Meteorology

2.1

Aims and overview

This sub-project is led by Professor Brian Hoskins, Professor Julia Slingo and Dr David Grimes with regard to the analysis of present-day meteorological data, and Professor Bruce Sellwood with regard to palaeoclimate modelling. It employs Dr Emily Black and Dr Iain Russell as post doctoral research fellows. A further PDRF dedicated to palaeoclimatic modelling will be appointed early in 2006. The aim of this sub-project is to use past and current data to evaluate the ability of state-of-the-art climate models to simulate the climate, particularly its hydrological aspects, in the MENA region, and to perform model simulations that will provide high resolution data for the past, present and future in the region. Specific objectives are to:

1. Improve understanding of the controls on climate and its variability and change in the MENA region

2. Perform high-resolution global climate simulations for representative periods in the past, present and future

3. Produce very high resolution limited area climate simulations for these same periods suitable for driving impact-models in the MENA region.

Research has been initiated in all these areas and progress has been made in them.

2.2

Understanding the climate of the MENA region

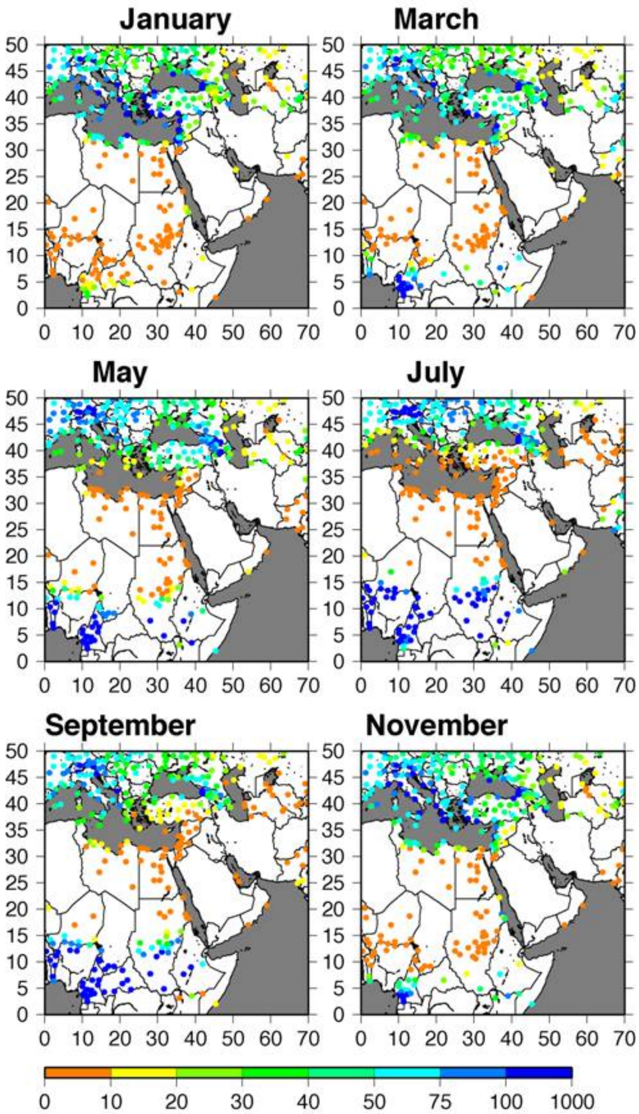
Rainfall has very large spatial and temporal variability, which means that great care has to be exercised in studying its behaviour. Rainfall data has been obtained from a number of different sources: constructed from gauge and satellite data (1° grid from1986 on), constructed only from satellite data (2.5° grid, 1979 on), gauge data for the whole region (1850 1995), and for Jordan and Israel only (1850-2000). The climatological seasonal cycle has been determined. The variability of the annual mean in the second half of the 20th century has been calculated and initial comparisons have been made with various indices of the large-scale circulation.

In the region of interest there is no rain in the summer, so links with the Asian monsoon are not relevant. The rainy season does coincide with the peak in the El Niño-Southern Oscillation, but any impact in this region is not yet understood. The North Atlantic Oscillation could be of more relevance, but its impact here is a matter of scientific controversy at present.

This on-going research has shown that: above (below) average precipitation in southern Europe is in general associated with below (above) average precipitation in MENA; there is no clear relationship with African rainfall in general; and seasonally averaged rainfall in the MENA region tends to be spatially coherent

Emily Black is using computer models to investigate present and future rainfall variability in the MENA region.

Before beginning to model either future or past rainfall within the study region, the meteorology sub-project has to gain an understanding of current rainfall patterns and has been accumulating and beginning to analyse a large data-base. These figures show that almost all of the present day rain falls between November and March. Each point represents a rain gauge with sufficient data to calculate a 1970-1999 climatology.



Consistent with the first finding, wet years in the MENA region are also associated with higher surface pressure over Western Europe. However the average pressure field in the region itself is not very different in wet and dry years. The third finding is important as it suggests on the one hand that conclusions from analysis of one site in the region may have more general implications, and on the other hand that there are strong relationships to the larger-scale atmospheric circulation. The latter encourages the hope that models may indeed have success in providing valuable estimates of local rainfall.

Using longer records at particular sites, little change in annual rainfall has been found, but there is evidence of systematic changes in the seasonal cycle over the period.

2.3

Palaeoclimate modelling

In preparation for the appointment of a PDRF in Palaeoclimate modelling (April 2006) this sub-project has been compiling, from the literature and with some ground-truthing following a fieldwork visit, a major data set of palaeoclimate proxies. This work has been done in collaboration with the WLC Palaeoenvironments team. The data includes: temporally constrained speleothem stable isotopes, palaeosol (fossil soil) data, lake level, marine records, lacustrine sediments and fossils (including coral reef data from Aqaba).

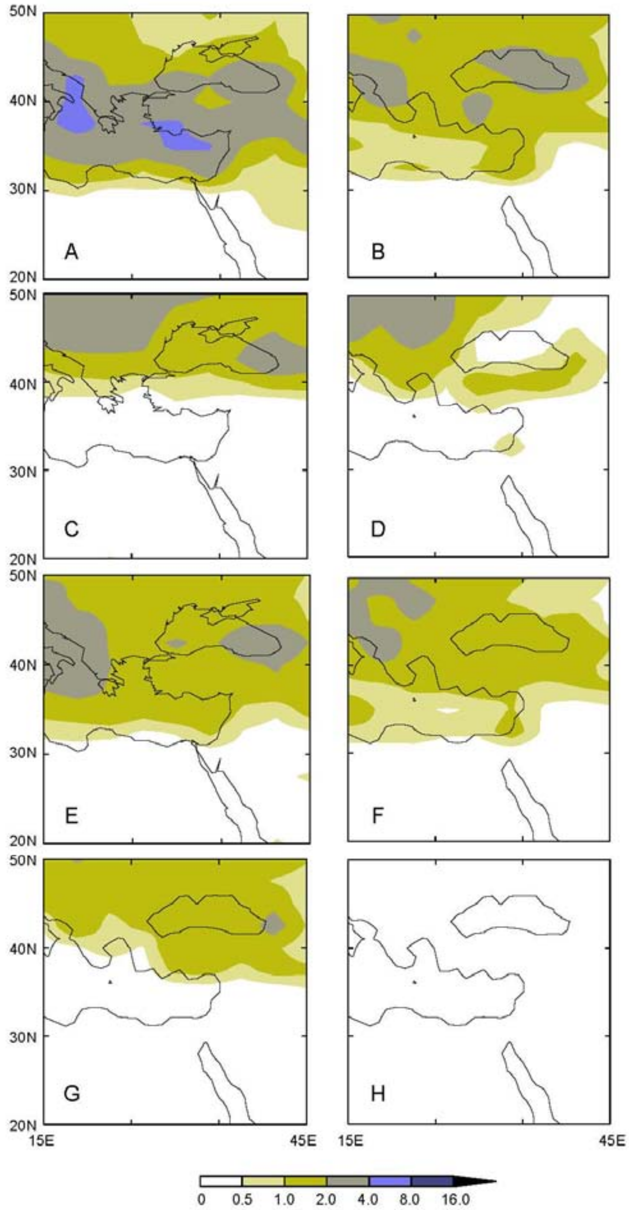
In collaboration with Prof. Paul Valdes (Bristol University) this sub-project has begun to collate GCM output on key time intervals in the past from simulations generated using the HadAM3 version of the UKMO coupled atmosphere-ocean GCM. The last Glacial Maximum simulation has followed the protocol of the Palaeoclimate Model Intercomparison Project and the boundary conditions on the model have included the CLIMAP sea surface temperature reconstructions and Peltier's ice sheet reconstructions.

Climate model output can throw light on the way lakes (as closed systems) have responded through time, the balance between precipitation and evaporation (P-E) controlling the rates of response (rises, falls and stasis). Similarly rainfall, combined with the overall temperature regime, will influence palaeosol generation. Simulations have been run for the Last Glacial Maximum and the sub-project has begun to compare the outputs from the model with modern observations.

Most precipitation today occurs in the Eastern Mediterranean during the winter months (December, January and February, DJF). In the far north of the area precipitation, mostly from the Atlantic, falls as rain (and some snow), at between 2 and 4 mm/day (Anatolian Uplands northwards of 36°N). There is a rapid decline in the amount of precipitation southwards, falling to between 0.5 and 1.0 mm/day around 30°N. This marked contrast in rainfall, between north and south, has been noted by previous authors and, by reference to palaeoclimatic geological proxy data, is believed to have also operated in past times. Average winter (DJF) temperatures range between 8 and 12^{o}C. During the summer months (June, July and August, JJA) virtually the whole region experiences virtually no precipitation and high temperatures. In the south, and over the Dead Sea, there is a marked excess of evaporation over precipitation which, coupled with the major abstraction of water from the Jordan system, has resulted in Dead Sea levels dropping by around 0.5m per annum in recent years. The annual average rainfall between about 31° and 36°N is around 180 mm/yr, rising along the coastal strip as far east as Jerusalem, to around 400/450 mm per annum.

Model results for the Last Glacial Maximum at first sight seem very similar to the observations for the Present, with most precipitation modelled to occur during the winter (DJF), but with 1 – 2 mm/day precipitation extending between 37 and 31°N, particularly adjacent to the coastal strip. Summers, like today, are modelled to be very dry throughout most of the area. However, much of the winter precipitation over the Anatolian uplands falls as snow, released in a major spring thaw. The resolution of the model (2.5^{o} in latitude and 3.75^{o} in longitude) precludes depiction of the Mt. Hermon Jordan catchment as a discrete area, but it too was likely to have received very heavy snowfalls. Anatolia is modelled to receive some rain even during the summer months. The overall pattern is for a small but significant increase in precipitation across the northern parts of the area. Modelled temperatures, much lower than today's account for far less evaporation. This helps to explain how lake levels (e.g. Lake Lisan) could have grown during the glacial phase, even though the Earth climate system was generally colder and drier.

A key priority for 2006 is the development of palaeoclimate models for the study region. These will draw on outputs from Global Circulation Models (GCM). Initial studies have been comparing the simulated precipitation for the Last Glacial Maximum(LGM), 20,000 years ago, with that observed for the present day. In this diagram, the left hand column figures (A, C and E) illustrate the present day rainfall for the winter (December-February), the summer (June-August) and the annual average, respectively, and are compared against equivalent figures for simulations of the last glacial maximum in the right hand column (B, D and F). G shows snow thickness for winter months in the LGM. H shows that winter snows disappear entirely during summer months during the LGM.



2.4

High resolution climate modelling

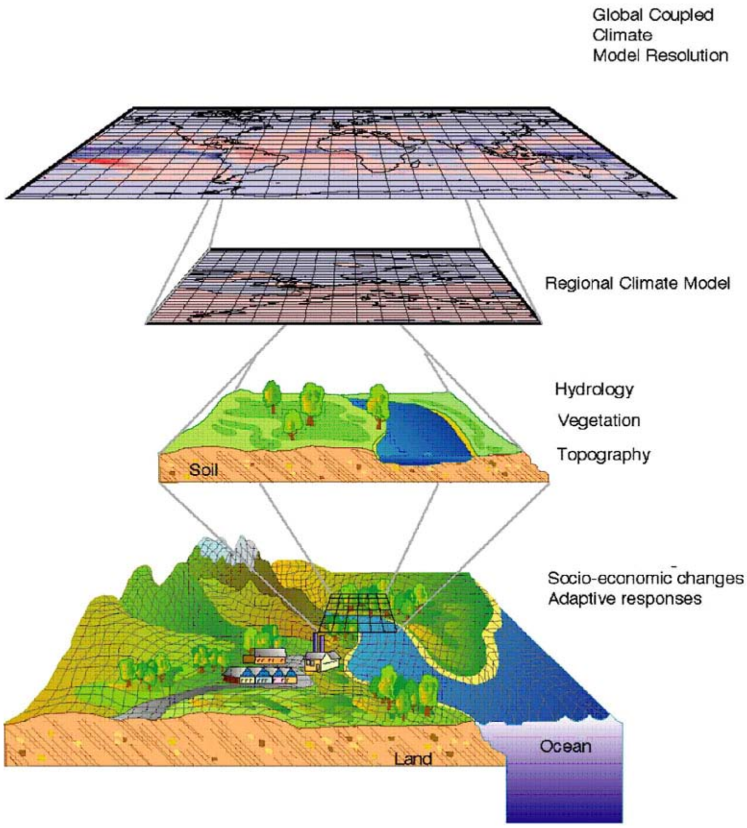
The very high resolution modelling of the climate in the MENA region will be performed through a nesting technique. A high-resolution global climate model will be run and will provide boundary conditions to a regional version of the same model. The very high resolution of the latter will, it is hoped, enable it to produce data that is of good enough quality to input to impact models for the MENA region.

The global model, HiGEM, is being developed under another project. It is a version of the latest climate model used by the Hadley Centre that is being run by us on a 1° grid. The current research is aimed at improving the performance of this model.

The regional version of the previous Hadley Centre atmospheric model (HadAM3) is available to us. In this first year, two versions of this have been developed and initial test results obtained. The first one, developed and tested (by T. Woollings) under another project, uses a relatively large domain designed to capture the whole of the North Atlantic storm-track. In consequence it stretches from the Mid-West in the USA to east of the MENA region. The resolution used so far is 60 km, but it is hoped to use 25 km later. The test results have been with analysed data as boundary conditions. Interesting biases in the model compared with reality are being investigated.

The second version is much more local to the MENA region, with its western boundary in the eastern Mediterranean. This would be much quicker to run at the same resolution as the larger regional model, or could be run with higher resolution in order to give hydrologically relevant information to drive impact models. At the same 60 km resolution and with analysed data for boundary conditions, it is found that this model captures the seasonal cycle in the MENA region quite well. Rainfall events have the correct frequency but are less intense than observed. The latter could be dependant on the resolution of the model.

If the output of global climate models is to be relevant to detailed socio-economic studies, the data must be "downscaled", i.e. written at a more detailed spatial scale. The methodology used to do this is shown in this figure. A global climate model is used to drive a higher resolution regional climate model, which in turn provides input data for a hydrological model, which then drives a detailed socio-economic model.



Courtesy of Dr David Viner, University of East Anglia

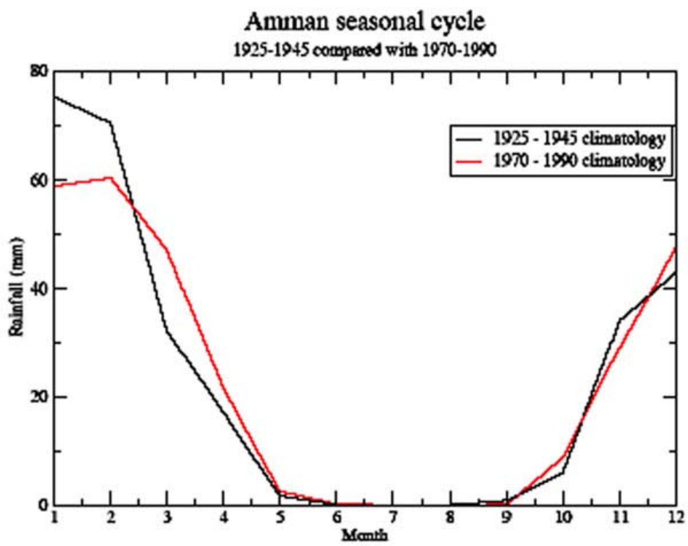
One possible mode of working is to perform a double nesting in the global model. The global model could provide boundary conditions to the large regional model and this, in turn, could provide boundary conditions to the MENA model. The latter would then provide data for the impact models.

2.5

Research priorities for 2006

The study of monthly to decadal climate variability in the MENA region will be continued. The individual storms that produced rainfall in the period 1957-2002 will be tracked using feature-tracking software developed at Reading. The relationship of these storms will be related to the larger-scale flow in which they are embedded, and their variability will then be interpreted.

To get a better picture of the rainfall in the region, a larger database of raingauge data from the The Global Historical Climatology Network has been obtained with more than 400 stations in the MENA region. This data set is undergoing quality control to eliminate dubious records. An attempt will also be made to produce properly calibrated daily time series for the last 10 years using satellite data. The spatial variability of rainfall within the MENA region will be assessed using geostatistical analysis of the gauge data.



Collation of data for rainfall in Amman since 1925 illustrates a shift in the seasonal cycle, with a slightly longer, but less intense wet season between 1970-1990 as compared to between 1925 and 1945.

Preparatory work for the palaeoclimate modelling will be carried out by the new PDRF. As a first step, time slices of relevance to the archaeological and palaeoenvironment projects will be identified. Sea surface temperature and land surface data for these periods will be used to compile the ancillary files that will drive the climate model (HiGAM). Test simulations of HiGAM will then be carried out and evaluated.

We plan to begin work on the future climate scenarios by exploiting the data that was been compiled for the Intergovernmental Panel on Climate Change fourth assessment report. We will use this data to assess the performance of coupled models in the study area, and to investigate large-scale climate change in the MENA region.

The performance of the two regional climate models when fed with analysed boundary conditions will be evaluated and the problems that emerge will be investigated. Specifically, rigorous testing of model rainfall output under current climate conditions will be undertaken by comparing with observed rainfall transformed to the appropriate spatial scale using geostatistical techniques. The models will then be run for longer periods with analysed data and their climates compared with those observed. One test of the ability of the models will be to evaluate the performance of the MENA impact models developed in the project when driven by the model data. The first simulations in which the boundary conditions are provided by the global model will be run for the current day. The performance of the impact models when driven by this data will also be assessed. Following these tests, the first nested model palaeoclimate simulations will be performed.