Climate change scenarios

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Climate change impact studies often require climate predictions with a higher level of detail than the current General Circulation Models (GCMs) are able to simulate. Climate scenarios can be used to fill this gap. The Climate Scenario Group at the Royal Netherlands Meteorological Institute (KNMI) makes use of empirical relations between different climate elements to transform an observed local meteorological time series with daily resolution into an internally consistent daily time series that could occur in a future climate. A climate scenario in this form meets the requirements of many impact groups, as it has local detail and gives a plausible description of day to day variation including daily extremes.

For a general definition of a climate scenario, we follow Viner and Hulme (1993): A climate scenario is an internally consistent representation of a possible future climate, based on sound scientific principles, that can be used to gain a better understanding of the consequences of climate change. The scenario should represent long and short term variations (including extreme events) and should possess a high spatial and temporal resolution (daily or perhaps hourly values for stations or localities). At the same time it should be simple and plausible. Finally, we want it to be drawn up in such a way that new knowledge about climate change can easily be incorporated.

The requirement of internal meteorological consistency is a very important one. Its consequence is that certain combinations in climate elements are more probable than others. If a value of one climate element is given, the number of realisations for the weather (the other elements) is sometimes surprisingly low. An example from everyday meteorology may illustrate this point. Suppose for instance that nothing is known about a certain future day other than that the air pressure will be high. Meteorological consistency then immediately informs us that it will probably be dry, that there is a high probability of sunshine, and that the temperature will be high (in the summer), or low (in the winter).

GCM predictions of climate

There is no basic difference between weather and climate,

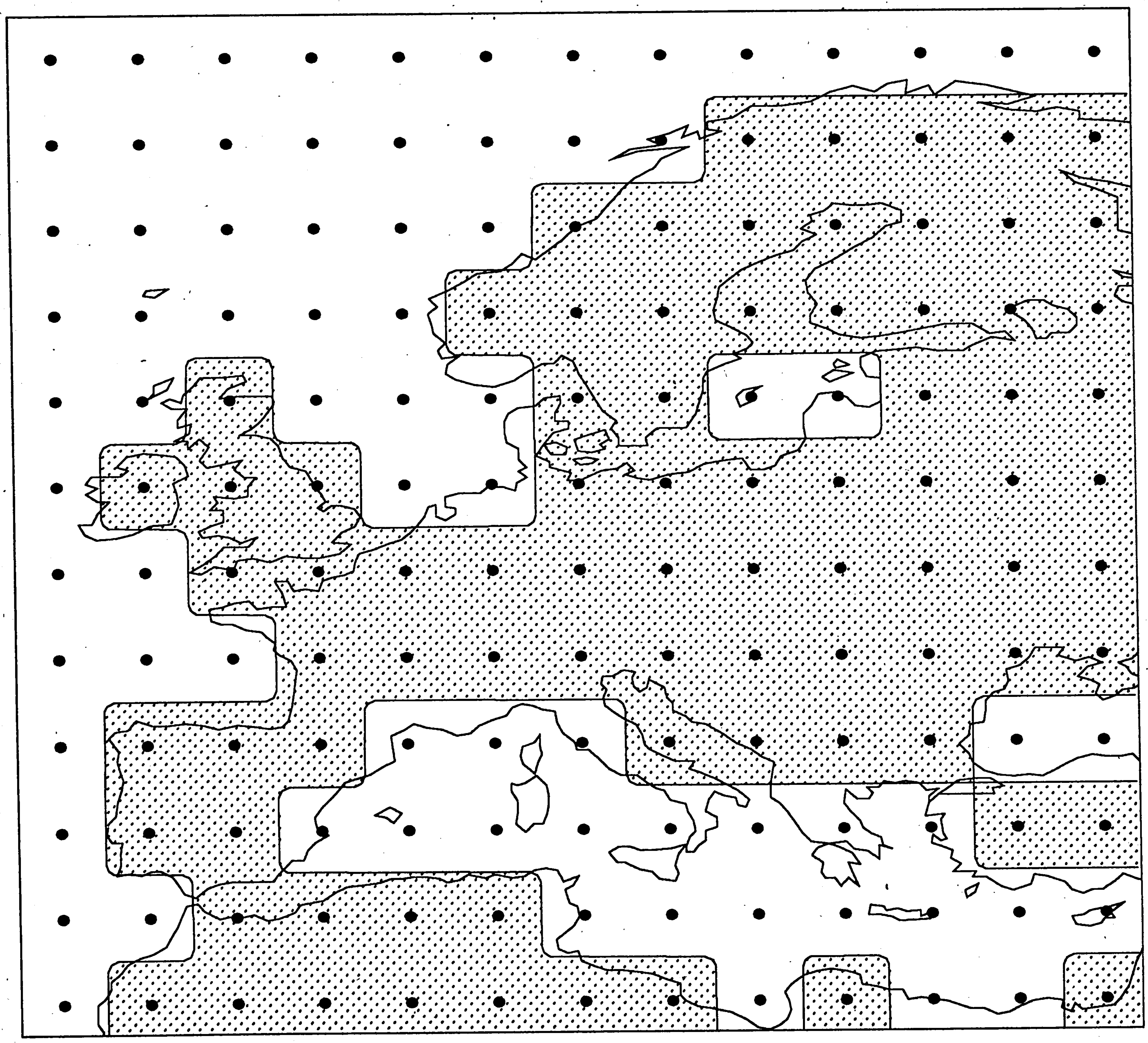

Figure 1: Distribution of grid-points in a GCM. The actual calculations are done only for these points. Since the grid points are so sparsely distributed over the earth, not much detail can be expected in the model results. Shaded is the representation of Europe in the model; its irrealistic shape is also the result of the wide spacing of the model grid-points. The example here is the high-resolution GCM of the Canadian Climate Centre; other GCMs have similar resolution.

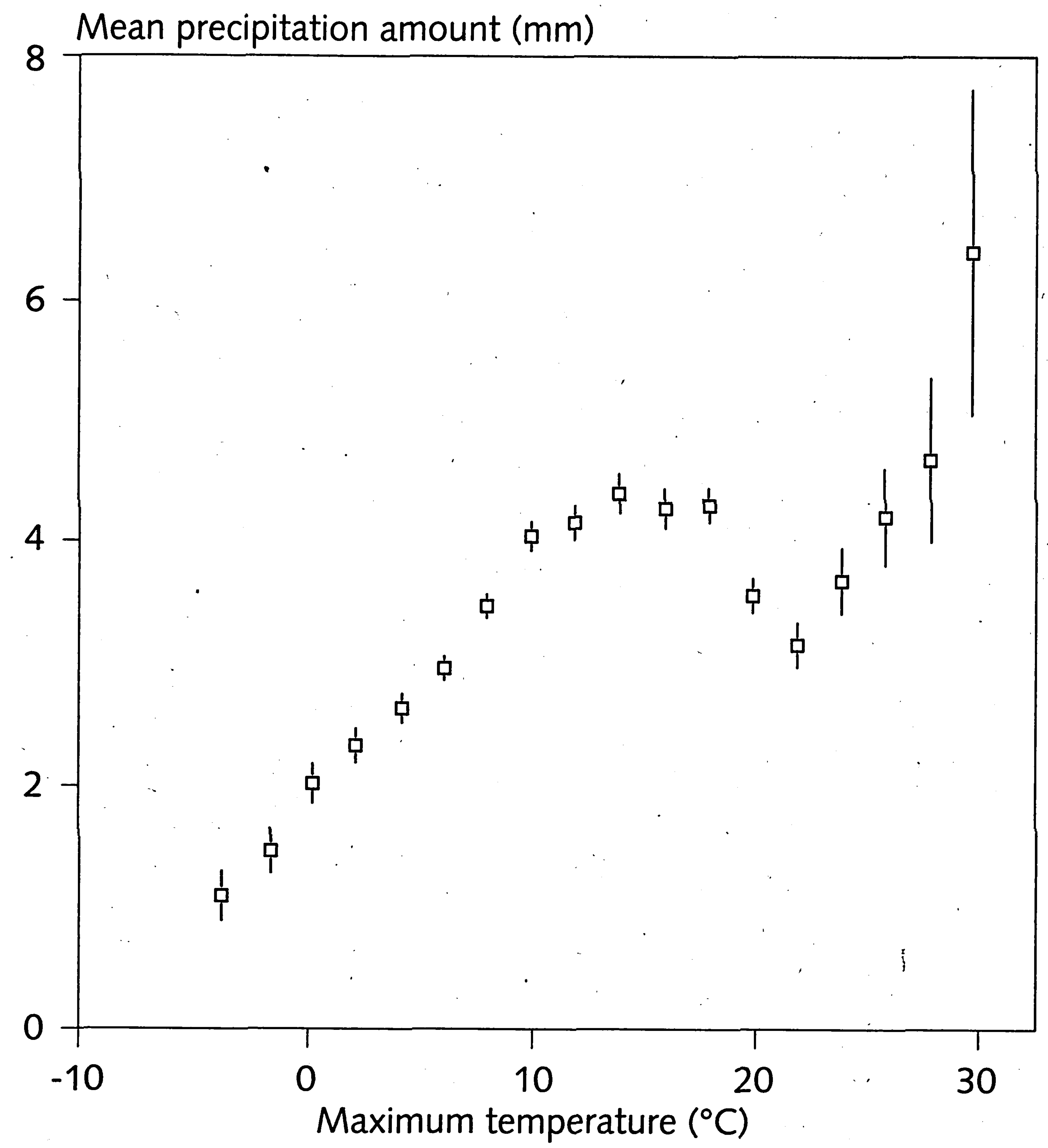

Figure 2: Observed relation on wet days at De Bilt between the mean precipitation amount and maximum temperature. Only days with at least 0.1 mm of precipitation are considered. This relation can be used to transform an observed time series of temperature and precipitation into a series representative for a future climate.

since climate is just the set of all weather situations that may occur. Hence, for the formulation of plausible climate scenarios with daily resolution, the requirement of internal meteorological consistency is in fact a powerful tool.

Weather and climate are determined by the state and evolution of the atmospheric circulation. This circulation is simulated numerically by GCM's (General Circulation Models). Their simulations are the logical basis for estimates of climate change. A problem of the current generation of GCMs is that their horizontal resolution (see Figure 1) is too coarse to derive the information on the required scale for impact studies. At the moment, GCM-predicted seasonal mean temperature changes are considered to be rather realistic and can serve as a guideline for the mean change in daily temperature on the local precipitation. Apart from the coarse resolution, the reasons for this are the simplified GCM representation of the physics of clouds and precipitation, and the low spatial correlation of actual precipitation fields. Precipitation is therefore one of the elements for which a scenario should be constructed.

Outline of climate scenario construction

The Climate Scenario Group has developed techniques to transform local daily time series into daily time series that are representative for a possible future climate. The approach can be illustrated by a concrete example. Consider a locally observed daily time series of for instance temperature and precipitation amount. In the temperature a change is prescribed that depends on season; its magnitude is based on GCM predictions. This prescribed temperature change is applied to all days in the time series. The next step is to change the observed precipitation amounts in such a way that the consistency with temperature is preserved. For this purpose, the empirical relation between temperature and mean precipitation on wet days in the present climate is used (Figure 2). This relation provides a multiplying factor that gives the relative change in the mean daily precipitation amount on wet days, which is dependent on both the old and new values of temperature. This factor is then applied to the precipitation amounts at all days in the series. The result is a new time series of temperature and precipitation, such as could occur in a future climate if the number of wet days would remain unchanged, with a realistic day to day variation, including daily extremes.

The foregoing is just a simple example to illustrate the method. In our actual approach more parameters, like surface air pressure, are considered in order to describe the effect of a changing atmospheric circulation and to estimate the change in the number of wet days. Another refinement (yet to be incorporated) is a description of the temperature - precipitation relation based on a separate treatment of large scale rainfall and convective amounts (Figure 3). The ultimate goal is to obtain a 'total scenario' for local scale daily precipitation in terms of amounts and probabilities.

The basic assumption behind our approach is that the relations between the various climate elements are rela-

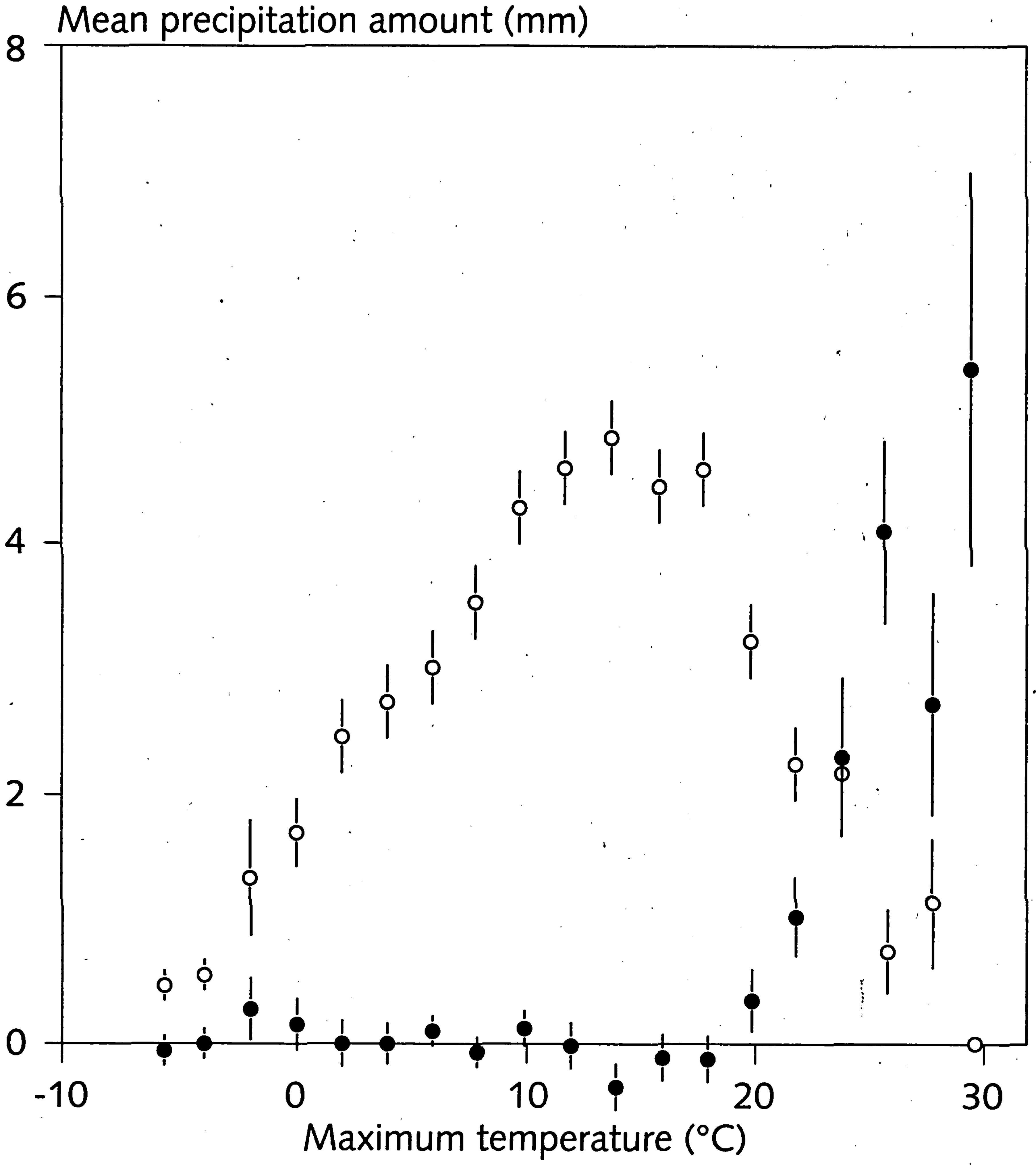

Figure 3: As Figure 2, but here the amounts are separated objectively into large-scale rainfall (open circles) and deep convective precipitation (heavy showers, solid dots).

tively invariant with respect to climate change. By using these relations the requirement of internal meteorological consistency is automatically fulfilled. The scenario requires only for a limited number of elements a GCM-based prediction. We call these elements the governing parameters; in the example above this parameter is temperature. In principle the choice for the governing parameters is open, but in practice it is very important to make a proper choice for these. The criterion for their selection is the existence of a clear greenhouse signal in the GCM-simulations. In order to select the climate elements for which this holds, the Climate Scenario Group is continuously analyzing and validating the output of various GCMs for the present and changed climate in which the observed climate serves as a reference.

GCM predictions of climate

A wide range of impact studies have been incorporated into theme C (Effects) of the Dutch National Research Programme on Global Air Pollution and Climate Change (NRP). These include, among other things, the impact of climate change on regional hydrology and on land use and terrestrial ecosystems. It is recommended (SPA & HCG, 1992) that for all of these various impact studies similar or standard climate scenarios are used in order to facilitate the integration of the results. The KNMI Climate Scenario Group believes that it is to rigid to prescribe one single climate scenario. The required standardization can be achieved by using the transformation algorithms as developed by KNMI. A standardization on that level opens the possibility to perform intercomparable sensitivity experiments by means of manipulation of the governing parameters and to integrate their results.

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