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MODELLING AND SIMULATION OF TERRESTRIAL SOLAR RADIATION FOR INTERBUILD EGYPT 2000

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1- ABSTRACT- For planning as well as for the operation of solar systems, the knowledge of the existing local irradiates conditions is of decisive importance. On account of this, a solar radiation model has been developed and verified which renders the simulation and calculation of the daily momentaly as well as the monthly and yearly of the global, direct and diffuse radiation intensity. The simulation to the geographical sites the topographical and regional situations with regard to the water vapor content of the atmosphere the aerosol as well as the aerosol turbidity. Validation measurements of daily, monthly and yearly irradiation in southern areas of the Mediterranean show good agreement with model simulation results.

2- INTRODUCTION

For planning as well as for the designer of solar systems must be important meteorological data and measurements for installation position. The solar radiation equations on account of this solar radiation model is essential, the for design the important data of solar radiation to excepted the available models and simulation! 87. NUL, /84. SHE]explain the exception output data and the theoretical calculations of solar radiation components from point of view. for practice not always seasonable view, because in the rule it is very long data base and special meteorological help way very essential. To take in consideration the complications of climatic effect and whether conditions are mentioned [85.BAL.86.DES]in the modeling on the stochastic handling problem, in available meteorological measurements and data base statistic published . this validity for gross whether effect is relevant. This cases is based on south zones of Mediterranean sea. This is clear assumed solar radiation climatic without seasons conditions shortly whether sunrise, yearly,daily periodicity realize [84. No, El] .It can be seen the effects as deterministic considered. It means in modeling depends on refraction's-, absorption's-, -and reflections rays in the atmospheric and aerosol to take in consideration, in this paper can be the interactive input procedure user friendly simulation package presented.

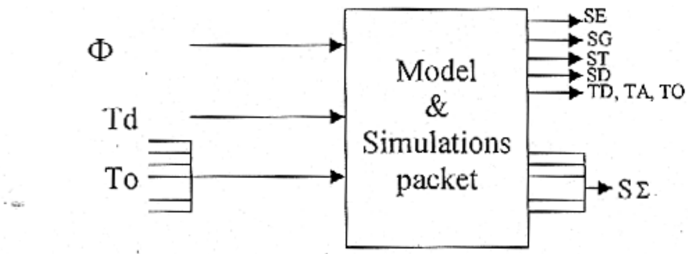


Fig 1 : Input, output of the simulations package

- Geographic attitude = Φ
-Time date (day length) = T_d
-Topographic relation = T_o

As output parameters can be daily, monthly, yearly various solar radiation's components (Extraterrestrial radiation S_E ,Global radiation SG, direct radiation S_G, diffuse radiation S_T). The day length T_D, sunrise T_A, sunset T_U, the sum of out put solar radiation daily, monthly, yearly (solar radiation component S_Σ).

3-MODELLING THE TOPOGRAPHIC GEOGRAPHIC EFFECT FACTORS

The decision for the modeling of solar radiation component with net radiation climatic is the optimal exception of relative humidity and cloudily of under atmospheric layer of aerosol, and water vapor ratio in high atmospheric layers [70.sch] .This components can be through topographic and vegetation's geographic factors (transpiration, condensations, reflex-no, etc,.) influenced [61 .GEL]. in the development of simulation program can give the possibility through the interactive input parameters.

The geographic space structure of installations position solar thermal plant sector to explain in (fig.2). Especially can be questioned as vegetation geographic and zones, typical regional and local vegetation and inter build effects factors. The single sections of space models can through given the vegetation amount, the micro -~ and macroreliefs, the specific hydrographic given and inter build is the same for infrastructure. These factors influenced the aerosols cloudily relative humidity and water vapor ratio of under and middle atmospheric layer.

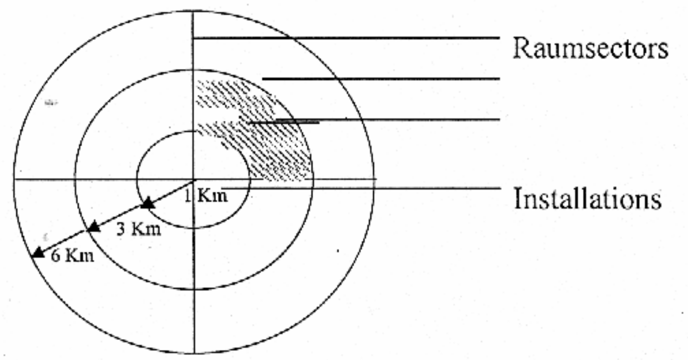


Fig. 2 : Aeromodel - sector including of the topographic and geographic area structure .

Climate Model for Sunbelt Region 3-Layers Model

Losses Factors

1) Rayleigh Scattering

$$\tau_\sigma = q_\sigma^m = 0.907 * m^{0.018}$$

by m ~ 1/sin β optical line

q_σ – Rayleigh Factor

2) Absorption in Watersteam, Ozon, Oxygen

$$\tau_\alpha = q_\alpha^m$$

by q_α – Transmission Factor H_2O, O_3, O_2

3) Absorption, Scattering at Aersol

$\tau_\delta = q_\delta^m$

by $q_\delta^m = q_\delta^{m*T} / q_{\alpha\iota}^m * q_\delta^m$

T – Linke Tarnish Factor

$S = S_0 * \tau_\sigma * \tau_\alpha * \tau_\delta$ direct radiation

$S_d = 0.5 * S_0 * (1.8\, \tau_\alpha - 0.8 * \tau_\delta$ diffuse radiation

$G = S + S_D$

1.7 Climate model for countries with intense sun (three-layer climate model)

It is apparent from the previous section, 'that up until now established climate models could only be used in the areas for which they were originally intended, that means, not for countries with intense sun, e.g. Germany. Due to this, it is necessary to set up a new model which is also suitable for countries exposed to intense sun. The biggest influences, e.g. clouding factor and water vapour content in die atmosphere must be included. Because of the deviating climatic and geographical conditions in the varying areas it is necessary to set up a climate model which includes parametric conditions.

At this point, it is worth mentioning that such a climate model does not allow for the clouding over of the sky, that means its dealings assume cloudless days because during the summer or autumn months this condition is usually fulfilled in these countries.

This transmission factor $T_\alpha(\beta)$ is dependant upon the angle of sun height β as well as upon die water vapour content. In fig. 1.7.1 the protruding part of solar radiation after absorption in steam, ozone and oxygen is shown.

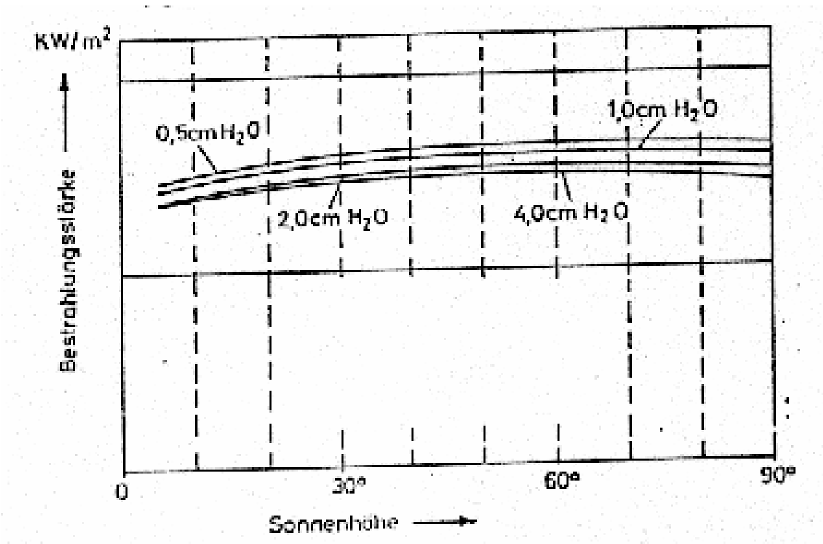


Fig. 1.7.I: Dependency of direct solar radiation and the transmission factor upon sun height in conjunction with Rayleigh-scattering and the absorption in steam

The dust and air pollution in the atmosphere, which is indicated dirough aerosol, cause, as third factor, a lessening or decreasing in direct solar radiation. This decreasing is dependant additionally upon sun height. The loss of radiation in aerosol effects up to around 20% of the absorption process and up to around 80% in scattering.

Fig. 1.7.2 shows the dependency of direct solar radiation, after the absorption and scattering in and upon.aerosol, for varying sun heights.

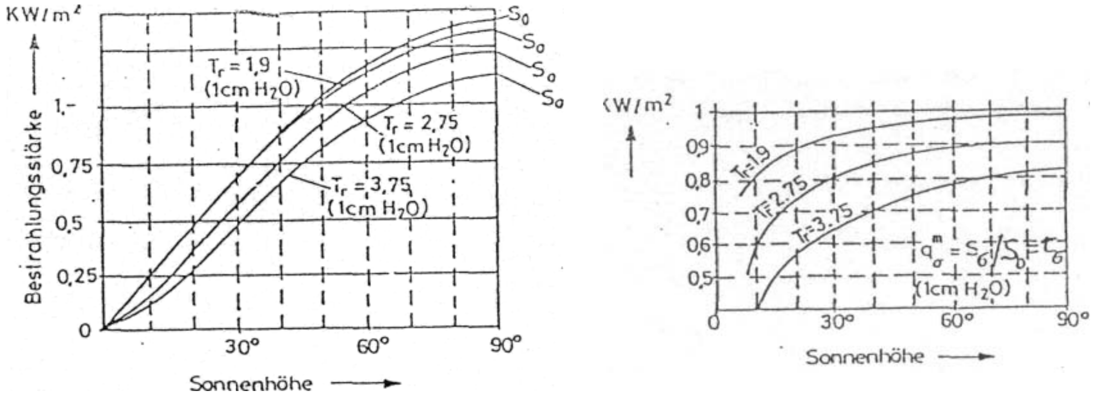


Fig 7.7.2: Course of direct solar radiation viewed dependant upon sun height for different clouding factors

Annual or daily climatic changes in winter or spring (as Khamassin in Egypt, Kebli in Libya, Aasefa in Kuwait as well as Nawwa in Alexandria) can be later included. Because the number of days are mostly known through forecasts they will be allowed for in this context, within the climate model. Accordingly, the annual and monthly sun hours or sum of solar radiation will be influenced. The rest of the year would be observed as purely atmospheric climate, for which the absorption or the reflection is decisive of the atmospheric Data. The setting-up of the following model is based upon the fundaments of the absorption and scattering of the earth's atmosphere /70.Sc/. The extraterrestrial solar-radiation is diminished upon it's way into the atmosphere. The following factors are responsible for this /70.Sc/:

a) Scattering on the molecules of the atmosphere (Rayleigh scattering)

b) The absorption of water vapour, ozone and oxygen in the atmosphere

c) Scattering and absorption in and on aerosol.

The diminishing factor, which is caused by the Rayleigh scattering and from which the transmission factor can be determined is dependant upon the length of the optical way of solar-radiation through the earth's atmosphere. The diminishing factor is dependant, from its part, upon the angle of sun height P. The transmission factor $T_\sigma(\beta)$, which is met by the Rayleigh scattering can be given with satisfactory exactness as follows /70.Sc/:

$T_\sigma(\beta) = 0.907(m)^{0.018}$ (1.27)

The parameter m is in first proximity proportional to 1 / sin P. The radiation performance, according to following appearance of Rayleigh scattering, amounts to then:

S_σ-S_o. $T_\sigma(\beta)$ (1.28)

In table 1.2 the transmission factor T^(P) is given for different angles of sun height.

β	90	60	30	10	5
$T_\sigma(\beta)$	0.906	0.908	0.915	0.933	0.948

Table 7.2; Transmission factor for different angles of sun height/70.Sc/

The diminishment of direct solar radiation through absorption in water vapour, ozone and oxygen, can be shown in a similar formula, whereby the corresponding transmission factor $T_{\alpha}(\beta)$ is simply put into the formula

S_{α}-S_{o}. $T_{\alpha}(\beta)$ (1.29)

1.8 Estimation of direct, diffuse and global solar radiatio^ .(three-layer climate model)

As shown in the previous section direct solar radiation decreases due to three factors during its course. The resulting decreased factor can be worked out through the multiplication of the single decreasing factor. After the event of the decreasing factor has taken place, the penetrative direct solar radiation can be deduced through the multiplication of the extra-terrestrial solar radiation So with the resulting decreasing factor. This corresponds to the direct solar radiation S (fig. 1.8.1).

$$S = S \bullet T_{\sigma}(\beta) \bullet T_{\alpha}(\beta) \bullet T_{\delta}(\beta) \qquad (1.30)$$

The total amount of slowly scattered solar radiation arises out of Rayleigh scattering (1-T□)
and the scattering on the aerosol. Half of this radiation returns to the outer earth's atmosphere. However, half of this radiation returns to earth as diffuse radiation Sd.

$$S_d = 0.5.\ S_o \bullet (1.8 - T_{\sigma}(\beta) - 0.8\ T_{\delta}(\beta)) \qquad (1.31)$$

The global radiation G can be obtained in accordance with fig. 1.8.1 from:

$$G = S + S_d \qquad (1.32)$$

1.9 Results from the three-layer climate model for countries with intense sun/

The climate model shown in fig. 1.8.1 is based upon a three-layers atmosphere, which leads to a Rayleigh scattering, an absorption in steam, ozone and oxygen and a scattering and absorption in aerosol. After the extraterrestrial radiation has been decreased through Rayleigh scattering, absorption in steam and aerosol, the direct solar radiation S can be then calculated from this.

In countries exposed to intense sun, the geographical position of an area can, (according to its degree of latitude ϕ) be taken into consideration. This geographical factor, ϕ, determines the angle of sun height β, which on the other hand determines the length of distance of the radiation in the extraterrestrial stratum and in the process the transmission factors $T_{\sigma}(\beta)$; $T_{\alpha}(\beta)$; $T_{\delta}(\beta)$ are determined also. In the outer atmospheric stratum (A) the Rayleigh scattering is only dependant upon geographical position ϕ (i.e. dependant upon relevant angle of sun height). The middle atmospheric stratum (B) is likewise dependant on b as well as on steam content (or steam pressure).

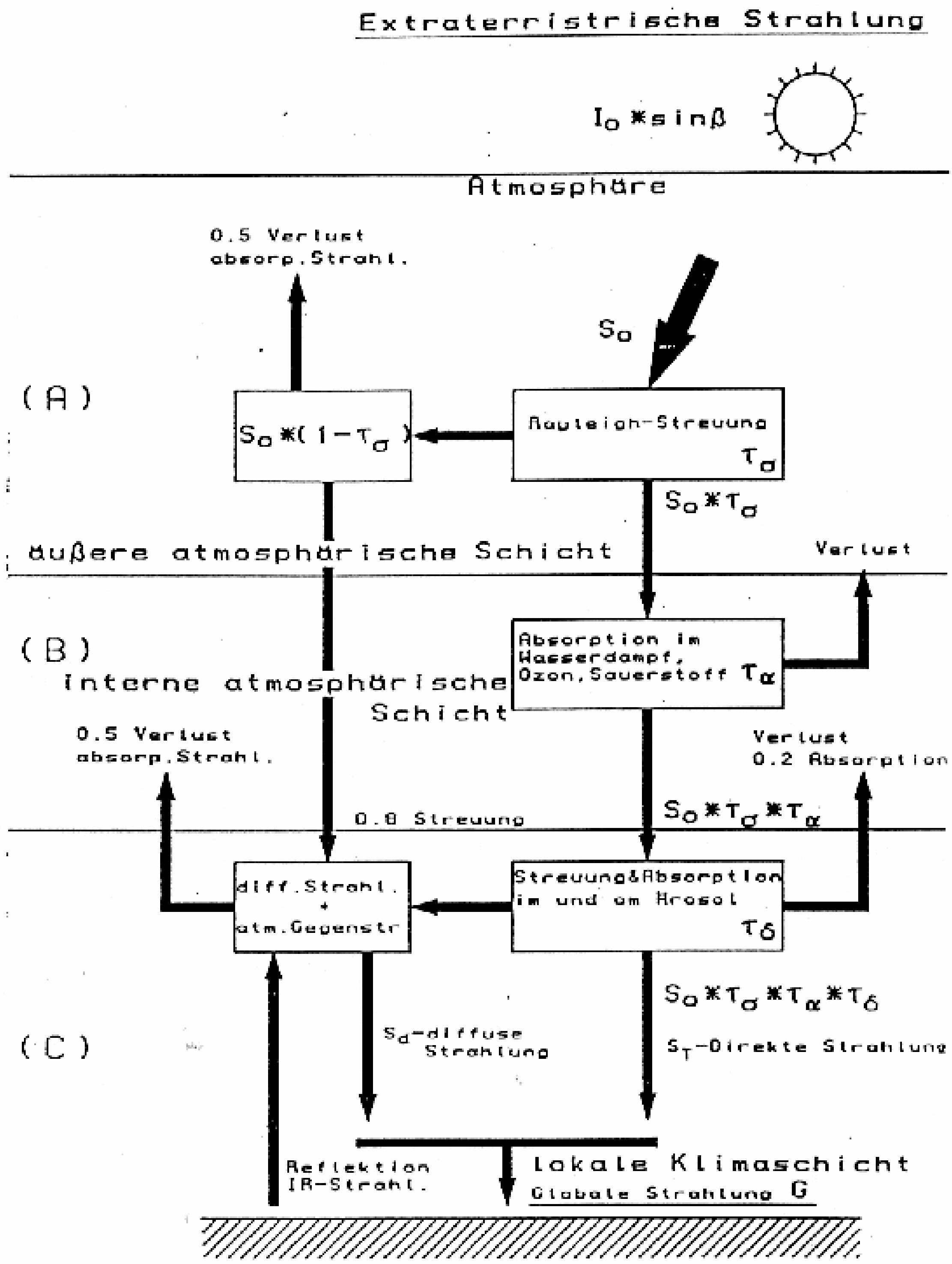


Fig. 1.8.1: Three-layer climate model for countries exposed to intense sun

Results:

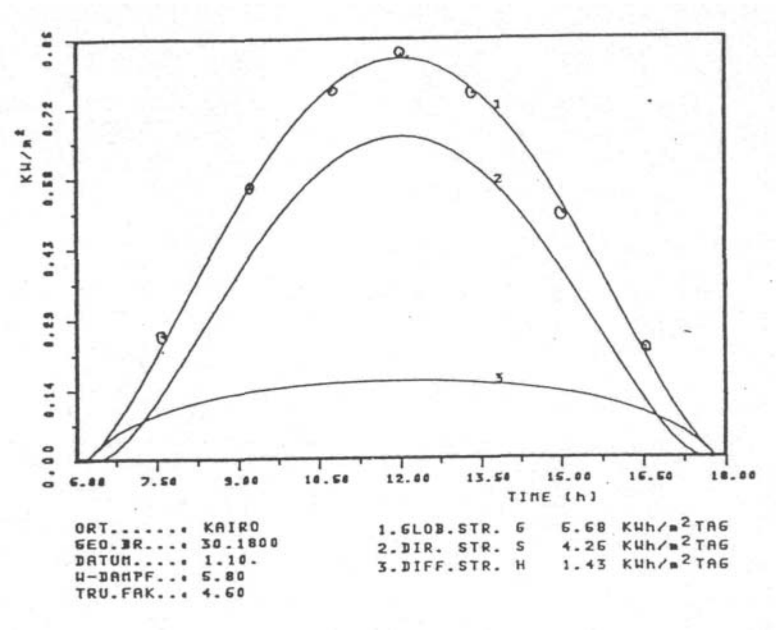
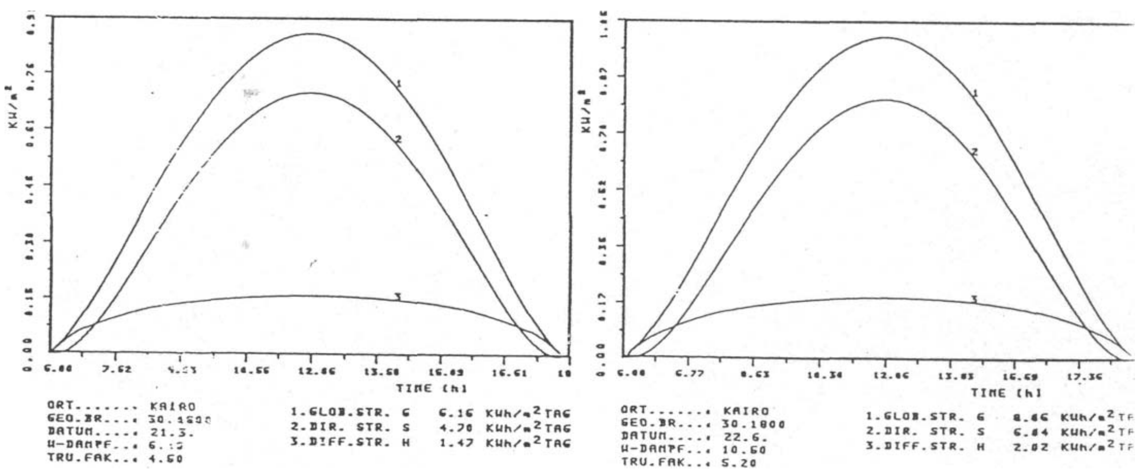
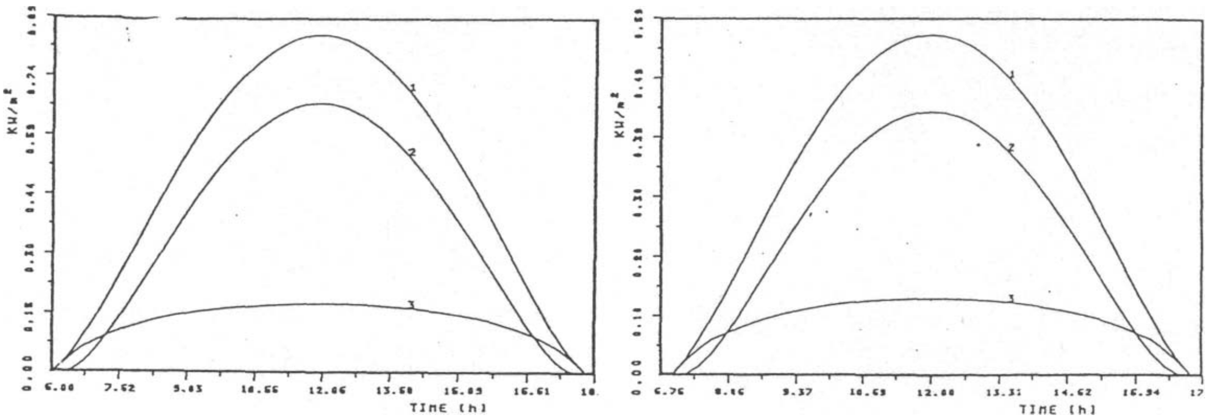


Fig. 1.9.1: The determined and measured global radiation for Cairo city on October 1st 1985

The determined results of the 3-layered climate-model of all times of the year are geographically represented here.



Figs. 1.9.2 and 1.93: The determined solar radiation of Cairo city on March 21st resp. June 22nd 1985



Figs.1.9.4 and 1.9.5: The determined solar radiation of Cairo city on September 23rd resp. December 21st 1985

The solar radiation in the course of the year as well as the calculated and measured global radiation are represented in the figs. 1.9.6 and 1.9.7.

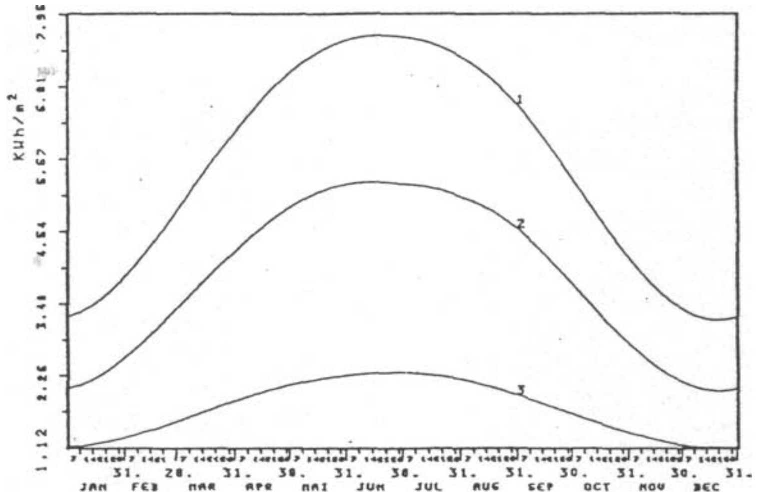


Fig. 1.9.6: The solar radiation of Cairo city in the course of the year 1985 -ft)

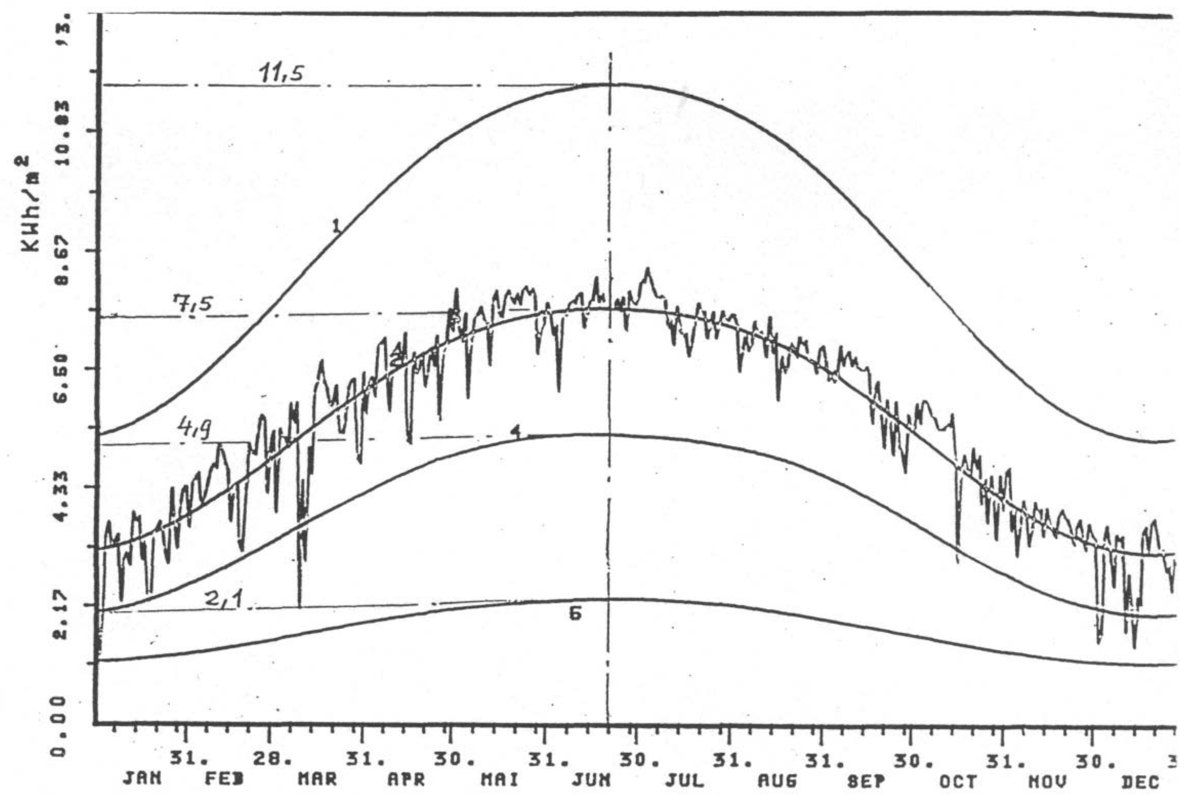


Fig. 1.9.7: Determined solar radiation for Cairo in the course of the year based on the 3-layers climate model. The underlined curve shows the measured results of global radiation.

The fig. 1.9.8 shows the 3-layers global radiation distribution with the 3-layers climate model.

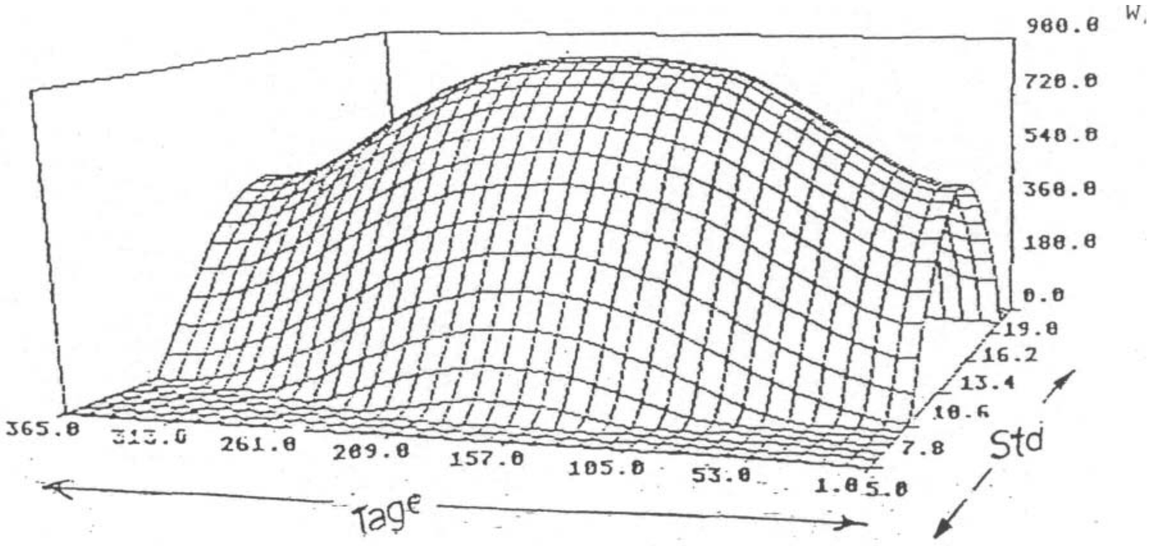


Fig. 1.9.8: Solar radiation distribution in Cairo

Cairo $\phi = 30.033$	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	[illegible]
G_Σ (MW/m²) measured	0.102	0.126	0.182	0.206	0.232	0.240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
G_Σ (MW/m²) weather-forecast	0.102	0.128	0.167	0.194	0.234	0.224	0.233	0.212	0.179	0.150	0.106	0.093	[illegible]
G_Σ (MW/m²) climate-model	0.116	0.131	0.184	0.211	0.240	0.241	0.243	0.225	0.188	0.159	0.117	0.107	[illegible]
h sunhours (measured)	225	227	274	295	233	364	372	532	314	289	245	223	[illegible]
h sunhours (astronom.)	324	327	372	387	424	422	430	410	371	355	320	318	[illegible]

-Table 1.3

Average of months values of global Solar Radiation MW/m² and Sunshine hours in Cairo whith Egyptian weather-forecast /75. Ha/

-The Average of daily Global Solar Radiation G from weather forecast $G_a = 5.539$ Kwh/m²

measured $G_b = 5.868$ Kwh/m²

from Climate Model $G_c = 5.92$ Kwh/m²

Explanation:

a) Measured by myself in Cairo in the Year 1985

b) Measured Average Value for 15 Years, Data from weather forecast in Cairo

c) Calculated global Solar Radiation after 3-Layers Climate Model

1.10 Summary

In the previous sections the essential fundaments of solar radiation were presented. The physical basis of a radiation climate, the radiation theory, the geometry and the earth-sun movement, which were all necessary for these calculations to have been explained. The calculations for the geometrical angles, the day-length (i.e. day duration) t^ and extraterrestrial solar radiation SQ have been dealt with and concluded. Because the weather conditions in countries with excess sun levels are not taken enough into consideration in specialist literature a climate •• model was therefore set up so that the relevant climatic conditions could be represented as exactly as possible.

Due to the measurements in a country with high sun levels, here the example in Egypt, the DFVLR-climate model was'examined. The radiation intensity was not to be satisfactorily represented with the use of this model. Because of this, the 3-layers climate model for countries with intense sun levels was developed in order to calculate a more exact result of solar intensity, which could also match up better with the given measured results.

This climate model allows for no uneven climatic changes, like e.g. the clouding over in the sky. The 3-layers climate model determines the following values: t^ (sun rise), f^ (day-length), (3 (angle of swi-height) ^s well .as the absorbed solar radiation's from the atmosphere: SQ (extraterrestrial), S (direct), S^ (diffuse) and G (global radiation).

The model took the geographical degree of latitude ^> into account, as well as the regional water vapour content of the atmosphere and the local clouding factors, which could be given every month so that a sole adjustment for a place is possible. The climate model could also take season controlled weather conditions into consideration (like e.g. Khamassin in Egypt, Kebli in Libya, Aasefa in Kuwait and Nawwa in Alexandria).

The calculations from the model were proven to be correct from own measurements as well as from measurements taken from the meteorological office in Cairo. The determined results for the total global radiation in Cairo from G^ = 2.162MWh / m^a or the mid-day global radiation from 5.92 KWh/m d differing slightly from the weather dates of the actual measurements of Cairo. The model is therefore able to calculate the hourly, daily and yearly solar radiation for any place in countries with intense sun levels. Particular geographical areas such as (e.g. being situated close to the sea) and local weather conditions (aerosol, Sahara dust) can also be allowed for. The newly developed 3-layer^ climate model can therefore, during the planning and the operation of the solar thermal plant, be employed.

Zusammenfassung

In den vorangegangenen Abschnitten wurden die wesentlichen Grundlagen der Sonneneinstrahluno vorgestellt. Die Physikalischen Grundlagen des Strahlenklimas, die Strahlungsgesetze, die Geometrie und Bewegung Erde-Sonne die flir diese Berechnungen erforderlich sind, wurden eriautert. Die Berechnungen fur die geometrischen Winkel,Y,p Tageslangen td und extraterrestrischen Sonnen einstrahlungen So sind durchgefuhrt. Da die Witterungsbedingungen in sonnenreichen Landern in der Fachliteratur nicht ausreichend berucksichtigt werden, wurde ein eigenes Klimamodell entwickelt, das die jeweiligen klimatischen Bedingungen mbglichst genau wiedergeben kann.

Aufgrund der Messungen in einem sonnenreichen Land, hier Agypten, wurde das DLR-Klimamodell untersucht. Die Strahlungsintensitaten konnen nicht durch dieses Modell befriedigend wiedergegeben werden. Es wurde daher das Drei-Schichten-Klimamodell fur sonnenreiche Lander entwickelt, um genaue Solarintensitats-Werte zu berechnen, die mit den gemessenen Werten weitgehend ubereinstimmen. Das erstellte Klimamodell berucksichtigt keine unregelmaBigen klimatischen veranderungen, wie z.B. die Bewolkung des Himmels. Das Drei-S chichten-Klimamodell ermittelt die GroBen ta

(Sonnenaufgang), td (Tageslange), B (Sonnenhohenwinkel), sowie die von der Atmosphare absorbierte Sonneeinstrahlungs-Intensitaten So(extraterrestrische), S (direkte), Sd (diffuse) und G (Globalstrahlung).

Das Modell berucksichtigt den geographischen Breitengrad (|), den regionalen Wasserdampfgehalt der Atmosphare sowie die lokalen Tnibungsfaktoren. Wasserdampfgehalt und lokale Triibungsfaktoren konnen auch monatlich angegeben werden, so daB eine gute Anpassung vor Ort moglich wird. Es konnen auch saisonbedingte Witterrungsbedingungen (wie z.B. Khamassin in Agypten, Kebli in Libyen, Aasefa in Kuwait und Nawwa in Alexanderien) im Klimamodell berucksichtigt werden.

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