

Perez All-Weather Sky Model Analysis

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The *Radiance* extension utility *gendaylit* implements the Perez All-Weather Sky model¹. There are three options for input parameters:

- P epsilon delta Perez sky clearness (ϵ) and sky brightness (Δ) parameters²
- W direct_irrad diffuse_irrad Measured direct normal and diffuse horizontal irradiance (watts / meter²)
- L direct_illum diffuse_illum Measured (or calculated) direct normal and diffuse horizontal illuminance (lux)

Measured irradiance values are preferred, as many meteorological stations calculate direct normal and diffuse horizontal illuminance values based on the Perez All-Weather sky model rather than measuring these values directly.

The Perez All-Weather Sky model requires irradiance values as inputs³ if the sky brightness and sky clearness parameters are unknown. If instead *gendaylit* is provided with measured or calculated illuminance values, it must iteratively calculate the approximate irradiance values and Perez sky clearness and brightness parameters.

The sky model divides the sky clearness into eight categories and applies different coefficients for its luminous efficacy model equations. This, combined with the iterative calculation of irradiance values, leads to the question of whether there are discontinuities in the calculated irradiance values and Perez sky clearness and brightness parameters.

To answer this question, the *gendaylit* source code was rewritten to calculate sky brightness and clearness parameters and irradiance and illuminance values for values of direct normal illuminance and diffuse horizontal illuminance ranging from zero to 120,000 and 60,000 lux respectively. The results are shown in the following plots for these fixed parameters:

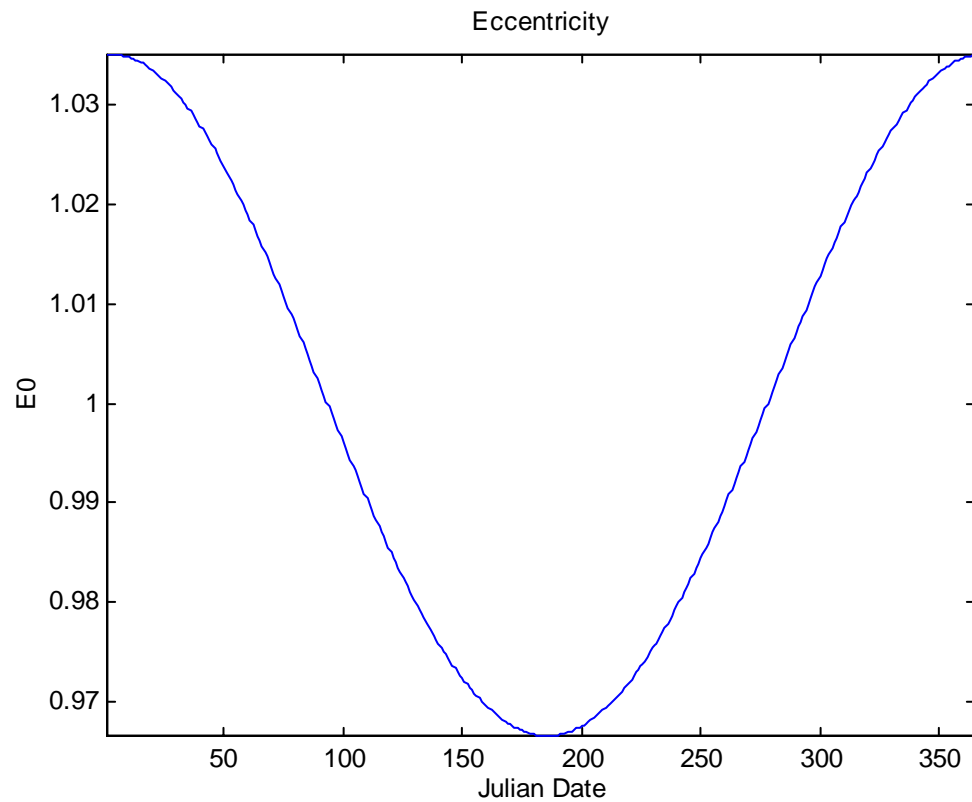
- Sun-zenith angle = 60 degrees
- Julian date = 150

When the solar position is explicitly specified for *gendaylit*, the Julian date is (apparently arbitrarily) set to 150. This sets the earth orbit eccentricity to a fixed value, which in fact varies by approximately 6.4 percent during the course of a year:

¹ Perez, R., R. Seals, and J. Michalsky, 1993. "All-Weather Model for Sky Luminance Distribution - Preliminary Configuration and Validation," *Solar Energy* 50(3):235-245.

² *gendaylit* internally limits sky brightness to the range {0.01, 0.60} and sky clearness to the range {1.0, 12.0}.

³ Perez, R., P. Ineichen, R. Seals, J. Michalsky, and R. Stewart. 1990. "Modeling Daylight Availability and Irradiance Components from Direct and Global Irradiance," *Solar Energy* 44(5):271-289.

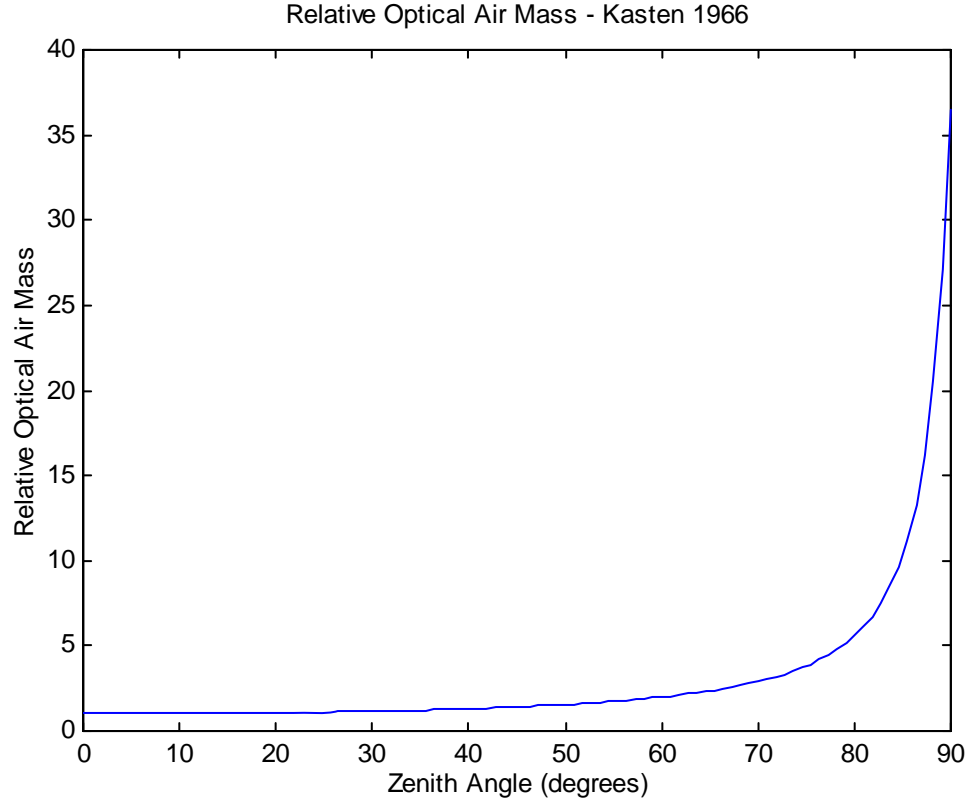


This affects the absolute zenith luminance, but does not affect the relative sky luminance distribution predicted by the Perez sky model.

The predicted diffuse horizontal irradiance is also influenced by the relative air mass^{4,5}, but this is a smooth function which does not contribute to any discontinuities.

⁴ Kasten, F., and A. T. Young. 1989. Revised optical air mass tables and approximation formula. *Applied Optics* 28:4735–4738.

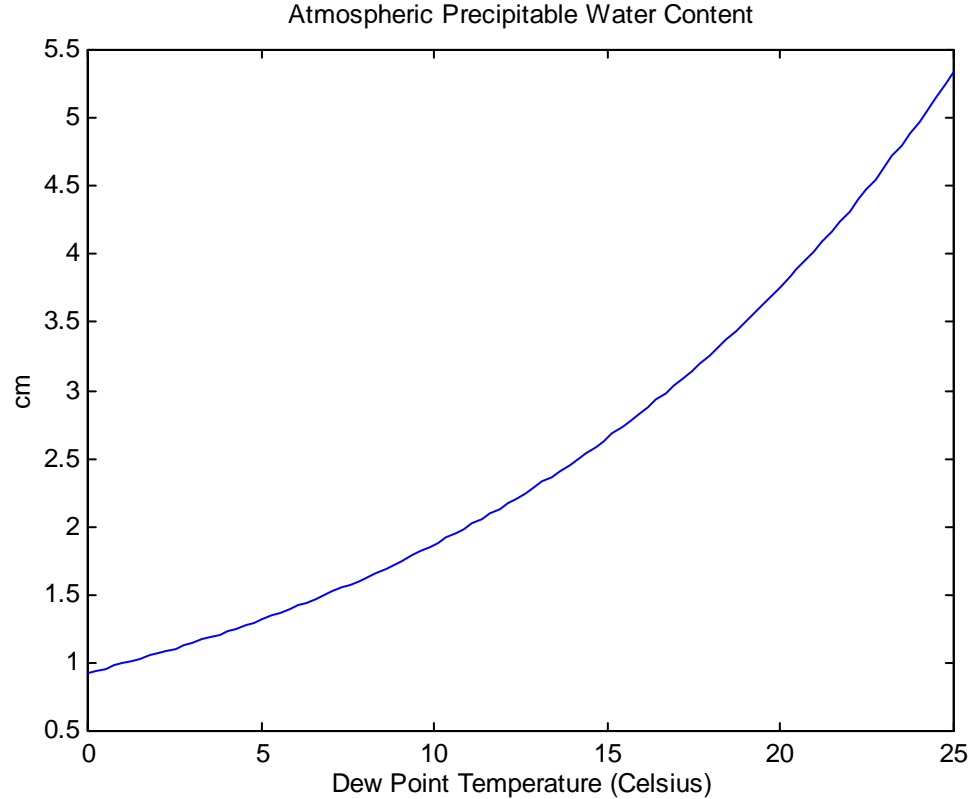
⁵ *gendaylit* uses an earlier relative air mass equation due to Kasten (1966), but the differences are insignificant for daylight modeling applications.



As can be seen from the following figures, there are some minor discontinuities in the calculated irradiance values and Perez sky brightness and clearness parameters. They are however mostly insignificant in comparison with the absolute uncertainties of meteorological station measurements. (The gross discontinuity in direct normal irradiance at very low diffuse horizontal illuminance should never occur in practice.)

Finally, *gendaylit* assumes that the dew point temperature for the Perez All-Weather Sky model is fixed at 11 degrees Celsius, resulting in an atmospheric precipitable water content of 2.0 cm. As noted by Muneer⁶, this has no practical significance for the measured illuminance values, as the water absorption bands are mostly in the near infrared. It does however have a significant influence on the measured and predicted irradiance values. This is another indication that measured irradiance values should be used where available for *gendaylit* rather than the (likely calculated) illuminance values if absolute sky luminance values are important.

⁶ Meneer, T. 2004. Solar Radiation and Daylight Models, 2nd Edition. Oxford, UK: Elsevier Butterworth-Heinemann.



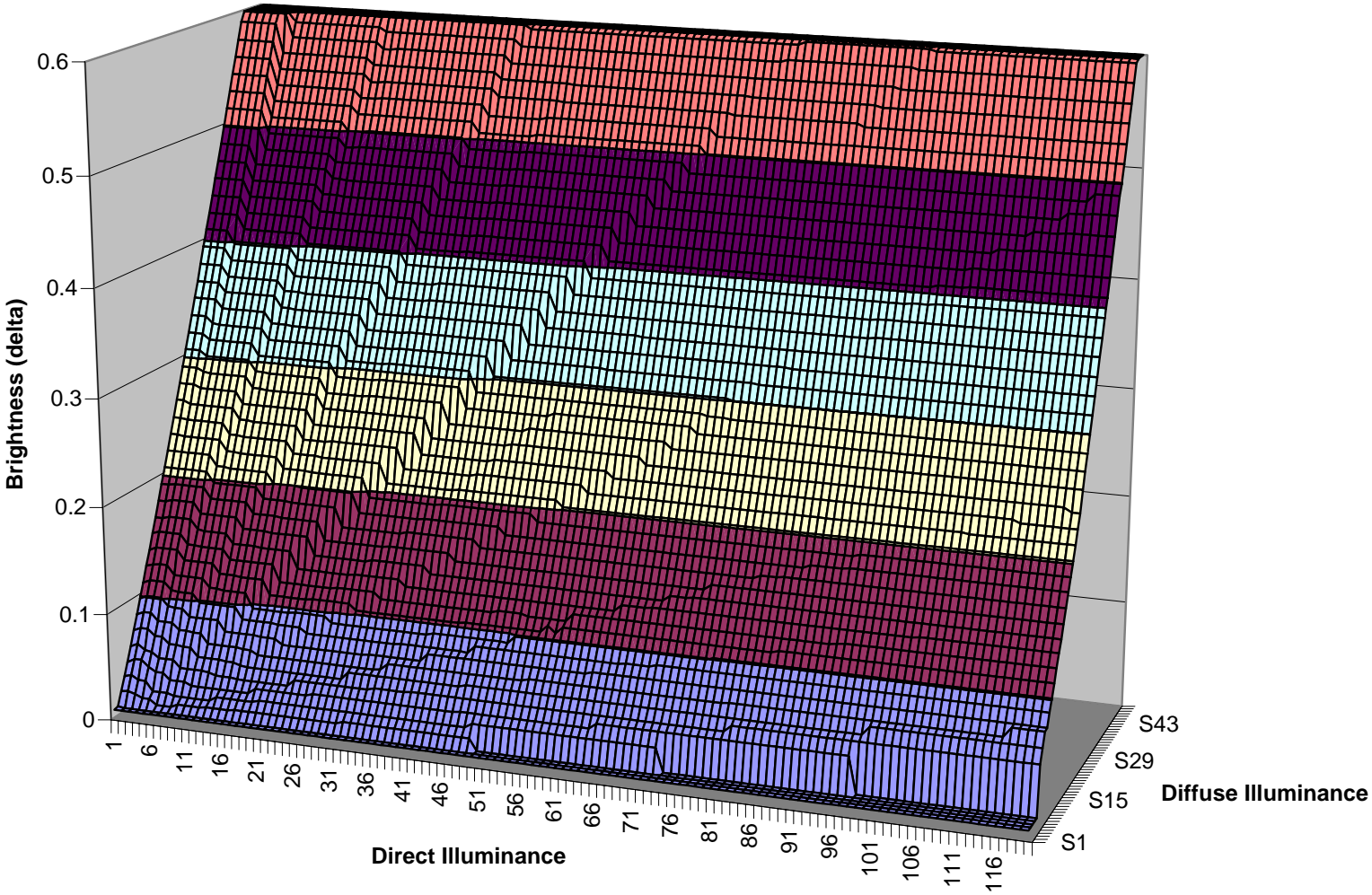
Conclusions

For daylight modeling applications where absolute sky luminance values are unimportant (such as for example daylight factor calculations), either measured irradiance or calculated illuminance values obtained from meteorological records such as EnergyPlus will likely yield acceptable results.

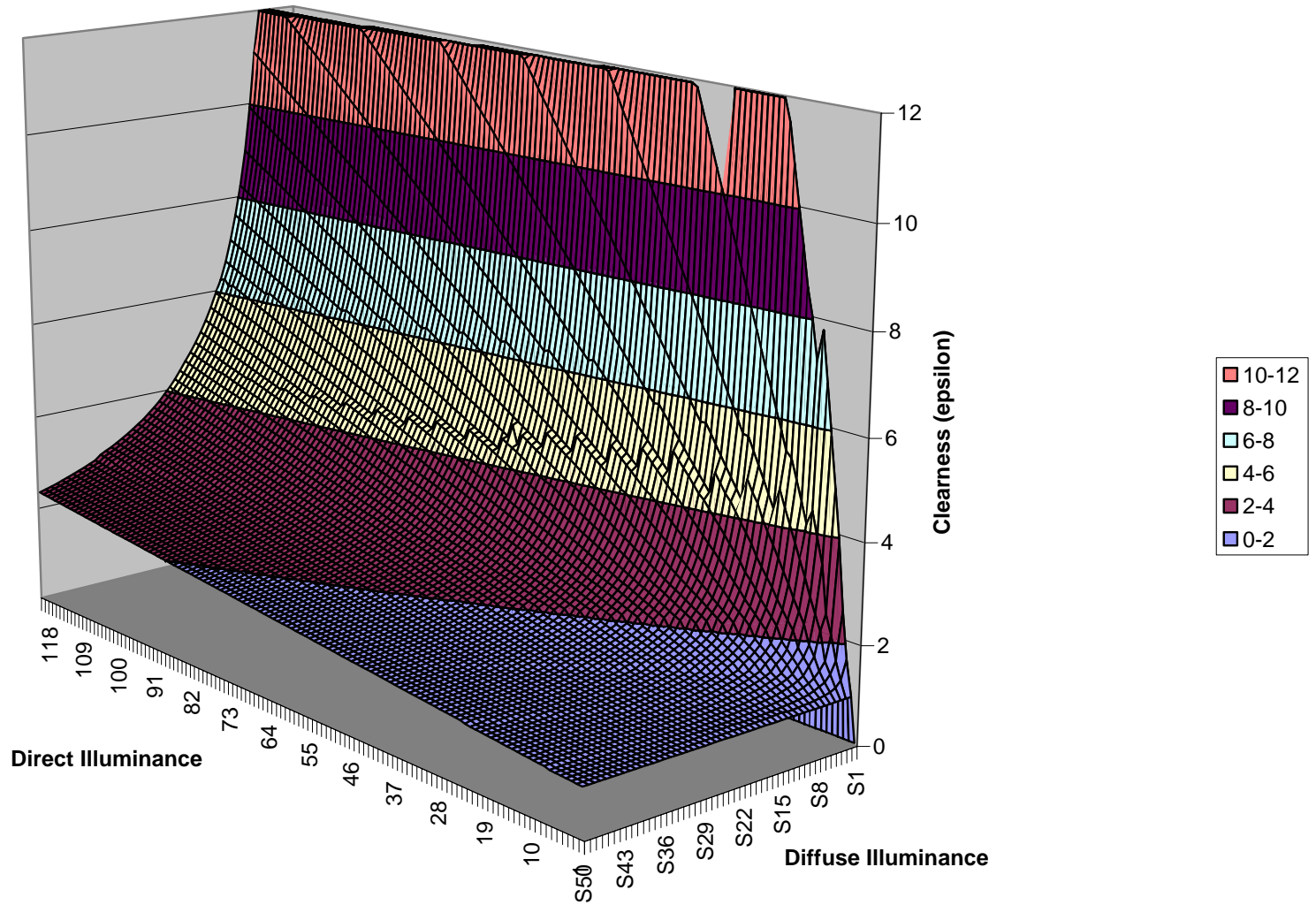
However, for applications where absolute sky luminance values are important (such as for modeling daylight control system performance), measured irradiance values are preferred.

It is also important to recognize that *gendaylit* ignores the variation in extraterrestrial solar irradiance due to the earth's orbital eccentricity when the solar position is explicitly provided rather than the time, date and geographic location, and it also ignores the effects of atmospheric precipitable water content for measured or calculated illuminance values when the `-L` option is used.

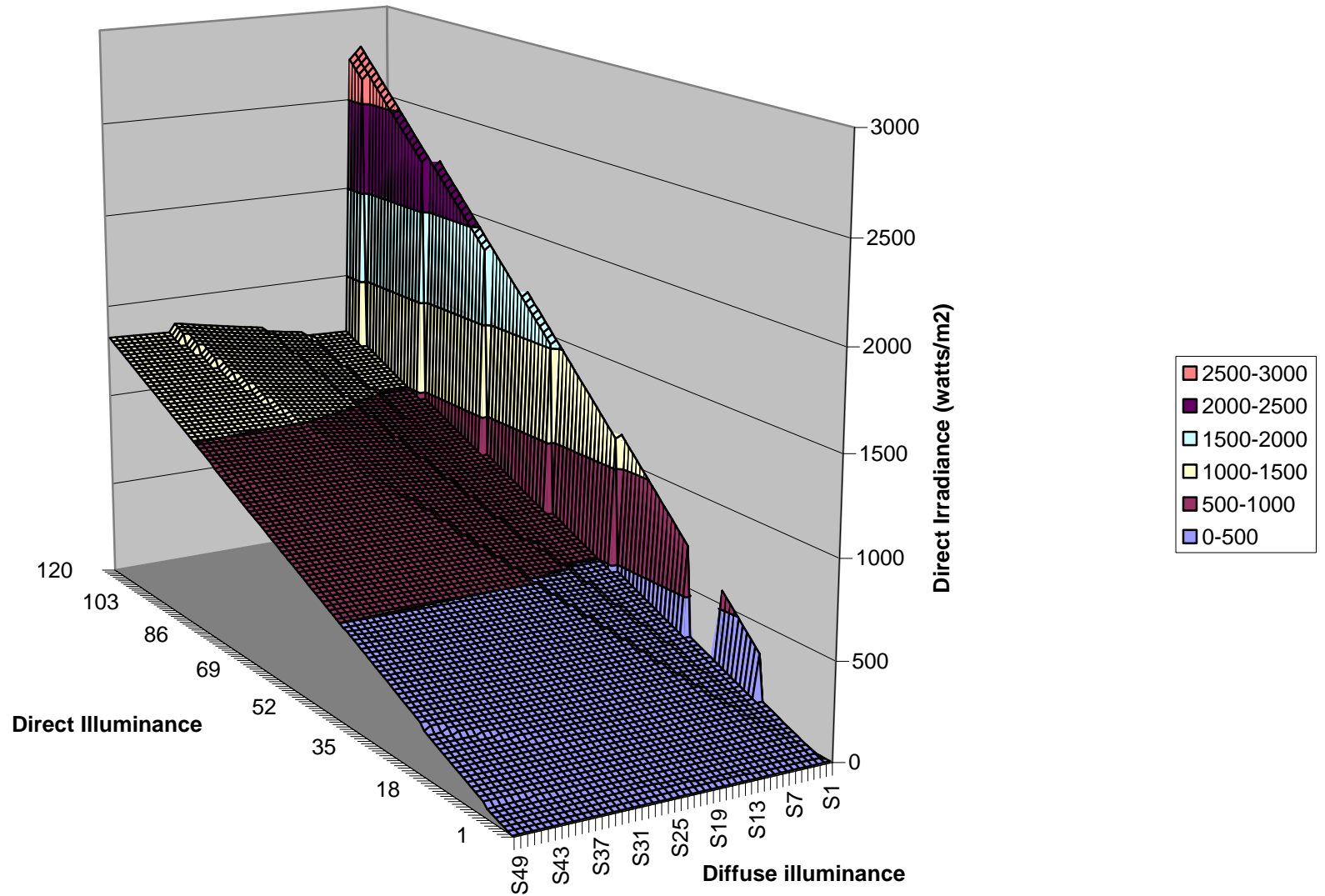
Sky Brightness - 60 degrees



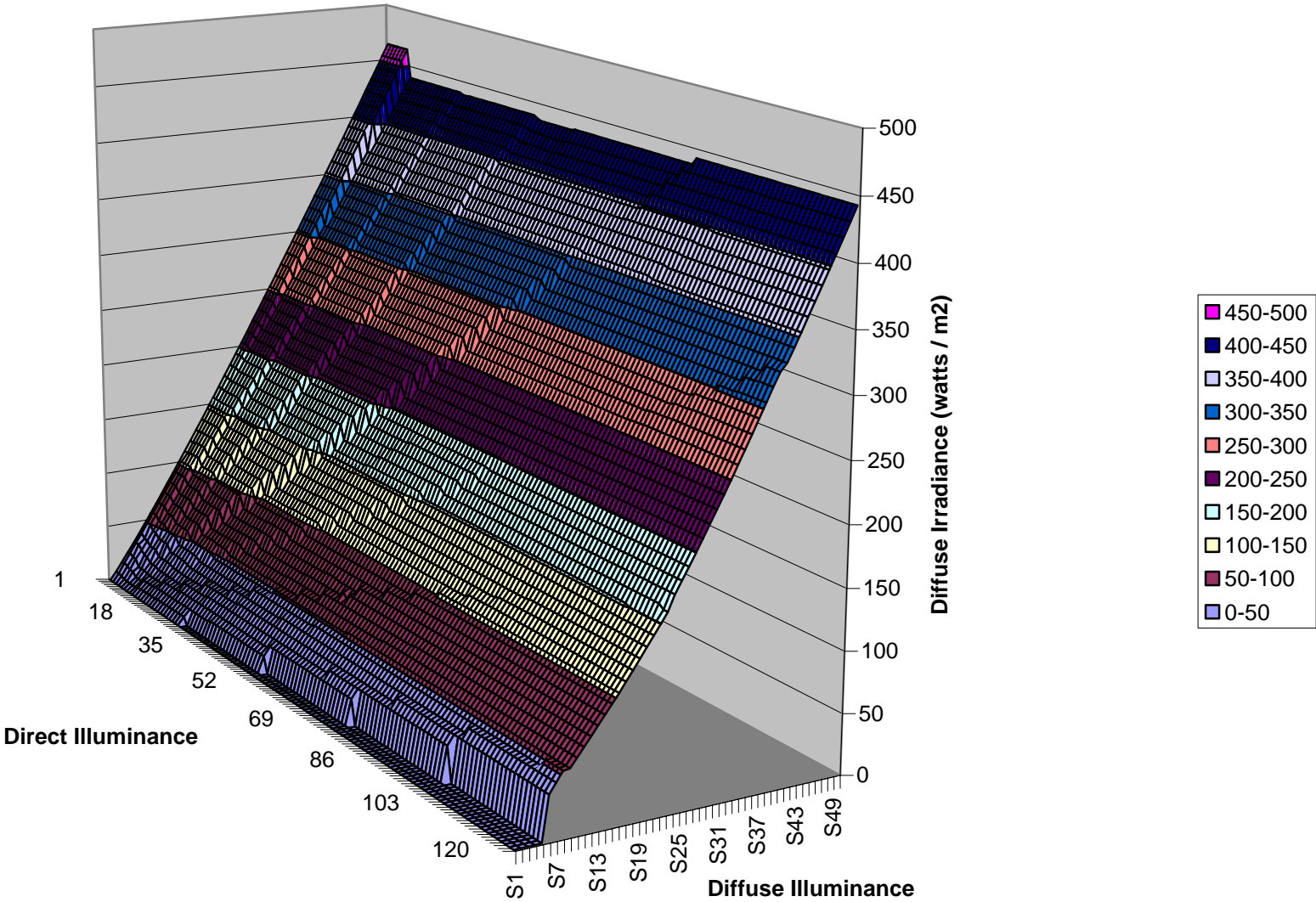
Sky Clearness - 60 degrees



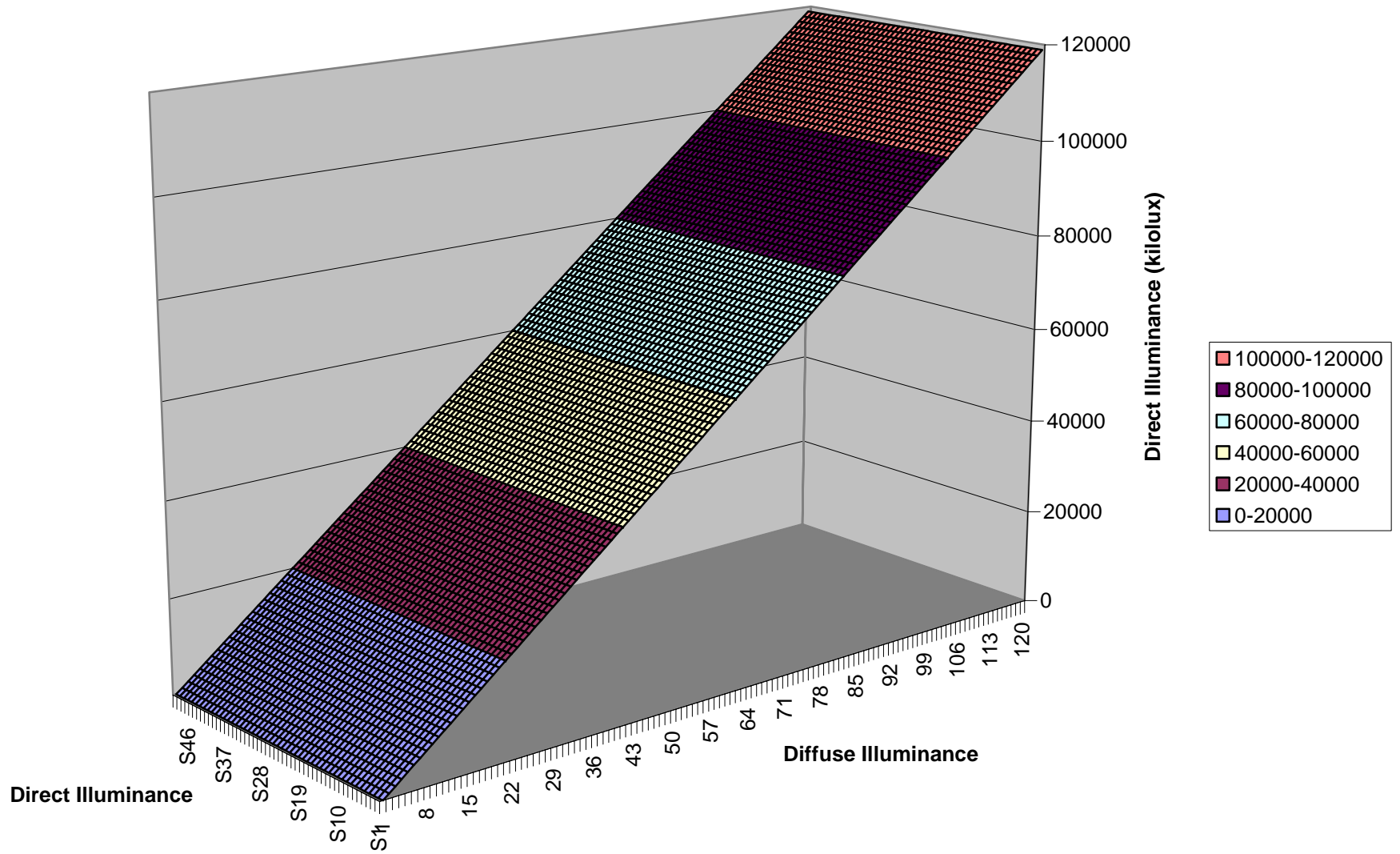
Approximate Direct Irradiance - 60 degrees



Approximate Diffuse Irradiance - 60 degrees



Approximate Direct Illuminance - 60 degrees



Approximate Diffuse Illuminance - 60 degrees

