Numerical modeling of solar irradiance on earth's surface

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Abstract. Modeling studies and estimation of solar radiation in base area, touch from the problems of estimating equation of time, distance equation solar space, solar declination, calculation of surface irradiance, considering that there are a lot of studies you reported the inability of these theoretical equations to be accurate estimates of radiation, many authors have proceeded to make corrections through calibrations with Pyranometers field (solarimeters) or the use of satellites, this being very poor technique last because there a differentiation between radiation and radiant kinetic effects. Because of the above and considering that there is a weather station properly calibrated ground in the Susques Salar in the Jujuy Province, Republic of Argentina, proceeded to make the following modeling of the variable in question, it proceeded to perform the following process: 1. Theoretical Modeling, 2. graphic study of the theoretical and actual data, 3. Adjust primary calibration data through data segmentation on an hourly basis, through horizontal and adding asymptotic constant, 4. Analysis of scatter plot and contrast series. Based on the above steps, the modeling data obtained: Step One: Theoretical data were generated, Step Two: The theoretical data moved 5 hours, Step Three: an asymptote of all negative emissivity values applied, Solve Excel algorithm was applied to least squares minimization between actual and modeled values, obtaining new values of asymptotes with the corresponding theoretical reformulation of data. Add a constant value by month, over time range set (4:00 pm to 6:00 pm). Step Four: The modeling equation coefficients had monthly correlation between actual and theoretical data ranging from 0.7 to 0.9.

1. Introduction

Modeling studies and estimation of solar radiation in base area, touch from the problems of estimating equation of time, distance equation solar space, solar declination, calculation of surface irradiance, considering that there are a lot of studies you reported the inability of these theoretical equations to be accurate estimates of radiation, many authors have proceeded to make corrections through calibrations with Pyranometers field (solarimeters) or the use of satellites, this being very poor technique last because there a differentiation between radiation and radiant kinetic effects. Because of the above and taking into account the existence of a weather station Vaisala, it proceeded to perform the following process:

1. Theoretical Modeling
2. Graphic study of the theoretical and actual data
3. Adjust primary calibration data through data segmentation on an hourly basis, through horizontal and adding asymptotes constant.
4. Analysis of scatter plot and contrast series.

2. Results

Based on the above steps, the modeling data obtained:

2.1. Theoretical Model Generation:

For the calculation of the equations Spencer, Cooper, Perrin, Lamm, Walreaven with changes Michalsky [1][3], where parameters of distance, decline, daylight radiation and assessments of surface graphics and will generate equations were calculated in this study they are occupied They were:

\[
\text{Tau} = 2 \cdot 3.14 \cdot (\text{Dia} - 1) / 365
\]

Equation 1. Daily conversion factor to Tau Expression Angle

\[
\text{Solar declination} = 0.006918 - 0.399912 \times \cos(\text{Tau}) + 0.070257 \times \sin(\text{Tau}) - 0.006758 \times \cos(2 \times \text{Tau}) + 0.000907 \times \sin(2 \times \text{Tau}) - 0.002697 \times \cos(3 \times \text{Tau}) + 0.00148 \times \sin(3 \times \text{Tau})
\]

Equation 2. Solar declination angle multiple Fourier terms.

Figure 1. Graphic expression Tau

Figure 2. Graphic solar declination
\[ E_0 = 1.00011 + 0.034221 \cos(\text{Tau}) + 0.00128 \sin(\text{Tau}) + 0.000719 \cos(2\times\text{Tau}) + 0.000077 \sin(2\times\text{Tau}) \]

**Equation 3. Earth Sun Factor Correction**

Then the calculation model of solar radiation on the surface, took the following formula:

\[
\text{Surface Solar Irradiance} = I_0 \times E_0 \times (\sin(\text{Solar declination}) \times \sin(\text{Slope}) + \cos(\text{Solar declination}) \times \cos(\text{Hour Angle}) \times \cos(\text{Latitude}))\times \cos(\text{Slope}) + \sin(\text{Slope}) \times \sin(\text{ACos}((\sin(\text{Solar declination}) \sin(\text{Latitude}) + \cos(\text{Solar declination}) \cos(\text{Hour Angle})) \cos(\text{Latitude})) \times (\sin(\text{Latitude}) - \sin(E_0))/ \cos(\text{Latitude}))
\]

**Equation 4. Surface irradiance**

The result given in terms of surface radiant flux (W/m²), because the above equation depends on the hour angle, you can calculate the irradiance, every hour of the day of the year (I_0 is the Solar constant).
2.2. Graphic study of the theoretical and actual data:

He proceeded to take the theoretical data modeling seed, proceeded to contrast with the actual data, it was found a strong time lag and amplitude variation in the data.

![Figure 5. Temporary difference of n hours](image1)

![Figure 6. flux amplitude difference of n hours](image2)

Which indicated that the theoretical models, do not come close to solving the local reality because they can not only specify latitude and longitude, the above made you decide to make a temporary displacement and based on asymptotic model for radiation.

2.3. Adjust primary calibration data through data segmentation on an hourly basis, through horizontal and adding asymptotes constant:

Generic steps were:

2.3.1. Displacement t-n hours:
It follows that the displacement was 5 hours, such as data modeling in December 20:00 hr, it was 15:00 hr.

**Table 1. Temporal displacement.**

| Month | Feb | Jan | Mar | Apr | May | Jun | Jul | Agu | Sept | Oct | Nov | Dec |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|
| Hours | 5   | 5   | 5   | 5   | 5   | 5   | 5   | 5   | 5    | 5   | 5   | 5   |

2.3.2 Asymptotic curve fitting process and first least-squares adjustment

Must be the actual values regarding the theoretical, show asymptotic gap type, so their values radical, as seen in the figure:

It is noted that segmenting the feature temporarily, it was indicated that all the radiation they had negative flow the following values:

**Table 2. Asymptotic initial value.**

| Month | Feb | Jan | Mar | Apr | May | Jun | Jul | Agu | Sept | Oct | Nov | Dec |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|
| Hours | -150| -150| -150| -150| -150| -150| -150| -150| -150 | -150| -150| -150|
Subsequently the total series underwent error minimization square minimum, where the values obtained were:

Table 3. Asymptotic fit value.

| Month | Feb | Jan | Mar | Apr | May | Jun |
|-------|-----|-----|-----|-----|-----|-----|
| Hours | -9.4 | -23 | -29.9 | -57.5 | -71.3 | -85.5 |

| Month | Jul | Agu | Sept | Oct | Nov | Dec |
|-------|-----|-----|------|-----|-----|-----|
| Hours | -108.6 | -91.3 | -92.1 | -108.4 | -16.2 | -16.1 |

Where the values of error minimization are obtained:

Table 4. Optimization parameters.

| Month | Feb | Jan | Mar | Apr | May | Jun |
|-------|-----|-----|-----|-----|-----|-----|
| a. | 0.66 | 0.8 | 0.76 | 0.6 | 0.52 | 0.44 |
| b. | 90.9 | 96.32 | 85.3 | 32.26 | 6.63 | -18.99 |

The error minimization model is linear type:

Optimized Radiation value = Asset Value Restricted by Asymptotic * a + b

Equation 5.

Equation Theoretical Parameter Settings

2.3.3 Displacement amplitude of the curve

Figure 8 is observed in different months amplitude differences between the theoretical model and the actual data, maintaining similarity in curved shape, so it is assumed, it could be corrected by an additive process. It must at this point as a correction minimum squares had, it must

\[ F(t) = \text{Equation 5} + C \text{ (time restricted domain)} \]

Equation 6. Parameters reformulation

He proceeded to add constant values in different months in different regimes of time, as indicated by the table:

Table 5. Addition constant value.

| Month | Feb | Jan | Mar | Apr | May | Jun | Jul | Agu | Sept | Oct | Nov | Dec |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|
| Hours | Value | 4 to 6 pm | 250 | 50 | 50 | 50 | 80 | 25 | 80 | 55 | 50 | 50 | 200 |

It has to curve made with the above processes, is:
The modeling equation is as follows, depending on the month and time in hours:

\[
Rad(t) \left( \frac{W}{m^2} \right) = (Theoretical \_Rad(t - n) \_with \_flux < 150 \_como \_at \_150) \ast a + b + Cte \_of \_4 \ pm \_at \_6 \ pm
\]

Equation 7. Model

2.4. Analysis of scatter plot and contrast series:

After all regenerative processes, facts on the theoretical series, to achieve similarity to the actual data, in order to achieve environmental demonstration event observed, the values to be had, as exemplified June:

In the analysis of the dispersion obtained following correlations:
Table 6. Correlation value.

| Month | Jun | Jul | Agu | Sept | Oct | Nov | Dec | Jan |
|-------|-----|-----|-----|------|-----|-----|-----|-----|
| Value | 0.77| 0.93| 0.77| 0.74 | 0.86| 0.93| 0.908| 0.79|

3. Discussion

It is noted that:

Radiation Theoretical values (t-5), Table 1 (This is because the problem of parallax).

Values of “a” and “b” in Table 4 (error minimization theoretical real value adjusted).

Constant values 4-6 pm in Table 5 (Setting Base).

It means that for example for the month of September, if you want to calculate the radiation at 6 pm, radiation at 1 pm is sought, if the flow is greater than zero this value is left then is multiplied by 0.48 and that adds value and how this value -18.25 in the time range between 4pm and 6pm, adds 55.

References

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