University of Thi-Qar Journal of Science (UTsci)
The 4th Scientific Conference of Science College/ University of Thi-Qar
Volume (7), No.2

Effects of Aerosols and Climate Properties on Solar Radiation amount Falling on Horizontal Surface at Kerbala City

Rasool Ramadhan Attab
Kerbala University/ College of Education for Pure Sciences
Rasuolramadan@gmail.com

***Abstract*: In this paper a mathematical description for solar radiance falling on the horizontal surface on Iraq (kerbala city) was investigated and compared with real measurements, the city having the position of (E,32° 37′ 0″ N, 44° 1′ 59.99″) 32.61, 44.03, the solar radiation as a clean energy source suffering many process that reduce its efficiency to providing many applications with a free source of energy this process mainly due to the absorption, scattering and diffraction of electromagnetic light wave, the results show that there is a major absorption by aerosols, clouds and atmospheric gases produced significantly by CO_2, CH_4,N_2O,CO and O_2 due to their size about 10^{-4} to 10 μm and its concentration in atmosphere, a main relation between the solar harvesting energy and geometrical, data for the position and day time for the sun on site of study, a climate data for the year 2018 used, finally a good identical among theoretical, real, and results obtained from other solar irradiance models.**

***Keywords*- Solar Energy, Climate Effect, Aerosols, Renewable Energy**

I. Introduction

The solar radiation incoming to earth passing throw our destined surface of climate produce a three main process due to interaction with the atmospheric particles and gas molecules in different directions without no change in the electromagnetic wave length, the first is the absorption of electromagnetic wave energy by aerosols and small particles reducing the amount of solar energy harvested by solar cells or other solar energy applications, the second one mainly occurred when the radiation passing throw small suspended particles and clouds that found in the direction of the transmitted solar radiation called scattering, the last one is the diffraction and involving reflection which means the alteration in radiation direction, scattering, diffraction and reflection processes have no change in the radiation ray's intensity[H. Khorasanizadeh]. In addition the solar radiation amount also depends on astronomical, geographical, geometrical, and meteorological data. The astronomical data are associated to the solar constant, solar declination, hour angle and hours of the day. The geographic factors based on the longitude and altitude of the position of area in study[K. Mohammadi]. The geometrical data are a surface height and the solar azimuth angle. Meteorological data are associated to the temperature, precipitation, humidity, and other data.

II. Solar Radiation and Solar Position

The actual amount of solar radiation falling on the horizontal surface over the atmospheric layers having no effect on absorption and attenuation for the solar insolation instead it depends directly on two parameters the first on is the so called the zenith angle and the second on is the ratio (dm/d) of the actual distance o the mean distance of the earth to the sun, therefore solar irradiance over atmosphere expressed by[Q. Fu]:

$$S_r = S_o\left(\frac{dm}{d}\right)\cos z \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where S_o is the solar constant, the timing of the day effect directly on zenith angle which given by [I. Reda]:

$$\cos z = \sin\lambda \sin\delta \;\; \cos\lambda\cos\delta\cos h \quad \ldots\ldots\ldots (2)$$

Where λ is the latitude of the sun , δ is the declination, and h is the hour angle which can be evaluated by [L. Wald]:

$$h = \left(\frac{2\pi}{24}\right)(T_{st} - 12)\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where T_{st} is define as the true solar time, and the figure (1) shows the sun position calculation[I. L. Alboteanu].

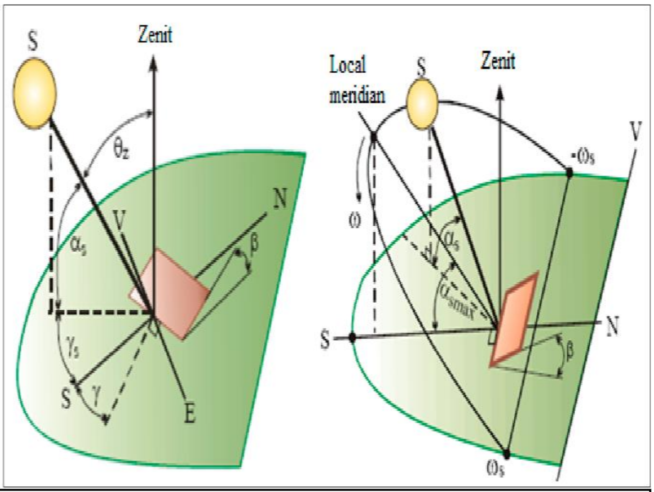


Fig (1) sun position calculation [I. L. Alboteanu].

To find the total amount of solar radiation falling with a time period from sunrise to sunset, and the zenith angle calculation the Angistrom relation satisfy solar radiation calculation to a given day of the year as[R.R.Attab]:

$$\frac{Q}{S_r} = a + b\,\frac{n}{N} \qquad \dots\dots\dots\dots\dots (4)$$

Where Q-total hour solar irradiance, $a = 0.29\cos\varphi$, φ- the latitude, b=0.25, and n, N are the real and theoretical sun radiance time, the real time can be expressed as:

$$N = T_{st} + 0.17\sin\frac{(4\pi j - 80)}{373} - 0.129\sin\frac{(2\pi j - 1)}{355} + \frac{12(s_m - l)}{\pi} \dots\dots\dots\dots (5)$$

Where j- day of the year, s_m - longitudinal

The total solar radiation falling at a given position of site varies in magnitude between day - night because of the rotation of earth and the earth orbit gives a different seasons , the latitude and longitude of position have a great effect on solar radiation in addition with present astronomical conditions as eq(4,5).

This is the reason for both sun and earth geometry and time play a great role in the amount of solar radiation received at earth surface for a specific location.

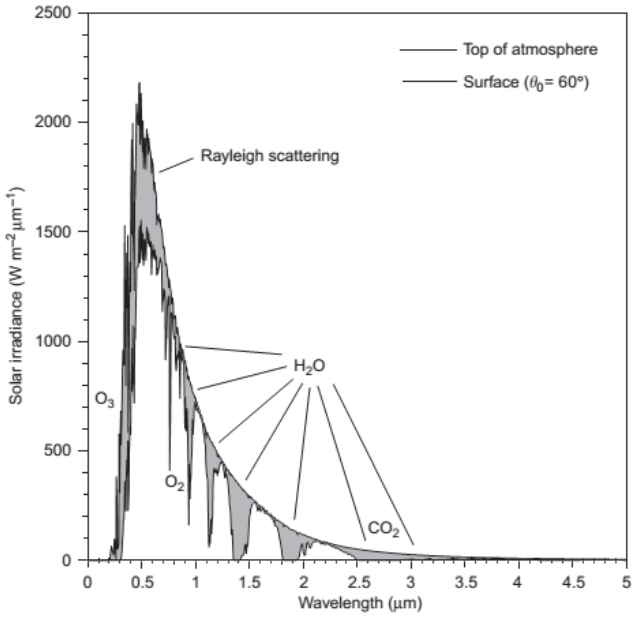
III. Absorption and Attenuation Processes Due to Aerosols and Air Components

The incoming solar radiation falling at Earth's atmosphere can be absorbed and scattered by the atmospheric gases, aerosols, clouds, and the water vapor reducing the solar radiation along the path, these processes are complex and required to analyzing physical, geometrical and metrological characteristics of the area of study almost due to the variable concentration of particles in the path of the radiation in addition the solar radiation passing will changes the environments properties like temperature.

The major absorption of solar radiation by air gases can be produced significantly by CO_2, CH_4,N_2O,CO and O_2 due to their size about 10-4 to 10μm and concentration in atmosphere[N. Halthore], In the case of scattering the Rayleigh theory can be used, which calculate the dispersion of radiation according to the size of air molecules and solar radiation wavelength as in figure (2)[M. Santamourois], the major constituents of the atmosphere are nitrogen and oxygen, which having two atoms with no dipole moments and therefore there will be no interaction or absorption in infrared bands, while the IR other active air gases and their effect are shown in figure (3)[I. L. Alboteanu].

The water vapor in the atmosphere have an asymmetric top molecule, has a strong dipole moment and because its molecule consists of two light hydrogen atoms resulting in a strong wide absorption for solar radiation.

The two other air cases, by importance, absorption are carbon dioxide and water vapor, which absorbed whole bands of wavelengths of solar radiation and the below figures shows that.



Figure(2): The Rayleigh scattering[M. Santamourois].

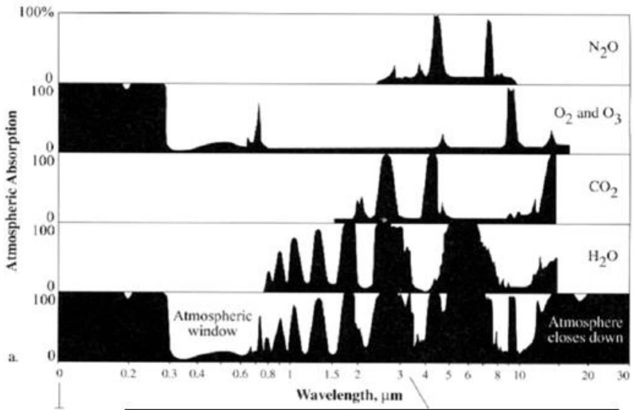


Figure (3): Absorption gases with wave length [I. Reda].

The two major affects (absorption, scattering) on direct solar irradiance, diffuse irradiance and total solar irradiance in term of the frequency of solar radiation falling on a horizontal surface can determined by the set of equations[A. J. Gutiérrez]:

$$I_d = I_s\cos(z) * 0.9662 T_R T_O T_{UM} T_W T_A \qquad \dots\dots\dots\dots\dots (6)$$

$$I_{as} = I_o\cos(z) * \frac{0.97 T_O T_{UM} T_W T_{AA}[0.5(1 - T_R) + B_a(1 - T_{AS})]}{[1 - M + M^{1.02}]} \qquad \dots\dots\dots (7)$$

$$I_T = \frac{(I_d + I_s)}{(1 - r_g r_s)} \qquad \ldots\ldots\ldots\ldots\ldots (8)$$

Where I_s – solar irradiance on the horizontal surface from scattered light including reflection light from ground and sky, $T_R, T_O, T_{UM}, T_W, T_A$ are the transmission coefficients for Rayleigh scattering, ozone absorption, mixed gases absorption, water vapor absorption and aerosols absorption and scattering respectively.

For equation (7) the parameters T_{AA} are transmittance of aerosols by absorption, B_a the ratio of forward scattering to the total scattering by aerosols, T_{AS} transmission of aerosols scattering and finally the air mass factor M_x.

The total amount of solar irradiance affected by the term albedo (the fraction of the incident solar radiation that is reflected from ground of earth r_g or atmosphere r_s)[S. Brody], a correction factor is adding to equation (6) to adjusting the wave length range of the incident solar spectrum, the transmission equations will be[R.E.Bird]:

$$T_R = e^{\left(-0.0903\, M_x^{0.84}\left(1 + Mx - M_x^{1.01}\right)\right)} \qquad \ldots\ldots\ldots\ldots\ldots (9)$$

$$T_O = 1 - 0.1611 X_o (1 + 139.48 X_o)^{-0.3035} \qquad \ldots\ldots (10)$$

$$T_{UM} = e^{\left(-0.0127\,(M_x)^{0.26}\right)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

$$T_W = 1 - \frac{2.4959 X_w}{\left((1 + 79.034 X_w)^{0.6828} + 6.385 X_w\right)} \ldots (12)$$

$$T_A = e^{\left(\tau^{0.873}\left(1 + \tau - \tau^{0.7088}\right)\; M^{0.918}\right)} \qquad \ldots\ldots\ldots\ldots\ldots (13)$$

Equation (9) evaluate the Rayleigh scattering transmission in term of pressure corrected air mass M_x , while in equation (10) X_o represent the total amount of ozone in the path of solar radiation , X_w represent the total amount of perceptible water in slanted path the solar electromagnetic wave traveled, the final equation obtained by calculating broadband aerosols optical depth from surface in a vertical path τ that the solar radiation traveled.

From the above equations its clearly that the aerosols and air molecules having a different interaction with the atmospheric transmission process due to these components have a different size and diameter and knowing that the scattering, absorbing processes depend primarily on the ratio between the wavelength of light and the size of the particles and molecules obstructing the path of the radiation of photons. Aerosols are about (10^{-6} up to 10^{-4}) in diameter and the air molecules are about (10^{-6}) meters in diameter. There for attenuation process on solar spectrum caused by the aerosols is the most important scattering contribution in the Infrared wavelength band because of their size[B. Hassler].

Air gases and other molecules forming the atmosphere, absorption phenomena is most wavelength-selective effect in the solar spectrum which caused by absorption of for example the blackbody radiation with the 10 µm region of molecules. The energy that the atmosphere absorbs is transformed into heat and the global temperature increases cases an increase of atoms vibrations subsequently increasing the solar attenuation[N. Hatzianastassiou].

IV. Results and Discussions

Form previous equations the almost variables that associated with total solar radiation falling on the horizontal site of study we can start with the sun position and sun declination according to date and time as in figures (4,5).

Figure (6) shows the extraterrestrial irradiance without atmosphere attenuation, from these three figures one can conclude that the total solar irradiance extraterrestrial is associated with sun position and the distance from the earth to the sun with different seasons,

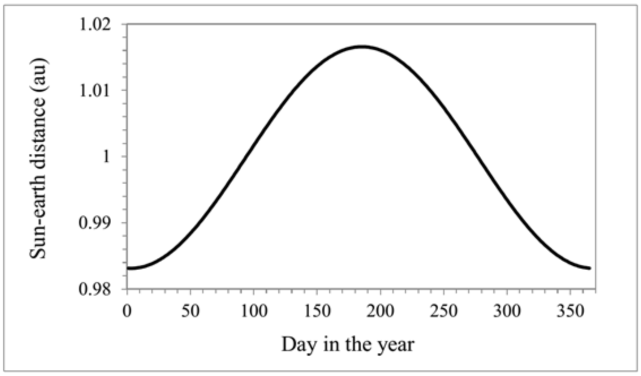


Figure (4): the relation between sun – earth distance and day of the year[L. Wald].

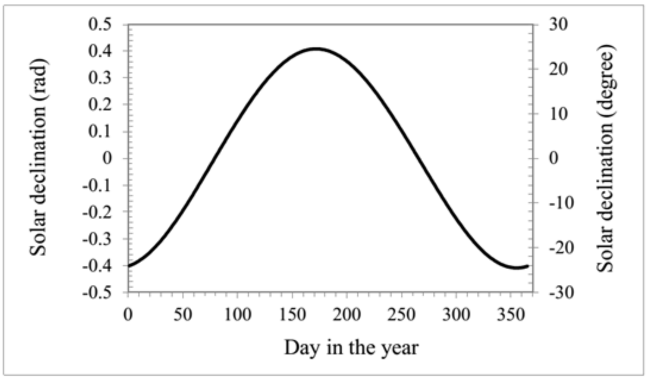


Figure (5): the relation between sun declination and day of the year[L. Wald].

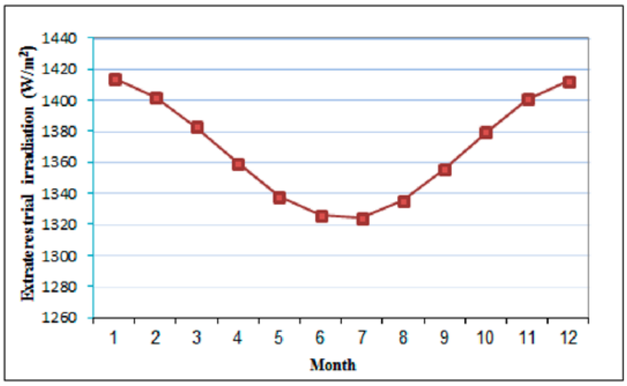


Figure (6): The relation between sun irradiance extraterrestrial and month of the year.

The decrease of solar irradiance outside the earth atmosphere due to the far distance at this season comparing with other seasons in which the distance of earth – sun measured, the second reason is the ray angle falling for the specified position on earth.

Now when applying the climate data taking from kerbala metrological station and some data taking from world meteorological organization, kerbala station having the position of (32.57476 latitude, 44.03183 longitude) the total solar irradiance in the units of watt/m^2 with the change of the time of a day between sun rise and sun set described in table (1).

Table (1): Total solar irradiance for different months with day time.

Month	6Am	7	8	9	10	11	12	13	14	15	16	17	18	19
January	0	0	84.3	267	466	503	510	433	297	122	1.28	0.01	0	0
February	0.13	2.51	175	289	531	568	512	456	455	312	33.8	0	0	0
March	18.9	33.1	246	443	642	656	668	674	587	377	167	0	0.01	0
April	22.6	254	533	742	822	931	930	921	785	502	208	9.06	0.02	0
May	35.6	167	678	878	875	923	933	939	803	534	267	27.9	0.67	0.002
June	61.1	365	789	820	897	943	940	977	865	607	314	32.0	1.56	0.037
July	17.8	233	749	878	902	919	936	965	911	602	322	28.8	2.12	0.056
August	3.98	186	465	888	807	798	710	685	821	341	256	14.6	0.17	0.034
September	0.318	101	333	531	688	721	689	501	412	123	12.7	9.55	0.025	0.001
October	0.19	56.3	201	432	576	634	687	499	387	119	1.56	0	0	0
November	0.11	1.11	103	298	371	407	400	467	329	98	1.18	0	0	0
December	0	0	78.1	231	320	424	398	436	294	110	1.13	0	0	0

It is clear from the above table that the amount of solar radiation reaching the horizontal surface changes from a small value during the first day hours to a maximum value during midday when the sun is at the highest point during the day (12-14) of daylight hours. While the solar radiation in this case is absorbed and absorbed by air components, gases and soil, the effect of climatic conditions towards reducing the value of solar energy as these factors increase the exposure of the solar beam transcription processes scattering and absorption.

The average values for solar irradiation compared with the values obtained from practical measurements and bird solar irradiance model shows a brave identical in some regions of the points the other points having small different values its maybe due to weather change or change in air mass or other gasses concentration and the figures (7-10) shows that for different seasons:

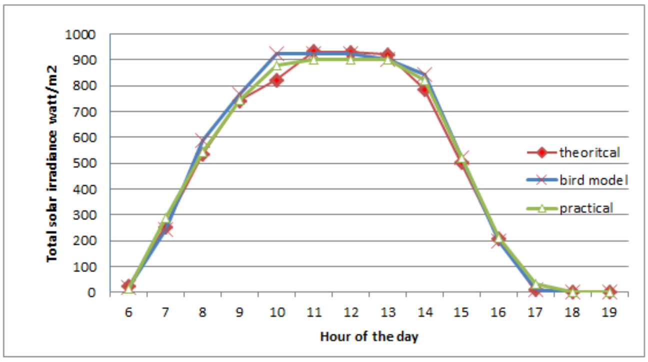


Figure (8): Total solar irradiance and hour of the day for different calculation at April.

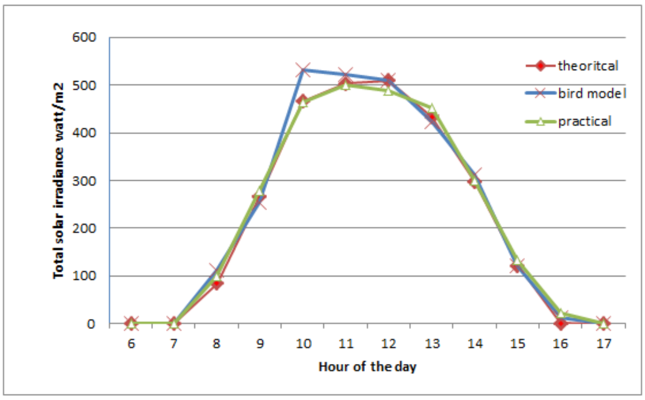


Figure (7): Total solar irradiance and hour of the day for different calculation at January.

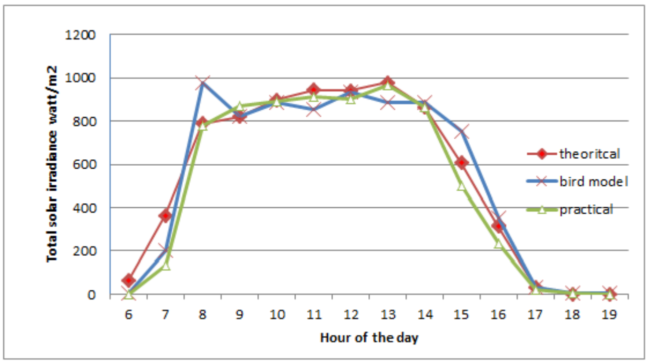


Fig (9): Total solar irradiance and hour of the day for different calculation at June.

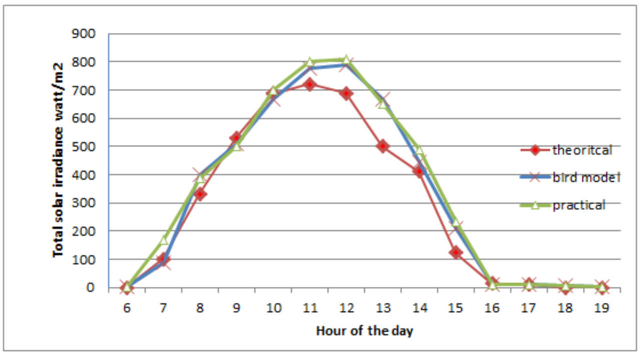


Figure (10): Total solar irradiance and hour of the day for different calculation at September.

V. Conclusion

From figures and tables mentioned before one can conclude that there is a lot of rezones reduced the total solar energy that reaches the horizontal surface on earth due to number of variable parameters like air mass, humidity, clouds, position of site, temperature and concentrations of aerosols and other gases, the sun position plays a main role in solar energy harvesting.

The major wave length reaching the earth surface is between (4-7) micrometer, the cloud, air gases, aerosols and humidity effect in this region is almost effective and the zenith angle too, it is clear to some extent, the results obtained identical for the practical calculations and global models and can be used in the application of solar cell by directing the solar cell appropriately towards the sunlight and taking into consideration the effect of the factors studied during the research.

VI. References

A. J. Gutiérrez, etal ,"Attenuation processes of solar radiation . Application to the quantification of direct and diffuse solar irradiances on horizontal surfaces in Mexico by means of an overall atmospheric transmittance," *Renew. Sustain. Energy Rev.*, vol. 81, no. June 2017, pp. 93–106, 2018.

B. Hassler, "Atmospheric Tarnsmission Models for Infrared Wave length", Master Thesis Division of Automatic Control Department of Electrical Engineering *Linköping University*," 1998.

H. Khorasanizadeh and K. Mohammadi, "Diffuse solar radiation on a horizontal surface: Reviewing and categorizing the empirical models," *Renewable and Sustainable Energy Reviews*. 2016.

I. L. Alboteanu, C. A. Bulucea, and S. Degeratu, "Estimating Solar Irradiation Absorbed by Photovoltaic Panels with Low Concentration Located in Craiova, Romania," *pp. 2644–2661*, 2015.

I. Reda and A. Andreas, "Solar Position Algorithm for Solar Application", National *Renewable Energy Laboratory*, January 2008.

K. Mohammadi and H. Khorasanizadeh, "A review of solar radiation on vertically mounted solar surfaces and proper azimuth angles in six Iranian major cities," *Renewable and Sustainable Energy Reviews. 2015.*

L. Wald, "Basics in Solar Radiation at Earth", MINES ParisTech, PSL Research *University O.I.E. – Observation, Impacts, Energy Center, France, HAL Id : hal-01676634, p. 57*, 2018.

M. Santamourois, " Modeling the Global Solar Radiation on the Earth's Surface Using Atmospheric Deterministic and Intelligent Data-Driven Techniques", *American Meteorological Society, Vol.12, pp.315*, 1999.

N. Halthore *et al.*, "Comparison of model estimated and measured direct-normal solar irradiance of New Sun-Earth distance) ' 2 ') *Rayleigh," vol. 102*, 1997.

N. Hatzianastassiou et al., "The direct effect of aerosols on solar radiation based on satellite observations, reanalysis datasets, and spectral aerosol optical properties from Global Aerosol Data Set (GADS)," *Atmos. Chem. Phys., vol. 7, no. 10, pp. 2585–2599,* 2007.

Q. Fu, "Encyclopedia of Atmospheric Sciences: Radiation (Solar)" no. 1981, pp. 1859–1863, 2003.

R.R.Attab, "Estimation and Analysis of Total Solar Irradiance Falling On Horizontal Surface for Nasiriyah City", *Thi-Qar science journal, vol.1 no.2*, January, 2010 [in arabic].

R.E.Bird, "A simplified clear sky model for direct and difussed insolation on horizontal surfaces" , solar energy research institute, 1981.

S. Brody, U. Rosing, and R. Tunell, "Obstetric analgesia. An interview investigation," *Lakartidningen*, vol. 75, no. 3, pp. 124–128, 1978.