Simulating Solar Irradiance through AM Wave Equations for Metabolic Pathways

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***Abstract*—Climate change will have serious repercussions on the planet, including an increase in solar irradiance. The aim of this article was to study how this problem will affect the behaviour of plants. This is a topic of high relevance in Systems Biology and Metabolic Networks. In particular, we will study the metabolic pathway known as the ascorbate-glutathione cycle. For this purpose, solar irradiance over the course of a year was modelled using the Amplitude Modulation technique and will serve as an input to this metabolic pathway. The aim was to study how the plant behaves in the different seasons of the year and how much increase in solar irradiance the plant will be able to withstand.**

***Keywords*- *Amplitude Modulation; Solar Irradiance; Metabolic Pathway*.**

I. INTRODUCTION

Light/dark cycles play an essential role in regulating plant growth and development. On the other hand, computer simulation is a key technology increasingly used in systems biology to analyze the dynamic behavior of plant metabolome. Therefore, solar irradiance becomes a relevant parameter for plant models. However, very few models contemplate this fact, and in the best of cases, they only simulate a few days.

Numerous algorithms have been developed to predict solar irradiance from meteorological data [1]. However, linking these calculations with model simulation can become difficult and many times such excessive precision is not necessary. Therefore, our aim was to address this question looking for a simple algorithm to simulate daily solar irradiance. For that, we have chosen the modulation technique known as Amplitude Modulation (AM), widely used in electronic communication in the transmission messages with a radio wave [2]. The corresponding equations have been adapted to design a basic model able to generate quasi-real solar irradiance data, which can be used as an input for metabolic pathways. Specifically, the ascorbate-glutathione redox pathway in chloroplasts has been studied [3][4] (see Figure 1).

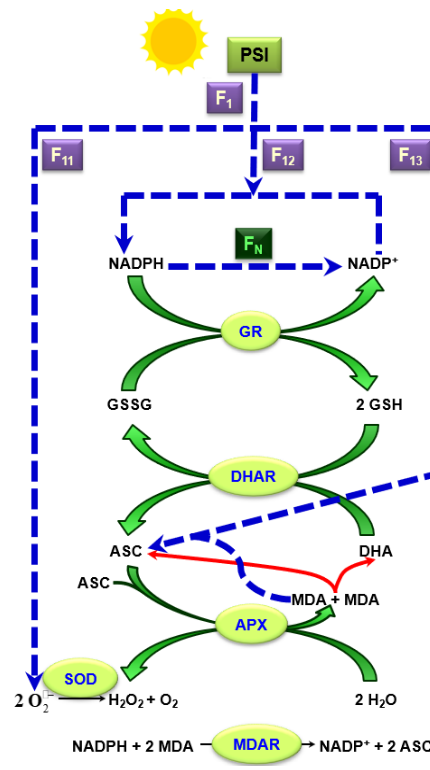

Figure 1. Scheme of the Ascorbate-Glutathione cycle.

II. MAIN RESULTS

The first step is to have approximate information about solar irradiance data at the target location for a typical year. It is also necessary to take into account the duration of day and night for that place. As a proof of concept, we shall consider the city of Albacete (Spain) (Lat/Long 38.998/-1.853) for the case of global horizontal irradiance in a typical meteorological year [5].

The equations have been described in a normalised way (maximum solar irradiance is 1), and a random value will be used to simulate real fluctuations. This factor can be adapted

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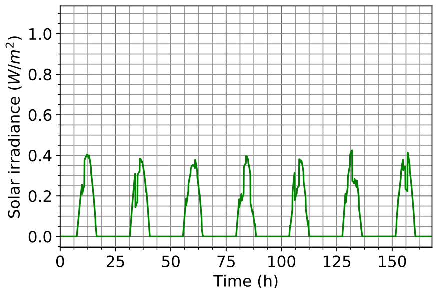

Figure 2. Normalised Solar Irradiance (7 days in winter).

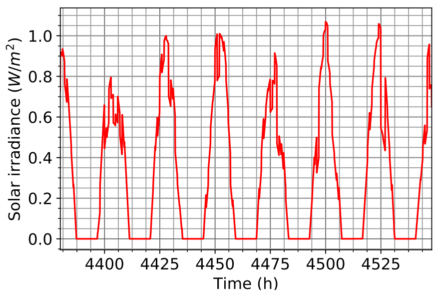

Figure 3. Normalised Solar Irradiance (7 days in summer).

and modified *ad-hoc*. Figure 2 shows a zoom for the 7 first days of winter and Figure 3, for summer. As can be seen, intensity of solar irradiance is different, and the length of light/dark periods has changed.

Figure 4 shows the normalised solar irradiance simulated through this technique for a year (8,760 h). This methodology is easily adaptable to other geographical locations.

Then, this yearly light/dark model is used to feed a complex metabolic pathway, in particular the ascorbate-glutathione cycle using Tellurium [6], a Python environment for reproducible dynamical modelling of biological networks. This cycle involves the photosensitive enzyme ascorbate peroxidase (APX) and Figure 5 shows the changes in the APX concentration over a year.

III. Conclusion

The model herein proposed can be easily used to simulate solar irradiance to input plant metabolic models. As a future work, we plan to increase the solar irradiance and study how it affects to the chloroplast; additionally we will consider other photosensitive pathways and geographic locations. All of them following the guidelines proposed in [7].

Acknowledgments

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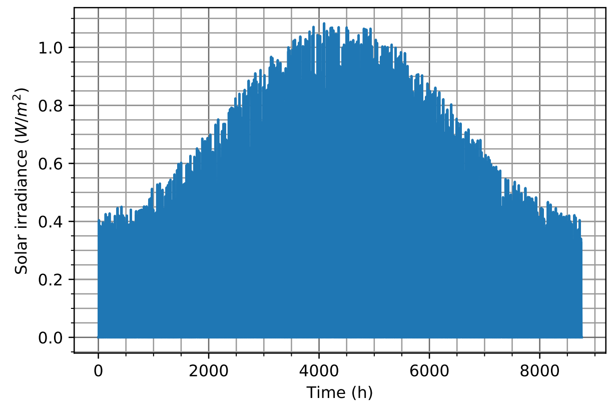

Figure 4. Normalised Solar Irradiance for a year.

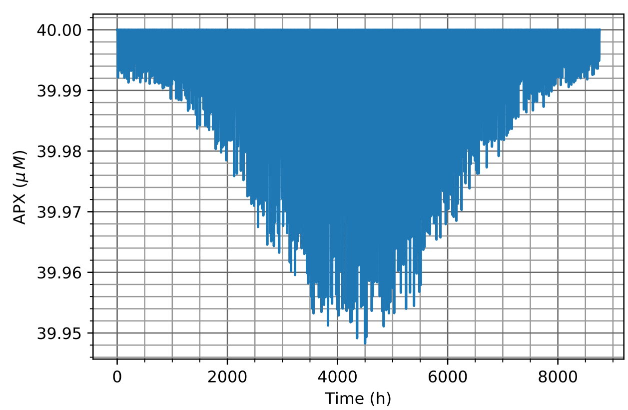

Figure 5. Fluctuations in APX concentration over a year.

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