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SHADOWPACK - A Computer-based design aid for assessing the consequences of overshadowing for available solar energy.

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ABSTRACT

The paper describes and illustrates some applications of a 3D computer modelling system, SHADOWPACK, which has been designed to aid solar shading studies. The programs were developed mainly to study the impact of shading on solar gains in buildings and the siting of solar components, but they can also be applied to microclimate studies where a knowledge of the effect of shading on the available solar energy is required.

In order to illustrate the application of the programs to microclimate studies some examples of the distribution of direct solar energy received inside square courtyards are presented.

INTRODUCTION

The SHADOWPACK package was developed at the J.R.C. within the Energy Management in Habitat Programme, to study shading and its impact on received solar energy. The package, and the algorithms incorporated in the programs, have already been described elsewhere (1) so only a short description will be given here. Some examples of the sort of applications for which the package has already proved useful will be discussed, together with possible applications to the study of microclimate.

The package consists of five main program modules which permit first the creation of the three-dimensional model, and then its analysis for solar shading. The model is created using the program ICON (Interactive CONstruction), and saved on file for further analysis.

The two programs SHADVIEW and SHADYEAR provide graphical displays of the model with shadows. The first provides views for a series of times on any chosen day of the year, while the second provides a set of shaded views sampled throughout the whole year - useful for obtaining a qualitative impression of the overall situation regarding overshadowing.

Two quantitative programs, SHADEN and ISOSUN permit the calculation of the amount of direct solar energy received on any of the model faces over a chosen integration period, and the examination of the distribution of energy received over any particular chosen model face by means of a contour plot.

ICON

This program provides the three dimensional modelling capability required to make models of simple buildings, or groups of buildings. It is used interactively, working at a graphics terminal (mainframe version), or with a personal computer, and the user has access to a library of shapes which can be transformed (scaled, shifted or rotated) and added into the model. As new elements and models are created they can be added to the library. The data structure and shading algorithms used allow for elements to have holes in them (useful for simulating windows). Facilities are also provided for the rapid creation of symmetrical shapes such as cylinders, domes and other surfaces of revolution (useful for simulating trees or towers).

Another facility which is particularly useful for solar work, allows the creation of a cylindrical screen of varying height around the building model to simulate the shading effect of the distant horizon. With this facility the height of the shading screen is specified by elevation angles which can be measured simply at the site using devices such as the "Solar Site Selector"(2).

During the model building process, models and elements of models, can be viewed at any time as either "wire frame" diagrams or with hidden line removal. They can also be displayed with the shading pattern for the direct sunshine corresponding to any chosen time and day of the year.

SHADEN

With this program, the user can choose to calculate the amount of direct solar energy received on any of the model faces over a chosen integration period, taking account of self shading and shading by surrounding buildings and objects which have been included in the model. The calculation is performed either using simulated clear skies throughout, or by taking Test Reference Year data for the incident solar radiation.

ISOSUN

This program generates a contour plot of the distribution of radiation received over a chosen model face during a selected integration period. A grid of points is set up across the face of interest and these points correspond to the elements of a two dimensional array into which the results are integrated. Again the calculation can be performed either for simulated clear skies or using Test Reference Year Data. The contour plotting facility has two features which have been developed specifically for this application. One is the facility to (optionally) not include zero values of radiation received in the contour plotting process as these would distort the results in some cases such as buildings standing on a ground plane giving zero energy received at the grid points underneath the buildings. The second is to include a plan view of the model on the plot if the chosen model face is actually the horizontal ground plane. This allows for a clearer interpretation of the contour lines in this case.

At present the programs are mainly oriented towards the analysis of the direct component of solar radiation and take no account of reflections. A version of the quantitative program SHADEN has, however, been written which includes an approximation for the diffuse radiation received on external building faces, using a simple albedo factor for the diffuse radiation reflected from the ground.

APPLICATION TO SITING SOLAR COMPONENTS AND SHADING DEVICES

The programs can be useful for the siting of solar panels or other solar components such as Trombe walls and solar ponds. After creating the model of the building and its surroundings several test locations can be chosen for the component and rectangular elements placed at these locations. The effects of shading can then be studied first qualitatively using the graphical programs, and then quantitatively using SHADEN and ISOSUN.

It is now realised that good passive solar design must incorporate ways of avoiding summer overheating and one of the simplest and most effective means of doing this is to provide moveable shading devices (3). In order to assess both the effectiveness of such devices, and their aesthetic impact, a three dimensional model and simulation can be very useful. Models can be created with and without shading devices and their qualitative and quantitative impacts investigated. Three dimensional modelling and visualisation via computer graphics would be even more useful in cases where competing designs were being studied.

APPLICATION TO MICROCLIMATE STUDIES

In order to illustrate the potential application of these programs to studies of microclimate some results were generated using square courtyards. These were chosen because courtyards are one type of structure which must certainly create a microclimate.

Two models were created in which the building surrounding the courtyard was square and was of square cross section. In the first (Courtyard A) the external dimension of the building is 100m and the cross section is 10m square, giving a courtyard of 80m square. In the second case (Courtyard B), the external dimension is also 100m but the cross section is 20m square, giving a courtyard of width 60m. The models are shown in figs 1a and 1b. In both cases a ground plane was placed underneath the buildings on which the distribution of received radiation could be studied.

The program ISOSUN was used to generate contour plots of the radiation received on the ground plane, integrated first over the period of six months from April to September inclusive, and second over the period from October to March inclusive. Latitude 51 degrees was chosen and clear skies were assumed.

A second series of plots was generated assuming the whole courtyard to be rotated by 45 degrees with respect to North.

The results are shown in Figs. 2, 3, 4 and 5.

Figure 2 shows the results for Courtyards A and B for the period April to September. For Courtyard B, the peak of radiation received is lower, whilst the area of maximum radiation is smaller and does not extend as far towards the south side of the courtyard.

For the winter period, Figure 3, we see that the peak in received radiation is very much shifted towards the northern side, particularly in Courtyard B, and in both cases there is a zone towards the southern side of the courtyard which receives no direct radiation at all.

The results for the 45 degree rotated courtyards, Figures 4 and 5, also show the broader area of maximum radiation for Courtyard A, and the movement of the peak towards the northern side during the winter period.

The usefulness of such results for a designer wishing to decide where to locate a swimming pool or solar pond within the courtyard is obvious. The results could also have applications to more detailed studies of microclimates within courtyards. Gertis and Rath (4) made an experimental study of the microclimates in two real courtyards, including measurements of temperature, insolation and wind speed, and found that direct solar radiation was the major cause of microclimate variations within the courtyards. The ability to be able to study such variations in a quantifiable way with computer models is therefore very useful for this kind of microclimate study, though exactly how these results could best be integrated with other studies of wind and temperature variations has yet to be investigated. For such detailed studies a more accurate treatment of the diffuse component of solar radiation, than is presently included, would be desirable, though in the majority of cases where direct radiation penetrates the courtyard, variations in this will be the dominant factor.

CONCLUSIONS

The SHADOWPACK package provides a three dimensional modelling system combined with programs for analysing quantitatively the effects of shading on the received direct solar radiation. The programs have been used successfully in a number of applications involving the siting of solar panels, siting of shading devices and the estimation of potential solar gains in existing buildings.

The programs could be used for more detailed studies of the relationship between microclimate and building performance. The examples presented have illustrated what can be learned about the distribution of direct solar radiation received on the ground inside courtyards.

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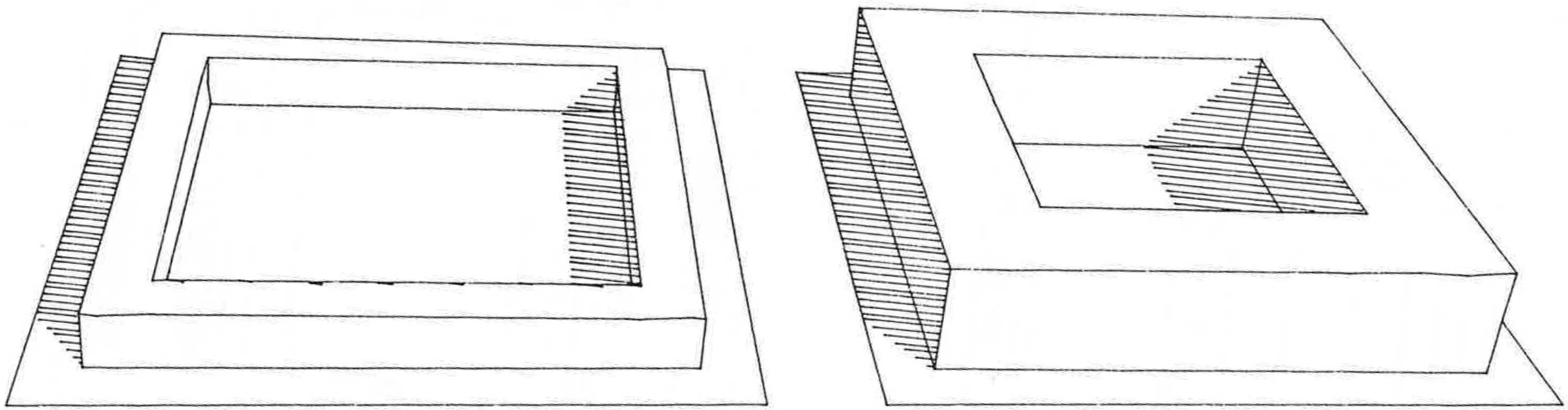

Courtyard A

Courtyard B

Figure 1. The two Courtyard Models, A and B .

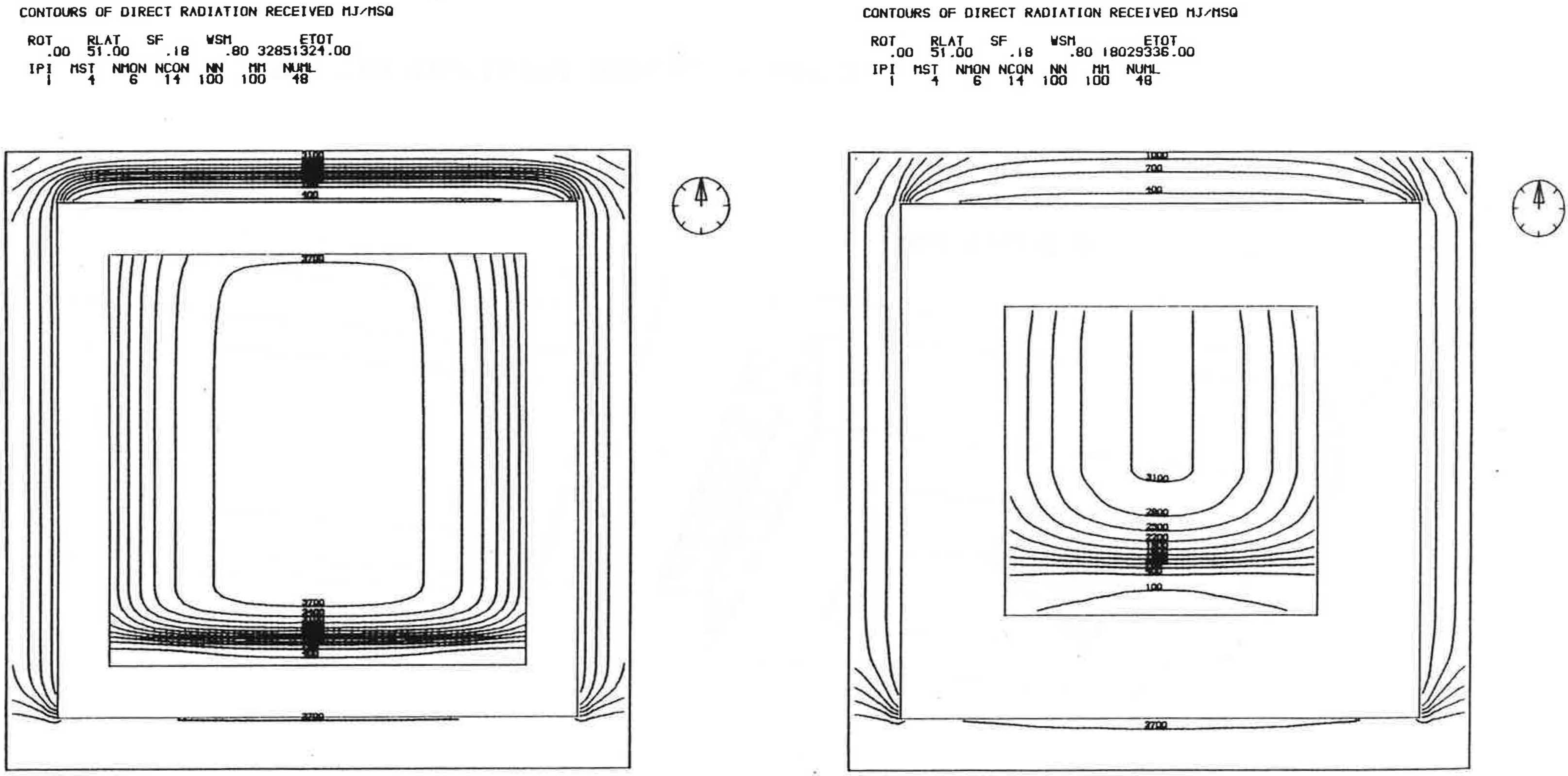

Figure 2 Contours of direct radiation received on ground integrated from April to September

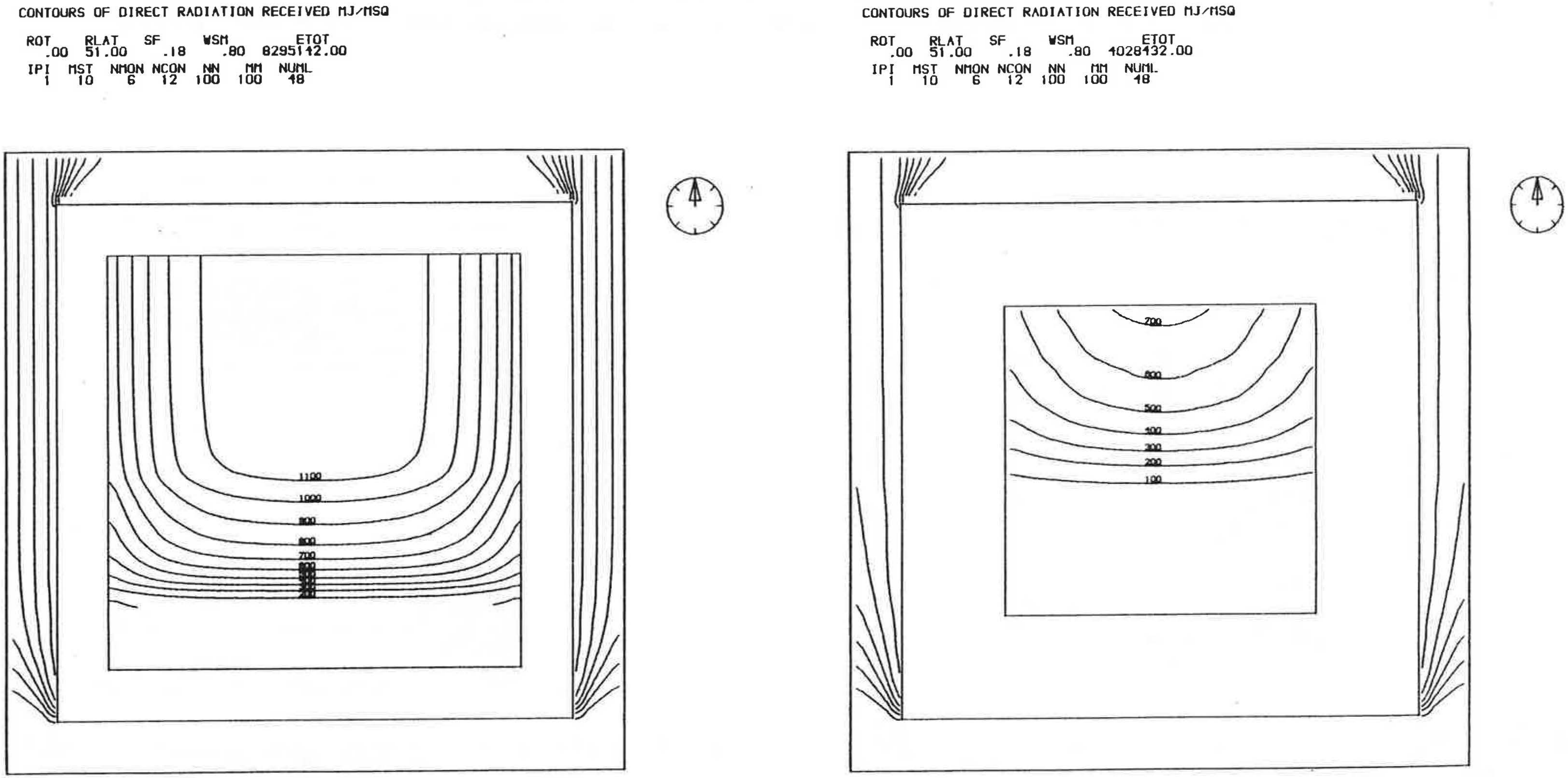

Figure 3 Contours of direct radiation received on ground integrated from October to March

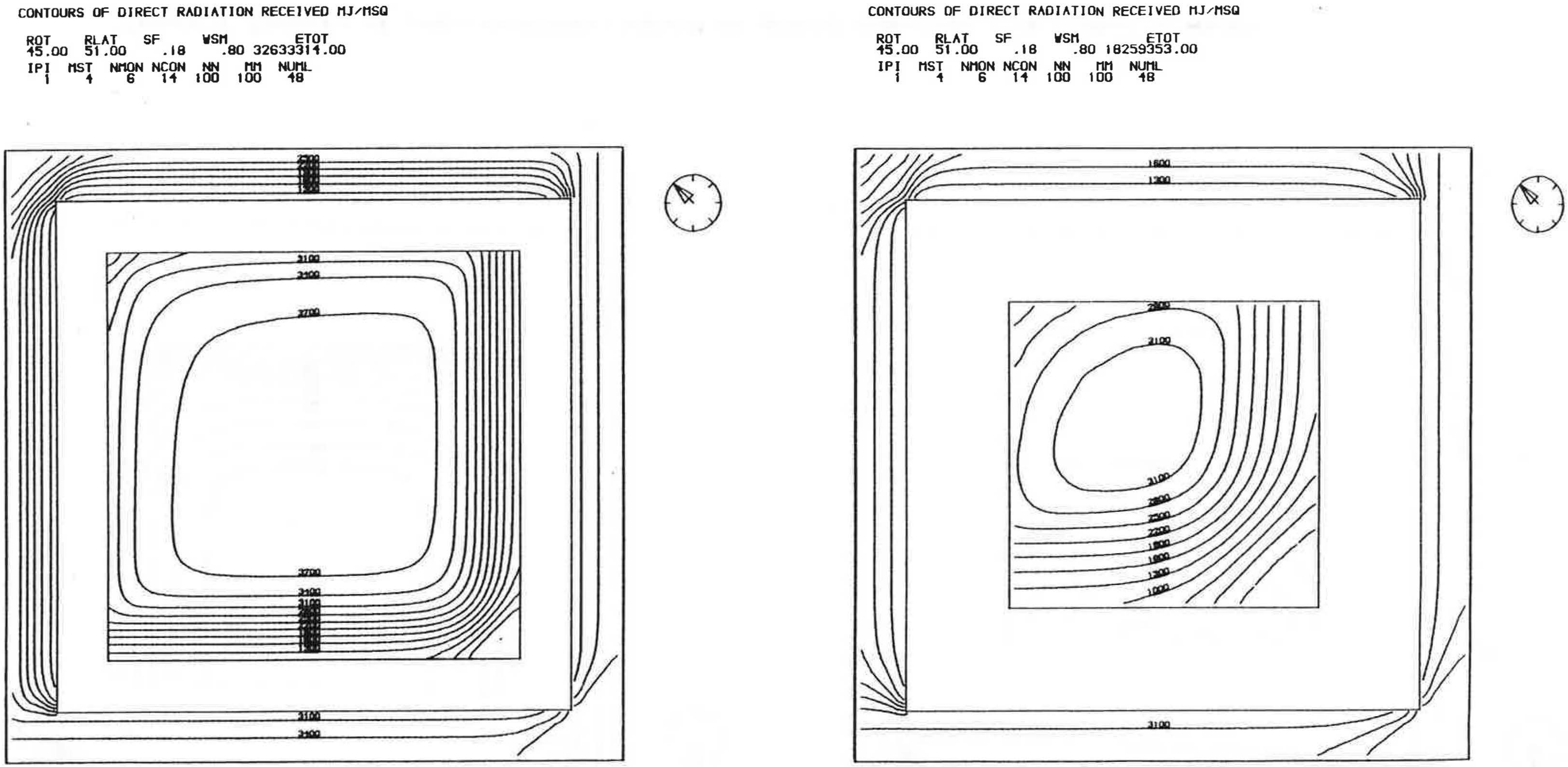

Figure 4 **Contours of direct radiation received on ground integrated from April to September**
Courtyards rotated 45 degrees with respect to North

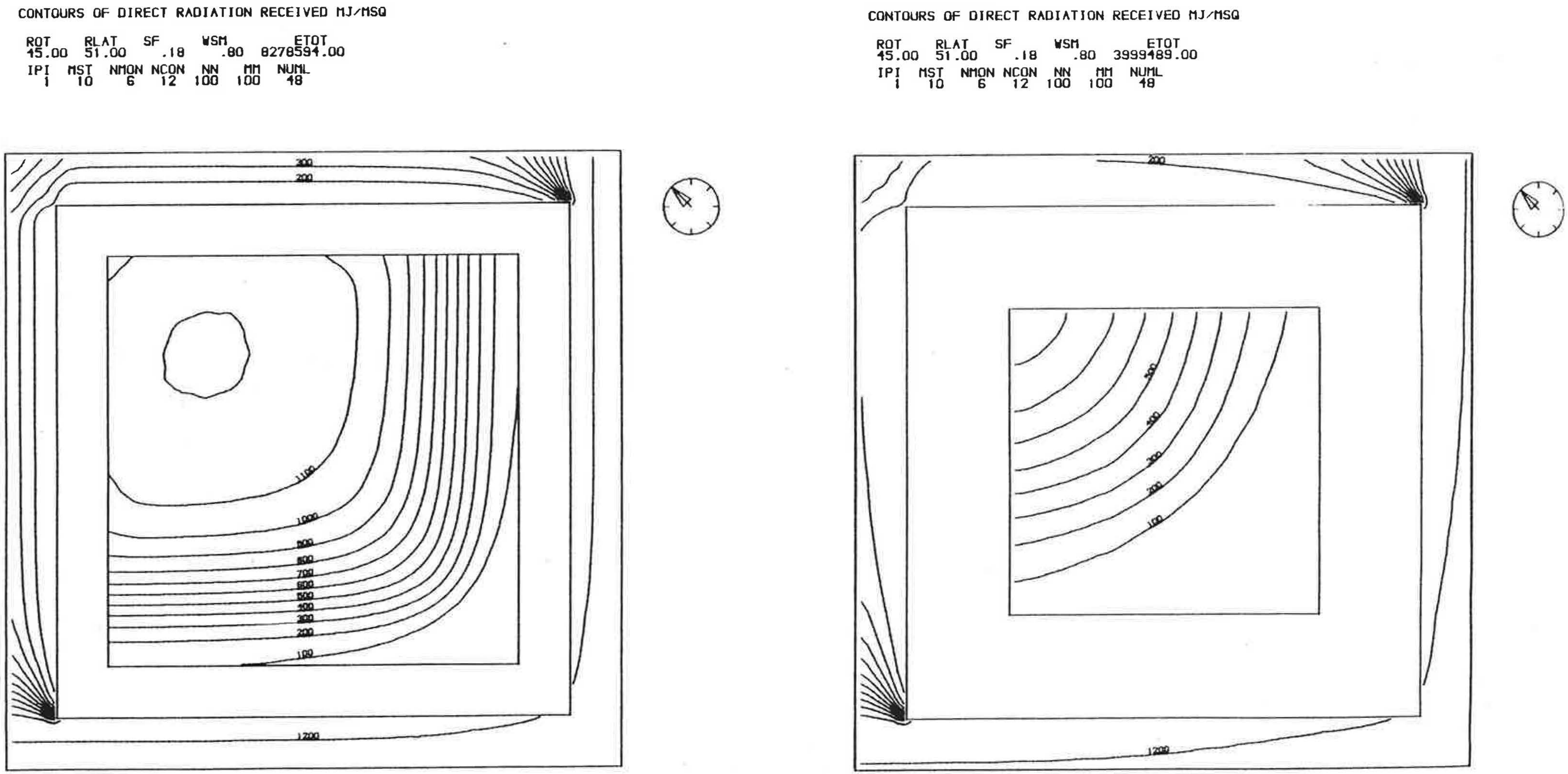

Figure 5 Contours of direct radiation received on ground integrated from October to March
Courtyards rotated 45 degrees with respect to North