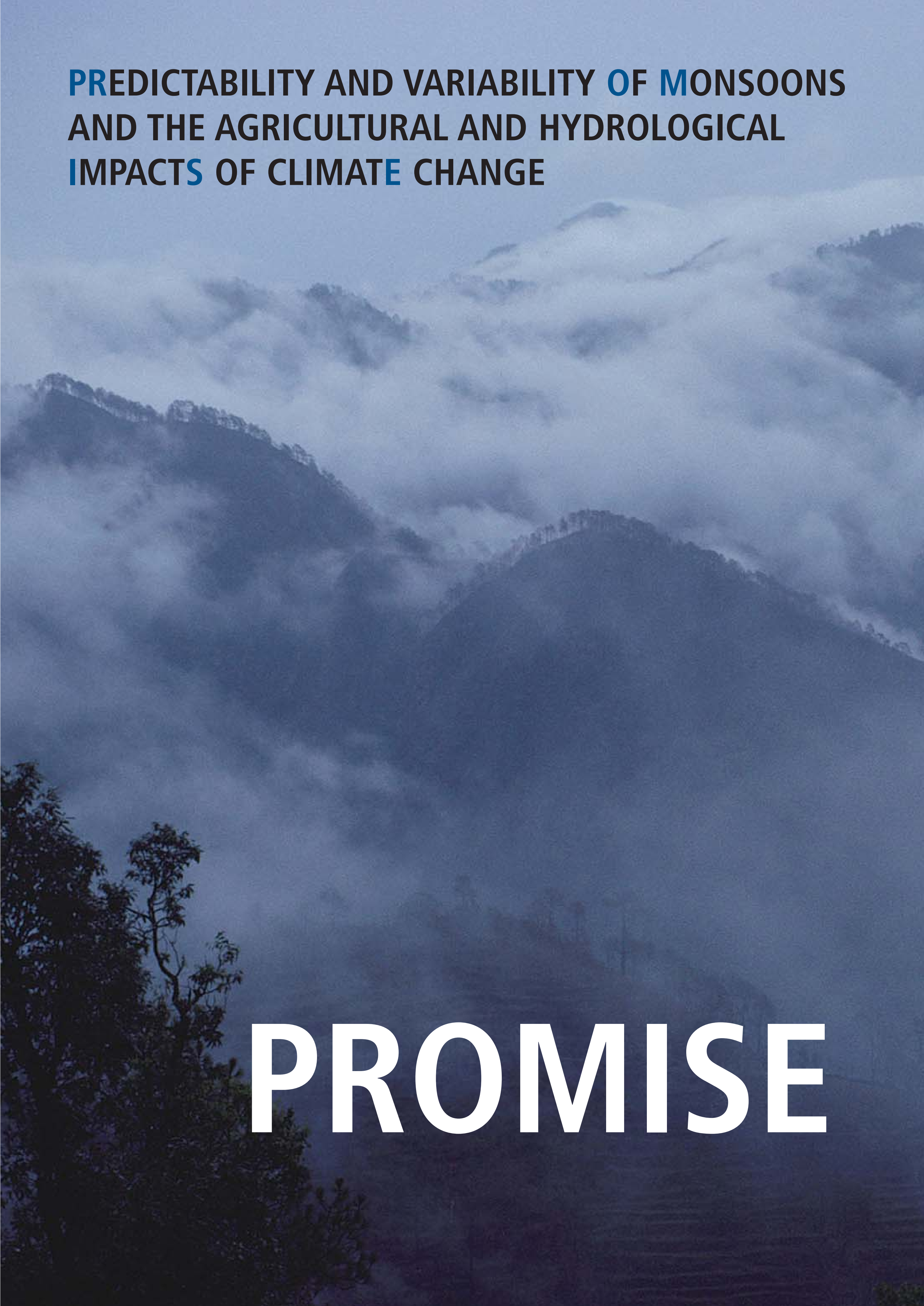
PREDICTABILITY AND VARIABILITY OF MONSOONS AND THE AGRICULTURAL AND HYDROLOGICAL IMPACTS OF CLIMATE CHANGE



PROMISE

PROMISE

is an EU funded project which aims to further understanding of:

- the potential for seasonal prediction and the benefits that would accrue in terms of management of water resources and agriculture
- the impacts of anthropogenic climate change on tropical countries, in particular on the availability of water resources for human use, and on the productivity of crops and the potential changes in the natural vegetation

The focus of PROMISE is on monsoon environments where the seasonally arid climate introduces particular stresses on resources. Over many centuries the livelihood of millions of people in Asia and Africa has become finely tuned to the regular return of the summer rains. When this balance is disrupted through natural or anthropogenic climate change, drought, famine and huge loss of life can result.

In the past, the impacts of climate change, such as its effect on hydrology and agriculture, have been considered as the results of the varying climate. A large body of research however shows that changes in agriculture and hydrology themselves may affect the evolution of the climate.
Thus rather than being linked as "cause and effect", climate change, agriculture and hydrology are connected by a series of feedbacks. By incorporating models of agriculture and hydrology into the prediction process, PROMISE aims to develop an integrated approach to climate modelling that will improve predictions both of climate change and of the future agricultural and hydrological challenges faced by monsoon-affected countries.

2003 PROMISE International conference currently sponsored by PROMISE, ICTP, WCRP and START

The end of PROMISE will be marked by an international conference entitled:
Monsoon environments: Agricultural and hydrological impacts of seasonal variability and climate change. The following sessions are planned:

1. Seasonal predictability and natural variability of monsoon climates
2. Assessment of future monsoon climates in response to anthropogenic climate change
3. Sensitivity of monsoon variability to land-surface processes
4. Hydrological impacts of climate variability and change
5. Agricultural impacts of climate variability and change
6. Bringing together scientists and end-users

The meeting will be hosted by The Abdus Salam International Centre for Theoretical Physics ICTP between 24-28 March 2003. We anticipate being able to provide approximately fifty scholarships for delegates from developing countries to attend the meeting. Further details can be found at:
http://ugamp.nerc.ac.uk/promise/research/conference2003

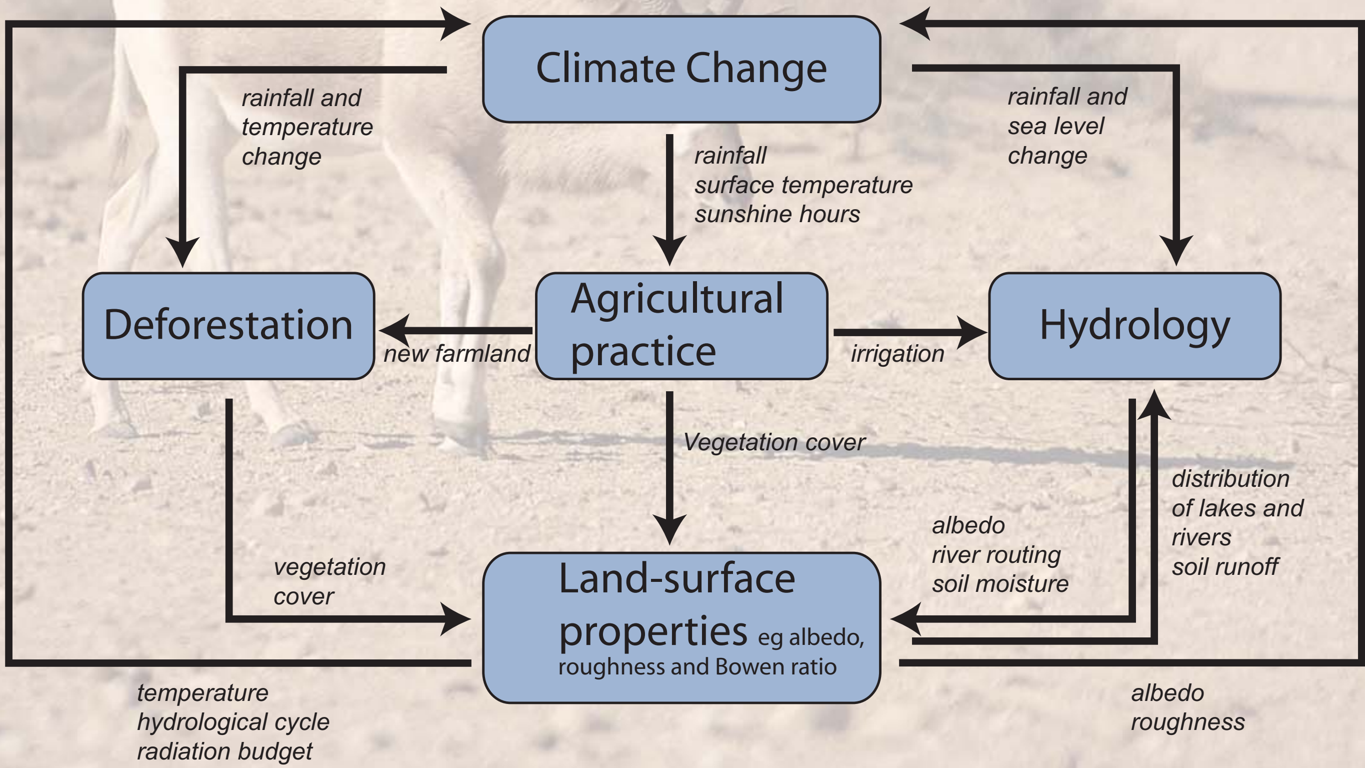
FAO photograph – G. Bizzarri

PROMISE research

There are twelve European groups collaborating in the PROMISE project (the PROMISE partners). The partners include groups specialising in agriculture, meteorology and hydrology. The PROMISE research and administration is divided into six sections, which are subdivided into "work packages". Each of these work packages is led by one of the PROMISE partners.

The PROMISE partners collaborate closely.
Every year there is a meeting of all the groups, as well as workshops on specific research areas such as crop modelling. PROMISE research is disseminated to the wider scientific community through the PROMISE web site (http://ugamp.nerc.ac.uk/promise), and through workshops and conferences sponsored by the project. The first of these was held in June 2001 at the International Centre for Theoretical Physics in Trieste and was attended by over one hundred delegates from developing countries. A second international event is planned in March 2003 to mark the end of PROMISE (see opposite).

FAO photograph – J. Van Acker



A flow chart showing some of the interactions between land surface processes and climate change

Agriculture and climate change

Changes in the seasonality and strength of monsoons will be of particular importance to the 60% of the world's population who depend on the monsoon rains for their livelihood. Understanding the way changes in land use, such as those associated with increasing cultivation, affect the climate is vital for the accurate simulation of the future monsoons. Furthermore, a detailed understanding of the relationship between crop yields and climate is essential for assessing the risk of famine associated with global warming.

The first of these issues can be tackled by running detailed global climate models (see overleaf). The second is addressed through the development of "crop models". A crop model attempts to simulate the various stages of development of the crop from germination, through flowering and finally to maturity. Crop models can be very sophisticated, allowing for variations in crop genotype and soil conditions. PROMISE is working with crop models that are sufficiently complex to capture the major sensitivities to climate, but are still simple enough to be coupled to the large scale global climate models. This approach should allow the impact of global warming on crop growth to be assessed and should also enable the impact of changing agricultural practices on the climate to be studied.

The HAPPY crop model

HAPPY (Huge Area Potential Peanut Yield) is a new crop model being developed as part of PROMISE. It simulates crop growth from first principles. The main driving variables are soil type, solar radiation, temperature and rainfall. Water availability is determined by a roots sub-model and a soil water balance. A parameterisation of leaf area index based on growth stage and water availability determines the transpiration. This in turn drives the biomass via the use of transpiration efficiency. The partitioning to the pod is determined as a function of time, following observed values of the time rate of change of the harvest index.

In order to use HAPPY with a climate model, the model must be applicable over large areas. Thus the crop yield is required to correlate on a large scale with the weather patterns and not be determined primarily by local variations in agricultural practices and soil type. The feasibility of linking climate and crops on this larger scale has been demonstrated using statistical analysis of rainfall and crop yield data for the specific case of groundnut yields (see figures).
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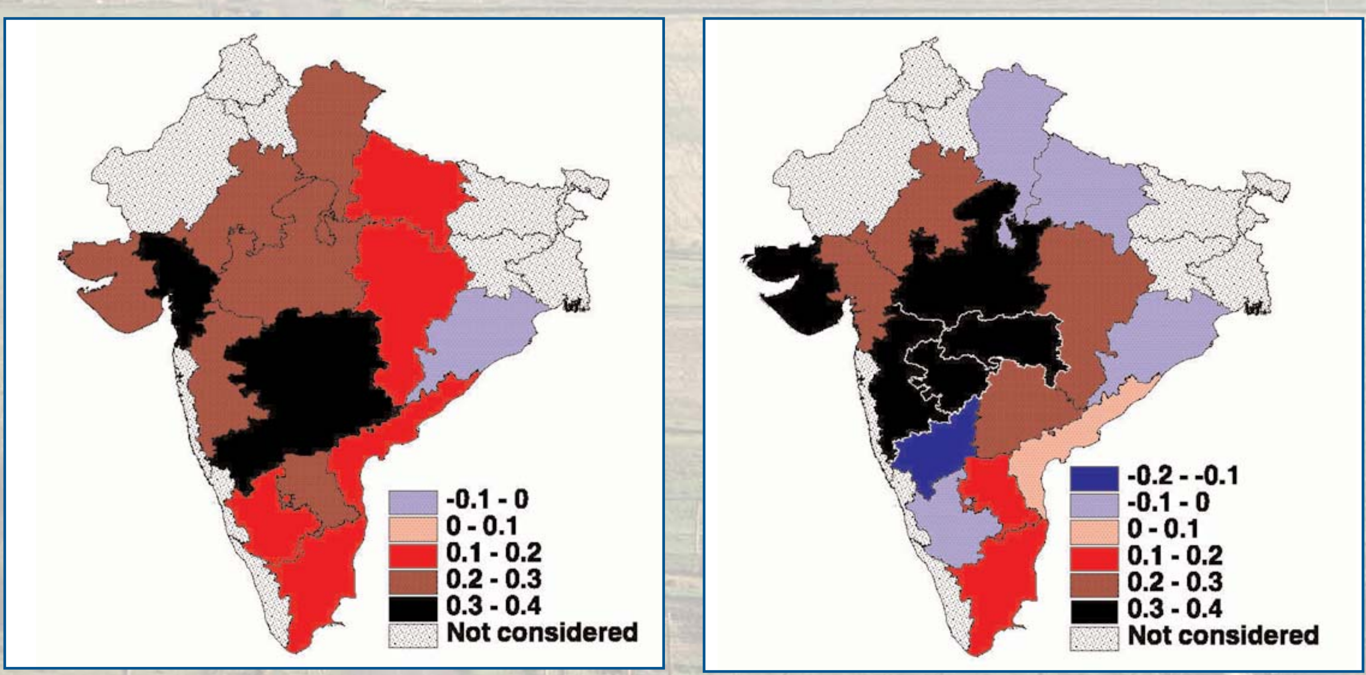

Dominant patterns of year to year variability in rainfall (left) and ground nut yield (right) in India
Note the similarity in these spatial patterns. Study of the behaviour in time of these patterns has shown that they are well related, confirming that seasonal mean rainfall and crop yields are linked at these large spatial scales.

Management of water resources

The management of water resources is vitally important for seasonally arid countries, such as those whose rainfall is driven by the monsoon. The impact of climate change on the hydrological cycle is therefore a key issue for policy makers. In addition, monsoon countries are likely to see dramatic changes in land use patterns and rises in population in the coming decades. Combined with the increasing desire for modern lifestyles, human factors are likely to introduce major stresses on water resources.

PROMISE is developing methods of assessing the impact of natural and anthropogenic climate change on river flows and water resources for monsoon-affected regions, while also taking account of the human factors noted above.

FAO photograph – J.M. Micaud

A detailed water resources model for West Africa

West Africa is extremely vulnerable to changes in water availability. For this reason it has been chosen as the subject of a case study on the water resources impacts of climate change. A detailed hydrological model is being adapted and applied to the region with the aim of assessing the impacts of land use and climate change on water resources.

The model incorporates both "natural" (for example, changes in rainfall patterns) and "man-made" (for example, irrigation, land use, population increase and migration) impacts on the hydrological cycle. The first stage – the development of a detailed hydrological scheme for West Africa – is largely complete. The final part of the case study will be to link the model with the future climate scenarios being developed within the PROMISE project. This will provide an assessment of the combined impact of climate, land use and population change on water resources within West Africa. Although the PROMISE research focuses on West Africa, the methodology developed will be applicable worldwide, enabling policy makers to make better informed decisions about resource allocation and water management strategies.

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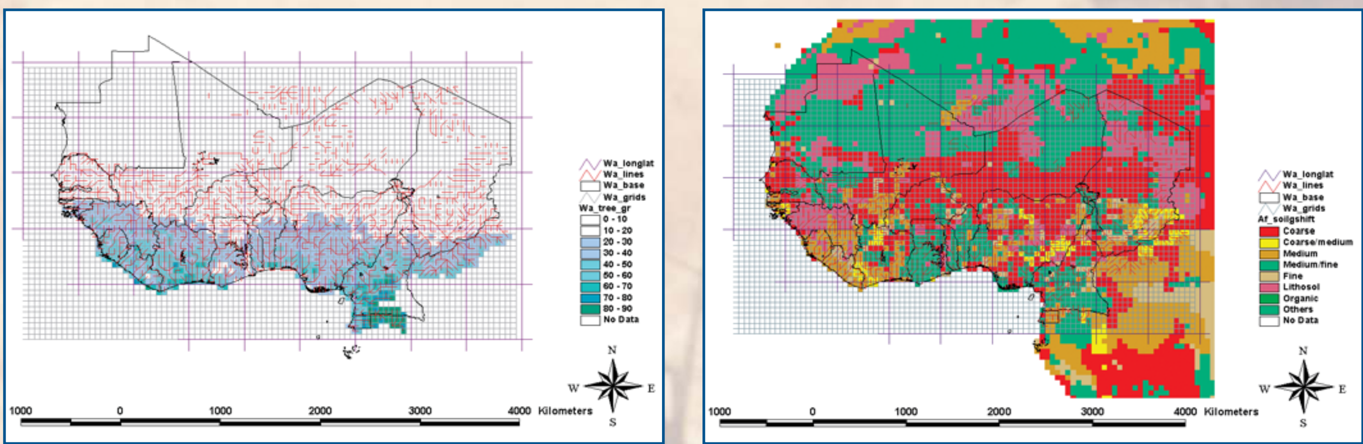


Two of the components of the hydrology model of West Africa: Density of trees (left) and soil type (right)

Predicting the climate in monsoon-affected countries

Variations in the climate for the coming season and during the next century can be predicted using a GCM (global climate model). GCMs encapsulate the dynamics (for example, winds and ocean currents) and physics (for example, clouds and rain) of the earth system (atmosphere-land-ocean-ice) in a series of equations that describe the time evolution of the system. These equations are solved on a 3-dimensional (x-y-z) grid using state-of-the-art supercomputers. GCMs form the basis of the methodologies used for weather forecasting as well as for predicting climate change scenarios. They also provide the laboratory in which the sensitivity of the climate to perturbations (for example, increased carbon dioxide, deforestation) can be explored.

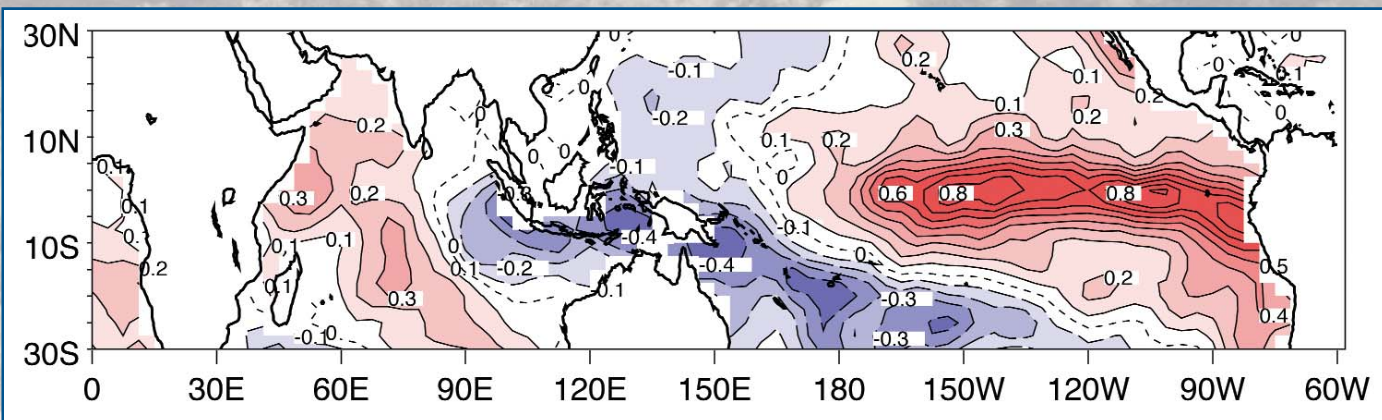
PROMISE addresses modelling issues related to both seasonal forecasting and anthropogenic climate change prediction. This approach emphasises the importance of seasonal forecasting as a test-bed for the global climate models, since the model's performance can be continuously evaluated against observations. PROMISE works closely with the EU DEMETER project (Development of a European Multi-model Ensemble system for seasonal to interannual prediction: http://www.ecmwf.int/research/demeter/) and will use their seasonal forecasts to investigate the predictability of monsoon climates.

PROMISE is also using global warming scenarios to study the future climate in monsoon-affected countries. Regional scenarios are being developed to aid the assessment of the impacts of climate change.

Some key results so far:

- The Indian and West African summer monsoons will be intensified in a future warmer climate due to the enhanced land-sea contrast and a northward displacement of the intertropical convergence zone.
- The representation of the land surface is vital for accurate simulation of monsoon climates. A sophisticated soil scheme has been developed to improve the simulated seasonal cycle and to enable the impact of irrigation on the Indian climate to be assessed.
- A better understanding of the relationship between African rainfall and the surrounding ocean temperatures has been developed, which is of importance for improving seasonal forecasts. For example, Sahelian rainfall has been linked to Mediterranean sea temperatures; extreme East African short rains are shown to be influenced by Indian Ocean temperatures.

FAO photograph – G. Bizzarri



The SST anomalies associated with very strong Autumn rainfall in East Africa

The PROMISE data archive

One of the major contributions of PROMISE will be a data archive that will be accessible, via a web-based interface, to researchers all over the world. The PROMISE archive includes observed and simulated datasets on meteorology, hydrology and agriculture, with a specific focus on regions affected by monsoon climates. It has been set up with the aim of improving the collaboration and exchange of results between research institutions in European and non-European nations (particularly in developing countries).

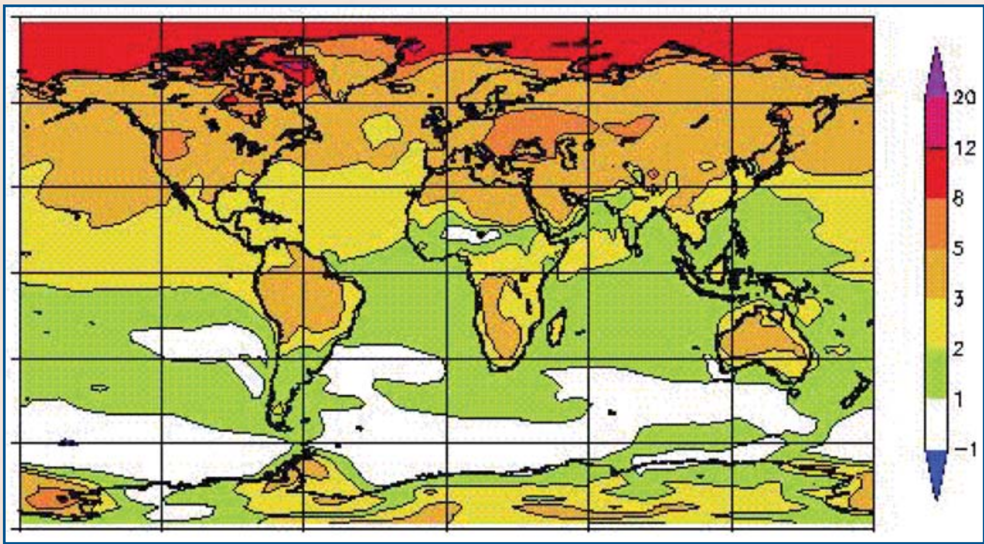
The architecture of the archive is now in place (see http://www.cineca.it/promise) and data and model results are being added as they become available. For more information about the archive see http://ugamp.nerc.ac.uk/promise/data/index.html To gain access to the data or to find out more, contact Emily Black (emily@met.reading.ac.uk)

Components of the data archive

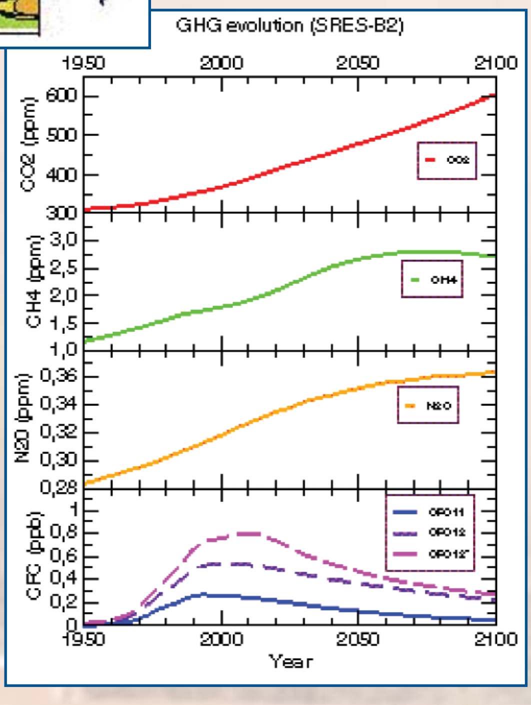
1 Current climate scenarios
The current climate scenarios will include simulations of at least 30 years of (including the years 1966-1995), ECMWF Reanalysis (ERA-40) data and seasonal prediction ensembles from DEMETER (1987-2001).

2 Future climate scenarios
The future climate scenarios will include simulations of 2010-2039 – to exploit the land-use change integrations and 2040-2069 for CO_2 induced climate change.

3 Observational data
Both agricultural and hydrological observed data will be made available on the archive. This is likely to include land-use maps and crop yields.



An example of the data in the data archive. This plot shows the difference between the average winter temperature in the period 2070-2099 and 1961-1990 assuming the gas concentrations in the graph below.



One of the IPCC scenarios for future concentrations of greenhouse gases and aerosol

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