP urges the development and implementation of a joint programme of regional activities in close collaboration with the Global Climate Observing System (GCOS), a joint body of WMO/IOC and the World Climate Programme (WCP) of WMO.

The World Bank, the African Development Bank and others have already recognized the potentially significant costs associated with either a failure to respond to climate risk or with responding inappropriately, and these organizations are beginning to consider how to "climate proof" their investment portfolios. Without planned adaptation and development of appropriate coping strategies that build in resilience to climate perturbations, disruptions and losses from extreme events can be expected to continue to rise steadily. On the other hand, lack of advance information on the windows of opportunities afforded by climate as a resource could deprive the community from fully exploiting them. Climate information essential for planning purposes has a very wide variety of forms including: precipitation changes, droughts and floods, heat waves and cold waves, severe storms and many others. The type and scale of information is essentially determined by decision making sectors; for example, the needs of information for water resources management, agriculture, energy supply, construction, etc. can be vastly different. Moreover, climate information is essential even in the absence of climate change to take care of the variability that is inherent within the climate system. For example, it is evident from the impacts associated with current climate that many societies are becoming less well adapted or mal-adapted to coping with events such as droughts, floods and violent storms: the adaptation defeat. Added to the challenges to planning posed by current climate variability, societies now face the challenge of a changing climate that could be increasingly different from present times.

Mitigation and adaptation are now seen as necessary and complementary approaches to dealing with the urgent challenges of anthropogenic climate change. In May 2007, the fifteenth Congress approved the WMO Strategic Plan for the period 2008-2011 and beyond to provide a blueprint for the 188 Members' countries and Territories to meet the changing needs of their communities for weather, climate, water and related environmental information. Successful implementation of the plan will contribute to the desired societal outcomes such as; improved protection of life, livelihoods and property; improved health and well-being of citizens; increased safety on land, at sea and in the air; sustained economic growth in both developed and developing countries; and protection of other natural resources and improved environmental quality.

The societal and economic impacts of weather, climate, water and environmental conditions are very high – and they are growing. Today, up to 30 per cent of a developed country's Gross Domestic Product (GDP) is sensitive to weather, climate and water conditions, and the corresponding share is even higher for developing economies. At the same time, there are new opportunities for the application of weather, climate and water information to help governments improve the safety and well-being of their peoples, reduce poverty, increase prosperity and improve public health and security. There are also new opportunities to use this information to take decisions that protect the environment for future generations. In fact, scientific and technological advances are providing tools and opportunities to enable more effective action for adaptation to climate variability and change.

The WCRP Strategic Framework 2005-2015 focuses on research needs for: improving understanding, modelling and prediction of the climate system; anthropogenic projection and attribution of climate

change; climate prediction on seasonal-to-decadal timescales; assessment of sea- level rise; atmospheric chemistry and climate; monsoons in the natural climate and under human-induced climate change; and climate applications and services for sustainable development. WCRP activities support the requirements of the UN Framework Convention on Climate Change (UNFCCC) and also underpin key World Meteorological Organization (WMO) programmes and its Strategic Plan. In developing countries, where climate research needs are greatest, the WCRP strategic framework facilitates actions that help these countries establish and use the climate information supporting achievement of the Millennium Development Goals.

It is clear that many countries are not now able to devise effective strategies to adapt to future climate change because access to and/or the quality of the regionalized climate projections available are inadequate, especially at impact and application scales. The IPCC 4th Assessment Report sought in its chapter on regional climate projections to explain these issues and to consider the overall needs for climate projection regionalisation in support of the UNFCCC. Specifically societies and nature must cope with rising sea levels; more frequent or intense droughts and floods; periods of extreme temperature and precipitation; changes in glaciers and snow affecting water supplies; impacts on agriculture, human health, and energy production; disruption of ecosystems, and changes in many climate-sensitive natural resources. Without adequate regionalised projections billions of dollars could be wasted implementing adaptation policies that relied on incomplete or poor information and projections of uncertain validity.

Reliable projections of future climate can only be made with the help of climate models, and these need sufficient data[1] to validate the accuracy of the models, e.g., by checking how well the models represent current climate and to enable reliable projections of the future. Global models are essential for setting the initial and boundary conditions that drive regional models and permit other regionalisation of model projections. Regionalisation techniques (often termed downscaling) including but not limited to regional models are dependant on global models for their large scale-patterns of change but are designed to provide much higher resolution projections about changes at the regional and national scales at which adaptation responses will be considered. All such techniques for projection need verification at a regional level and especially in areas that may be vulnerable and assessment of the confidence appropriate to the projection which could usefully include variability and spatial pattern as well as the mean.

The WCRP is pursuing all available means for improving regional climate projection capabilities on all timescales including: (1) seamless modelling which aims to achieve weather prediction resolution and skill in IPCC-employed climate models, including the natural and human-influenced forcing; (2) ensemble assessments which give an indication of the spread and hence the level of confidence in regional predictions; (3) downscaling intercomparison which aims to provide users with indices of credibility of regionalized projections; (4) climate projections' archive and access training which increases the pool of available climate projections and the world-wide community of knowledgeable users; (5) metrics of regional value including phenomena-based adequacy of regionalised projections ; and (6) the exploitation of expert opinion for regional climate.

The Global Climate Observing System (GCOS) (see partner submission on Data and Observations) has a special role to play in helping to ensure that the observations necessary to adapt to climate change, and thus to promote sustainable development, are available. Adequate climate observations are needed to facilitate planning and management in many natural and human systems, including agriculture, water resources, human health, energy, transport, communication, tourism, and diverse managed ecosystems. Improved observations will also support both improved warnings of significant short-term weather events and enable better management of current climate risks due to natural

[1] Such data include atmospheric and oceanic variables, sea ice, land ice, snow cover, soil moisture, and the state of vegetation, all of which are used in initializing the model so as to accurately depict current climate.

climate variability. As countries become more experienced managing current risks, the policies they design and implement will help in adapting to longer-term, human-induced climate change. Adequate climate observations are a necessary requirement for management of the risks associated with climate variability and change. WCRP works in partnership with GCOS on how to best optimize and utilize the observations and analyse them into gridded fields appropriate for use as initial conditions and verification for model-based projections. Synergy in improved observations, data assimilation, climate simulation experiments, data processing, and model validation and improvement will help in the development of new products for routine use. GCOS is also a partner with WCRP and the World Climate Programme (WCP), which works through WMO constituent bodies such as Commission for Climatology (CCl) to assist National Meteorological and Hydrological Services (NMHSs) in maintaining the end-to-end process of data collection, custody, product generation, and service provision. [2]

The Climate Information and Prediction Services (CLIPS) Project of the WMO World Climate Applications and Services Programme (WCASP), a component of WCP, is an end-to-end approach linking research, data, analysis, products including climate predictions, and services, through to end users in key socio-economic sectors such as renewable energy, health, tourism, water resource management, agriculture and urban management. Capacity-building including training is a key aspect of CLIPS implementation, and a number of training workshops were held by WMO across the world to create local capacities in developing and delivering user-targeted climate information. Regional Climate Outlook Forums (RCOFs) pursue development of user-driven products and services, which were successful in various regions in attracting the interest and support of sectoral user groups in development and dissemination of seasonal climate predictions and related products.

The WMO world conference on 'Living with Climate Variability and Change: Understanding the uncertainties and managing the risks', held in Espoo, Finland, 17-21 July 2006 was unique in the sense that the user sectors took the lead to review opportunities and constraints in integrating climate risks and uncertainties into the mainstreams of decision-making where sensitivity to climate variability and change is but one among many factors to consider. The focus was on risk assessment and decision-processes in real-world contexts. The conference agreed on the "Espoo Statement", which recognized that major socio-economic sectors are sensitive to climate variability and change, and that integration of climate information into decision-making would support development of effective climate-related risk management. While this requires multidisciplinary collaborations and partnerships, it is clear that strong climate programmes in National Meteorological and Hydrological Services (NMHSs) are essential to this process. The recommendations for WMO consideration covered research, data gathering, capacity-building and use of suitable financial mechanisms in support of climate-related risk management.

As part of the CLIPS project activities, WMO has actively supported the development of consensus-based approach to climate prediction, both at the global and regional levels. RCOFs constitute an important vehicle in developing countries for providing advanced information on the future climate information for the next season and beyond, and for developing a consensus product from amongst the multiple available individual predictions. RCOFs are regularly convened twice a year in the sub-regions Western Africa, Greater Horn of Africa, Southern Africa, Southeastern South America, West Coast of South America and Central America, and once a year in Asia. These existing mechanisms can be effectively exploited by taking up a coordinated activity in generating regionalized climate change scenario products relevant to the respective regions and sectors.

There is an excellent and longstanding collaboration between WMO and World Health Organization (WHO) which was further reinforced through a series of workshops on climate change and health being held in different sub-regions of the world. The WMO Commission for Climatology (CCl) Expert Team (ET) on Climate and Health, in partnership with the WHO is in advanced stages of

[2] See World Meteorological Organization, Climate Information for Adaptation and Development Needs, WMO No. 1025, 2007.

developing theoretical framework and guidance for Heat-health Warning Systems (HHWS). WMO is also involved in similar initiatives on aspects relevant to the tourism sector, in partnership with the World Tourism Organization (UNWTO). Such partnerships can be extended to regional and national levels to determine sector-specific adaptive responses.

WMO is also developing Regional Climate Centres (RCCs), which can provide regionally focused climate prediction products using state-of-art climate models to the developing and least developed countries, by optimizing the available resources. However, local expertise and adequate infrastructure at the national level are still needed to adapt such predictions to the national/sector context. WMO is developing a comprehensive CLIPS curriculum, which can be integrated into the national and regional training programmes to address this need.

Adaptation, the UNFCCC, and Climate Modelling and Downscaling

The Nairobi Work Programme (NWP), adopted at COP-12 in November 2006 and named in honour of the city in which it was approved, responds to the Article 4 of the 1992 UN Framework Convention on Climate Change (UNFCCC) which commits Parties to the Convention to cooperate in preparing for adaptation to the impacts of climate change. NWP identified *climate modelling, scenarios, and downscaling* as one of the nine areas of work related to adaptation needs to be undertaken in the next five years. Related areas of work included in the NWP are *data and observations* (see partner paper submitted by GCOS) and *climate related risks and extreme events* (see paper submitted by WMO).

In the climate modelling scenarios and downscaling section of the NWP, WCRP, IGBP, and other relevant organizations were specifically invited to indicate how their work could contribute to the development, availability and use of climate models, and development of, access to, and use of climate change scenarios, especially those that provide subregional and regional specificity, including data downscaled from general circulation models; and stakeholder data and capacity needs, especially at regional and national levels.

The WCRP Strategic Framework and WCRP Interaction with the UNFCCC

The ultimate objective of WCRP is to promote sustainable development and achievement of the Millennium Development Goals (MDGs) through better management of climate risks. Implementing improvements in climate observing and climate modelling on global and regional scales is fundamental to all other programme elements. The WCRP strategy for climate modelling and regionalization of model projections includes:
a) Development, availability and use of climate models, and development of, access to, and use of climate change scenarios, especially those that provide subregional and regional specificity, including data downscaled from general circulation models;
b) Enhanced capacity and experience with the use of these different models, statistical approaches and outputs, and any available training opportunities; and
c) Identification of and reduction in uncertainties in regionalised climate projections, including extremes, persistence of extremes, teleconnections and possible thresholds of climate change.

Specifically, WCRP's Strategic Framework 2005-2015[3] details (1) seamless prediction of climate and weather; (2) ensembles approach to climate prediction from seasonal to decadal scales; (3) downscaling of future climate projections; (4) establishment of access to and training in climate model archives; and (5) scenarios of forcing for climate modelling[4]. In pursuing these goals WCRP has already:

- established the CMIP3 archive of IPCC AR4 simulations, October 2005;
- offered support for CMIP3 users, since late 2005 and especially in 2006-7;
- created the IPCC AR4 users' archive at the Max Planck Institute; late 2005;

[3] More information on the WCRP Strategic Framework at http://wcrp.wmo.int/About_Strategy.html.
[4] http://wcrp.ipsl.jussieu.fr/Documents/ACC/Aspen_WhitePaper_1final.pdf

- hosted the Sea-Level Rise Workshop[5], June 2006;
- hosted the African Climate Change Workshop, March 2007;
- co-hosted the Seasonal Prediction Workshop, June 2007;
- co-hosted the "Learning from IPCC AR4", October 2007;.
- arranged the Developing Nations' Climate Projection Archive Training, November 2007; and
- co-hosting Downscaling and Regional Projection Verification Workshop, March 2008.

The proposed programme below builds on and further seeks to develop these efforts jointly with GCOS and WMO's National Meteorological and Hydrological Services (NMHSs) and their regional networks such as RCOFs and RCCs through WCP.

The proposed initiative described in the final section of this document advances actions with particular relevance for adaptation, consistent with the WCRP Strategic Framework, the GCOS strategy as a logical follow-up activity to the GCOS Regional Workshop Programme, and the climate services activities of the WCP. The larger objective of the proposed joint initiative is to help ensure that the global and regional observations required for adaptation are readily available to all who need them, including the Parties to the UNFCCC.

In addition, the WCRP has initiated discussions of potential of mutual interest between EC FP6 project ENSEMBLES and the North American Regional Climate Change Assessment Program (NARCCAP). Topics include:

- whether and how to appropriately weight different climate models (in multi-model ensembles);
- reducing bias factors, such as in trends; and
- important steps after and learning from IPCC AR4 Chapter 11 of WG1 on regional projections in which confidence in climate model results were based more or less on an informal expert judgement.

This joint community is writing a "white paper" on regionalisation of climate change projections to be finalised in October and submitted to SBSTA in December 2007.

The General Actions Needed

Modelling-related actions needed to support reliable projections that can assist climate risk management and adaptation planning fall into three streams:

1. Support for WCRP's global model improvement and verification including seamless prediction. Adequate global-scale data are required for testing and verification, and thus improvement of global climate models and assessments of confidence in them. As the output of global models is subsequently required to drive regional models, all Parties to the UNFCCC benefit by ensuring that sufficient global data are available to allow global models to produce as reliable as possible regional assessments, including estimates of confidence/uncertainty.In many cases they will not be particularly reliable.. A critical element of meeting Parties' needs is higher resolution in global models and from evaluation of these models on seasonal and interannual scales.

2. Support for regional and national level access to climate model projection data archives and especially to multi-model ensembles. As practical adaptation policies will, of necessity, be designed at regional and national scales, higher resolution (i.e., higher than the current generation of global; say 25-50 km) climate projections are required to produce reliable regional-level impact assessments. Global data and coarse-resolution model outputs are necessary, but not sufficient, for meeting adaptation needs.

[5] http://wcrp.ipsl.jussieu.fr/Documents/SeaLevel/SummaryStatement2006.pdf

3. Support for analysis and research leading to greater confidence for users of model results, particularly at regional scales, and for effective use of such results in adaptation policy development. Analysis and research is needed in at least three related activities:
    - agreed metrics which indicate the skill of regional simulations when compared with observations of present climate to create reliable climate data records;
    - improvement of regionalisation of models and the use of data to verify models; and
    - increased capacity in the use of model ensembles in practical applications.

Improvements in global models and regionalisation of their projections, areas 1 & 2, will be advanced through vigorous support of the WCRP Strategic Framework and GCOS Regional Action Plans. Generation of user-relevant climate products based on the model projections, effective use of such results in practical applications and capacity building can be integrated into the climate services being pursued by the WCP activities.

The willingness and resources to make future model projections available are implicit in the above needs. This availability has improved slowly, but, as noted in a recent WCRP report, it remains less than adequate. Improvements to climate modelling skill, including the regional aspects, depend upon:

- available computer capacity;
- available archive capacity (and accessibility);
- human resources, especially graduate students and postdocs working in model development;
- accuracy of regional aspects of the emission scenarios (e.g., land-use, aerosols changes) which can have a strong local effect without making global impacts;
- community confidence in model projections, especially in vulnerable areas; and
- valuable policy feedback into modelling centres to improve responsiveness to user needs.

Each of these topics is included as implementation steps of the WCRP Strategic Framework.

Specific Recommendations

The WCRP recommends the establishment of a workshop activity in the use of available records to assess global and regional projections of climate within regions. Such an activity would be of great interest to policy and planning activities in each region and would serve to provide information of immediate value together with actions needed to enable improved future advice. A key benefit to each region would be improved capacity to use model outputs in designing effective adaptation strategies. Such an activity extends to modelling and application areas which WCRP aims to support with observations but does not directly engage. WCRP is thus pleased that GCOS and the WCP both share the view of the value of this initiative and that their parallel submissions consider details of their prospective involvement and roles.

An inevitable and important consequence of this work would be an assessment of the adequacy of currently available regionalized climate projections to meet UNFCCC needs. The workshop activity would also encourage the required improvements in regional observing networks and the rescue of existing historical data that is not now in useable form. Such an activity would build on the previous GCOS Regional Action Plans and on such progress as has been possible to date in WCRP e.g. the WCRP-CLIVAR Variability of African Climate System (VACS) activity. This approach will require a significant, multi-year effort, to be carried out at the regional level,[6] to:

1. Assist developing countries and regions to assemble the available regional climate records required for regionalising climate model projections; and build on WCP (WCDMP) existing efforts to build and modernize Climate Data Management Systems with the aim of enabling NMHSs in developing countries better quality control, archive and climate services provision to the users, including climate modellers.

[6] The regions could be the same ten regions addressed in the GCOS Regional Workshop Programme.

2. Using these records, work with regional experts in all regions to characterize the current climate and (i) assess the ability of the global(driving) model to simulate the large scale climate (mean and variability) over and surrounding the area of interest;(ii) use re-analysis to drive the regional model to assess ability of the regional model to reproduce regional climate (given realistic boundary conditions), as well as assessing how good the regional climate is when driven with global model boundary conditions.
3. Thereby provide assessments of present day climate change risks for the region and feedback to modelling activities on the measure of confidence appropriate with current regionalizing techniques;
4. Having checked ability to simulate present climate and variability look for consistency amongst predictions over the region in multi model (global model) ensembles (AR4, QUMP Met Office Hadley Centre, climateprediction.net etc) and consistency over regional ensembles in accordance with IPCC/ TGCIA guidelines;
5. Facilitate the application of regionalization techniques within developing countries and their regional entities such as RCOFs and RCCs, with particular attention to regions for which such regionalized products do not yet exist.This will include higher resolution and improved parameterisations in global models (to get correct large scale flows and its variations) as well as improvements in regional models. It should be noted that for a scientifically credible assessment of future prediction at a regional level the best we can do is use scientific judgement, including intermodel spread, to assess confidence.

6. Based on these results, assess user needs and determine what additional developments in regionalisation would be optimal and/or sufficient to enable the more accurate projections required for adaptation purposes;
7. Assess the difficulties and weaknesses of regions to provide the required data, (following up the GCOS Regional Workshop Programme) and also assess the capacity to use and accessibility of climate projections required for adaptation and other *regional* needs;
8. Assess the need and capabilities of NMHSs in recovering and making available valuable historical data that is not in a form currently useable by global and regional models. This action will help WCP and NMHSs in designing Data Rescue Projects (DARE) at regional level considering regional modelling priorities and requirements.
9. Assess the need for, and utility of, satellite observations (e.g., aerosol, sea ice, sea surface temperature, etc.) over past and future decades to enable improved data input to and verifications of simulations, prediction and projection of the climate
10. Raise awareness in developing countries (in the meteorological community and among key decision-makers) of the importance of regional data and regionalized model projections for adaptation purposes and of the importance and benefit of its free exchange among climate communities, and
11. Build developing country capacity to regionalize global climate projections and use model outputs in the design of adaptation policies.

As noted in the parallel submission of GCOS these objectives could be met through a staged series of 3 workshops in each region.

The role of the WCRP: The objectives of the WCRP are to determine the predictability of climate and to determine the effect of human activities on climate. These two objectives underpin and directly address the needs of the UNFCCC and contribute to many other international policy instruments. WCRP has a central role in promoting and coordinating climate and Earth system model development. Hence, it would have a lead role in helping regions assess the current utility of the available regionalised model output in their respective regions, i.e. activities 2, 3, 4 and 6. It will also significantly contribute to activities 1, 7, 8 and 11.

The role of GCOS: The GCOS Programme has a central role in ensuring that the observations required for climate needs--in this case, the observations that will enable effective climate risk management and adaptation to climate change--are available. As such, GCOS has an important role

in activities 1, 6, 7, and 9 above. Use of the same data to meet immediate planning and weather service needs will give added value to such actions.

The role of the WCP: The objectives of the WCP are to improve understanding of the climate system and to apply that understanding for the benefit of societies coping with climate variability and change through the development and mainstreaming of user-targeted climate services. The WCP has a central role to play in the improvement of Climate Data Management Systems (activity 1) , the rescue and digitization of historical climate records (activity 8), to bring existing experience in using climate records to study climate extremes and climate change indices (activity 2 and 10), to facilitate application of regionalization techniques within NMHSs, RCOFs, RCCs, etc. (activity 5) and also in helping to raise awareness about the importance of regional data for projection and in encouraging its use in agriculture, health, energy, and other sectors (activities 10 and 11).

The role of the Earth System Science Partnership (ESSP): ESSP comprises the WCRP, the International Geosphere Biosphere Programme (IGBP), the International Human Dimension Programme (IHDP) and Diversitas (an international biodiversity research programme) and operates joint and regional projects which are likely to have input to activities 10 and 11.

While the WCRP, GCOS and the WCP have the required expertise to contribute to these needs, active participation in the proposed activities is not possible with the available resources. As with the GCOS regional workshops, this joint programme to improve the effectiveness of regionalised climate model projections in support of adaptation could be undertaken with the provision of financial or other assistance. Such assistance would be used to support a programme of regional workshops to explicitly consider the adequacy of existing regional data and regionalised model projections in exercises to evaluate *current* climate metrics. A second set of workshops is proposed to focus on building capacity to apply regionalization techniques and use regionalized model outputs in adaptation planning. The WCRP plans to work in concert with its partners in the Earth System Science Partnership (ESSP) and their joint projects in carbon, water, food security and human health in broader aspects of sustainability.

APPENDIX
WCRP' Metrics Relating the Adequacy of Downscaling Techniques for Future Climate

WCRP's Task Force on Seasonal Prediction has recommended that seasonal prediction capability metrics be created and used in testing of IPCC-type GCMS.

Important GCM metrics for regionalization / downscaling assessment

1) Accuracy of the fluxes at the surface (short-wave, long-wave, latent, sensible).
2) Accuracy of the fluxes at the top-of-the-atmosphere.
3) Accuracy of the hydrologic cycle (evaporation, precipitation, column atmospheric moisture amount).
4) A measure of the ENSO cycle.
5) Global average temperature, regional trends in time series over the last century in a few major regions
6) Equator-pole temperature gradient.
7) Centennial trend in global SST (i.e. does the model drift?).
8) RMS difference (model - observed) over land for 30-year mean precipitation for each season (i.e. does the model have a realistic hydrologic cycle?).
9) Chi-squared difference (model - observed) of the frequencies of the main four regimes for example in the extended winter (NDJFM) for Atlantic-Europe domain (i.e. does the model simulate the variability of the atmospheric circulation?).

Comments on GCM metrics: SST bias in the GCM is not evaluated in these indices (only the drift), because this bias is easy to remove in a two tier approach (as in PRUDENCE) for regional climate

modelling. The choice of Atlantic-Europe for weather regimes can be replaced by any mid-latitude large domain, according to the target area of regional modelling.

Important RCM metrics for regionalization / downscaling assessment

1) Accuracy of soil moisture.
2) Simulation of the interannual and decadal-scale variability in the spatial pattern of the subsidence regions in the tropics.
3) Regional air quality (involving species that also impact regional and global climate forcing).
4) when driven by ERA40, the RMS difference (model - observed) over land for 30-year mean 2m temperature for each season (does the model have a realistic temperature annual cycle ?).
5) when driven by ERA40, the RMS difference (model - observed) over land for 30-year mean precipitation for each season (does the model have a realistic hydrologic cycle ?).
6) when driven by a GCM (or a reanalysis), the Z500 anomaly correlation over the domain for extended winter (NDJFM) between GCM and RCM on 6-hourly fields (does the RCM reproduce faithfully the imposed variability of the atmospheric circulation over the target domain ?).
7) Diurnal cycle of precipitation: amplitude and time of maximum.
8) Diurnal cycle of temperature: amplitude and time of maximum.
9) The 99th percentile of daily precipitation in seasonal climatology (This is a trade-off between having something rare, but not so rare that it is sampled at best only a few times in the observational record).
10) Where significant mesoscale circulations exist, suggest a metric evaluating the maximum in circulation's time average wind speed.
11) regional precipitation pattern need to be resolved realistically

Comments on RCM metrics: there are some general principles that should be followed, whatever the final, specific metrics are: (a) Features measured should be well observed. For resolutions of typical regional climate models, observations with corresponding spatial resolution are generally at the surface: temperature, precipitation, humidity and wind; (b) Features measured should focus where the regional model most likely adds value to parent GCMs, near the surface, where spatial scales are often smaller than GCM resolution. This point again leads to focus on surface observations. The point also leads to a focus on the diurnal cycle; (c) Features measured should include focus on weather and climate behaviour accessed by the higher resolution of regional models, such as more intense precipitation; (d) Exceptions to the above points are regional scale circulations, such as mesoscale jets and sea-breezes.