WeatherEze®

The Next Generation of
Chamber Control Software

User Manual

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1 Introduction

All living organisms respond to alterations in environmental conditions from air temperature cycles to variations in incident solar radiation quality and duration. In particular, differences in spectral quality of incident radiation causes physiological and biochemical alterations in plants (Senger, 1987). Therefore, in order for an environmental control chamber to more accurately duplicate the natural environment, there is a need to simulate these environmental fluctuations. This is the main goal of WeatherEze™.

WeatherEze® is four programs in one. The first is a real-time weather duplicator, the second is a historical weather duplicator, the third is a climatological simulator, and the fourth is a climate change simulator. In all modes the software automatically calculates the intensity and quality of the incident solar radiation and correspondingly sets the lights, or allows one to select from a Daily Light Integral table (with an exception for DLI tables when using a personal weather station). These simulated lighting settings automatically mimic the conditions at the site at any particular time to the best of the ability of the available lighting options. For instance, incandescent lights lack significant control features and the output from the bulb is not limited to a few wavelengths. Therefore, the ability to match predicted spectra with incandescent lighting is limited. However, for chambers with LED lighting (or dimmable fluorescent banks with colored bulbs), the fact that the power is controllable as well as the fact that the LED lamps provide narrow output bands make this lighting system particularly suited for this type of control feature. In the latter three modes, data is retrieved from a cultured database that includes data based off of a variety of sources, including the IPCC, NOAA, and other historical weather sources. WeatherEze uses this data that we have cultivated for quality in order to calculate simulation files for a user to run.

Real-time Weather Data: The software can retrieve data from a METAR (Appendix A.5) reporting weather station and then "run" the observed weather conditions in the selected chamber. The coverage for the METAR stations is denser in the US. However, there are locations around the globe (mainly airports) that enable WeatherEze™ to have a global scope. The user also has an option to use a personal weather station.

Historical Simulation: The historical simulation allows the user to run past conditions based on any location on the globe. This is based on our database collection which has undergone severe vetting in order to sure that only time and locations with sufficient data can be run.

Climatology Simulation: The weather simulator enables the user to select any location on the globe and to run the chamber based on the simulated temperature, relative humidity, predicted CO_2 profiles, and incident solar radiation quality for that location.

Climate Change Simulation: WeatherEze accesses its personal database to obtain climate change information based on IPCC data. This function has a number of controls based on the differing datasets, models, and scenarios of different climate change simulations (A.6) that enable a variety of different possible future conditions.

Welcome to the next generation of chamber control software. The following chapters in this manual will lead you through what you need to know to get WeatherEze™ up and running on your computer.

Additional background information that will be helpful in getting your chamber set-up with WeatherEze™ can be found in Appendix A.

2 Getting Started

Before starting the installation of WeatherEze™, please make sure that your personal computer (PC) or laptop meets the specifications described below. If you plan to run real-time weather conditions or are generating a simulation file, please ensure that the computer is connected to the internet. An internet connection is not required if you have already generated simulation files to run. WeatherEze™ requires a Windows operating system between 7 and 10.

WeatherEze™ is designed to control more than one chamber if you wish. In general this depends on the computer, but for the minimum requirements one should be able to handle five, but simulation files should be generated before any new runs are made. Moreover, the number of times that a simulation file can be generated per day is limited.

2.1 Computer System Requirements

Minimum Hardware Requirements

- 1 GHz microprocessor
- 512 MB of RAM
- 200 MB of free disk space on your hard drive for software installation only
- 10 Mbps network card

Minimum Operating System Requirements

- Between Windows 7® to Windows 10®
- Network Connection (TCP/IP) (installed and functioning)

Recommended System Accessories

- Uninterruptible power supply (UPS)
- Surge protector

It is highly recommended that an uninterruptible power supply is purchased for the computer running WeatherEze™. This will ensure maximum uptime for the software in the event of power failures.

If you also have a personal weather station, the following is also required.

- An Ambient Weather capable weather station
- Internet capable router
- Two 120V power outlets
- The latitude, longitude, altitude, and rainy season of the location where you are setting up the weather station.
- Patience: there are many different components between most weather stations and your chamber and each one likely runs on different protocols. This is why there are so many intermediate components

2.2 Operation Notes

It is recommended that you run WeatherEze™ with an empty chamber for a few days before introducing any experiment to acquaint yourself with the software's operation and to ensure that WeatherEze™ meets the requirements for your experiments. It is recommended that you regularly check to ensure that WeatherEze™ is running properly.

The following can affect the operation of WeatherEze™:

- **Network connectivity:** WeatherEze™ must maintain a network connection with the chamber it is controlling. If network connectivity is lost the chamber will continue to control at the last set points successfully sent from the software. If running a real-time experiment, WeatherEze™ must maintain access to the Internet to successfully receive settings from the selected METAR station. If WeatherEze™ fails to access the Internet the chamber will continue to control at the last set points successfully sent from the software. After 15 minutes, WeatherEze™ will assume that there was a network failure, default to the last point before the simulation was started, and should be restarted.
- **Service connectivity:** In the METAR or personal weather station mode, WeatherEze™ obtains its information from a METAR or a weather station connected to the cloud. This means that if there is an issue with NOAA or Ambient Weather, then WeatherEze™ will treat these situations the same as if there was a network connectivity issue. Although we have vetted the NOAA and METAR location list based on our own lists and from suggestions by other users, this still does not exclude the possibility of future issues. Ambient Weather's connectivity is likewise dependent on the installation of the personal weather station, so one must ensure that the connection is stable there.
- **Computer power:** The computer running WeatherEze™ must be continually powered. If power is lost to the computer the chamber will continue to control at the last set points successfully sent from the software.
- **Operating system/running applications:** The Windows operating system and other running applications may affect the operation of WeatherEze™. *Be sure that sleep mode is disabled on the computer and that WeatherEze™ has the necessary permissions to run!* If possible, it is recommended that a minimum number of applications are run on the computer running WeatherEze™. Over time, the stability of the operating system may degrade if the computer is not restarted periodically.

The Intellus controller does not store the settings programmed via WeatherEze™ in permanent memory, and WeatherEze™ only sends one command a minute. Therefore, if power is cycled to the chamber while WeatherEze™ is running, the chamber will temporarily use the manual settings configured in the Intellus before WeatherEze™ was started until WeatherEze™ sends updated data. Before running an experiment with WeatherEze™ please configure these manual settings to values that are appropriate for your experiment. Please refer to the separate Intellus controller manual provided for information on setting the manual temperature set point, lighting set points, manual %RH set point (if applicable) and auxiliary set point (if applicable). It is also advisable to set up alarms or use the controllers' e-mail functionality, that way any drop in connectivity may be noticed immediately.

2.3 Chamber Requirements

Minimum Chamber Requirements

- Percival Scientific's Intellus C9

Additional Hardware Requirements

- For Temperature Control
  - All chambers have the ability to control temperature. However, the temperature control is limited to a high and low value that the chamber is designed to operate within. These limits are shown on the chamber or in your chamber manual.
- For Relative Humidity Control
  - In order to simulate changes in relative humidity, the chamber must have a relative humidity control option installed. The type of relative humidity control hardware will be the limiting factor for the software control.
- For CO_2 Control
  - In order to simulate changes in CO_2, the chamber must have a CO_2 control option installed. The type of control features for CO_2 will limit the potential control possibilities.
- For Lighting Control
  - The optimum lighting option is LED lamp banks (since these light sources have very discrete wavelength outputs). However, all lighting systems are supported from incandescent bulbs, on/off fluorescent banks, dimmable fluorescent banks, metal halide, and high pressure sodium lamp banks. The software's ability to mimic the solar quality is limited to the ability of the chamber lighting options. WeatherEze™ will automatically detect what options are available and enable those control features based on the current chamber configuration. The user can change control of the various features by means of the setup (3.1).
- For Watering Control
  - At this time of writing, there are many watering options that are available, and standardization of these options has been difficult. Especially considering that the watering level depends also on the soil type, which is difficult for a chamber to control. Therefore, we have opted for the simplest and most robust method of control. You should have a chamber that has a solenoid valve to control the watering schedule, and this event should be noted to you via the manual. With this knowledge, you can control the watering via this event using the simulation mode in WeatherEZE. Please see the end of section (3.8) for more information about how to do this.

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2.4 Installing WeatherEze

WeatherEze™ is distributed by CD or online.

1. To install WeatherEze™, simply insert the CD into the CD/DVD drive and open the CD's root directory, or the downloads folder for where you downloaded WeatherEze™. Run the WeatherEze Setup file as administrator if possible (Figure 1 Illustration of setup.exe) (if you cannot do this, please note the different instructions in step 3).

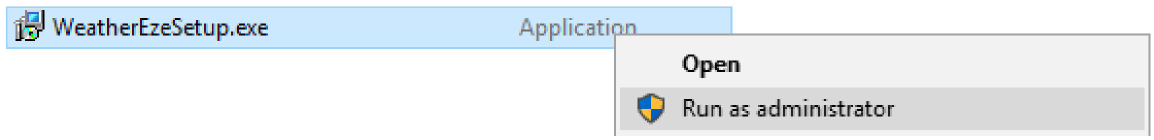
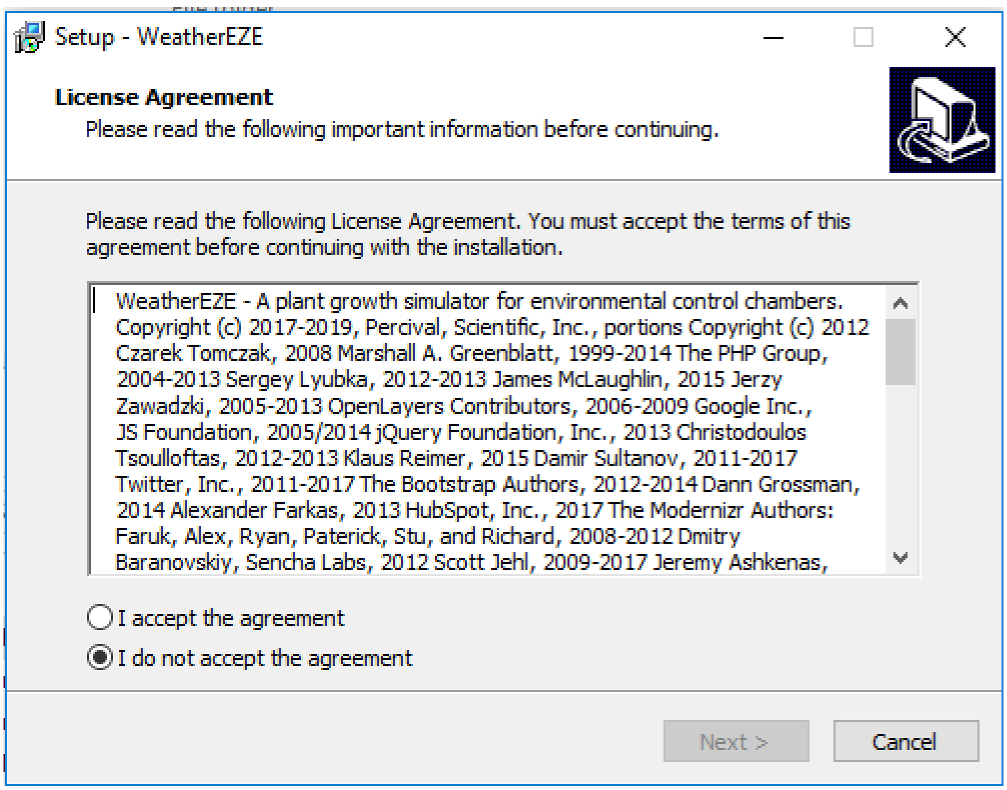


Figure 1 Illustration of setup.exe

2. After setup.exe is executed (manually or automatically), you will see a few windows relating to the licensing agreements (Figure 2 License Agreements). Click "accept" and then next to pass these screens.



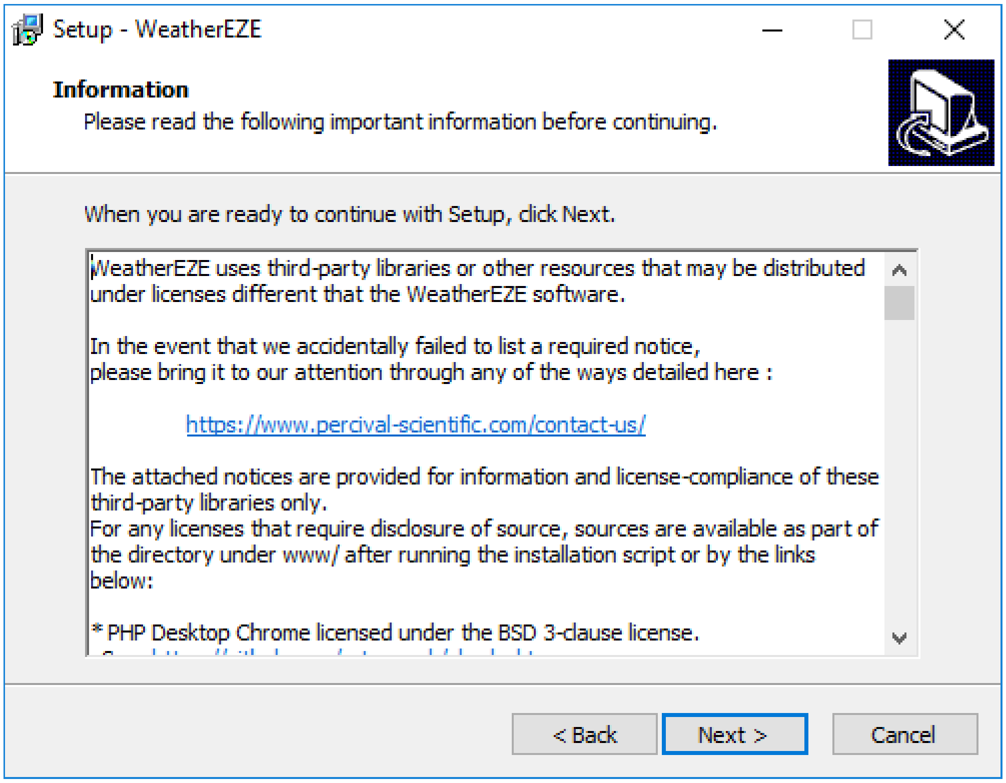


Figure 2 License Agreements

3. On the next screen (Figure 3 Installation directory), you can select the destination folder for the installation of WeatherEze™. The default directory suggested is shown in the folder entry box. This can be changed by the user if desired by either typing directly in the folder entry box or by selecting **"Browse…"** button. The radio buttons on the bottom enable the user to select if the software should be visible to all users of the computer or just the current user. **If you do not have administrator access, be sure to install in a folder where you have full access privileges.** Click next when you have chosen a suitable folder.

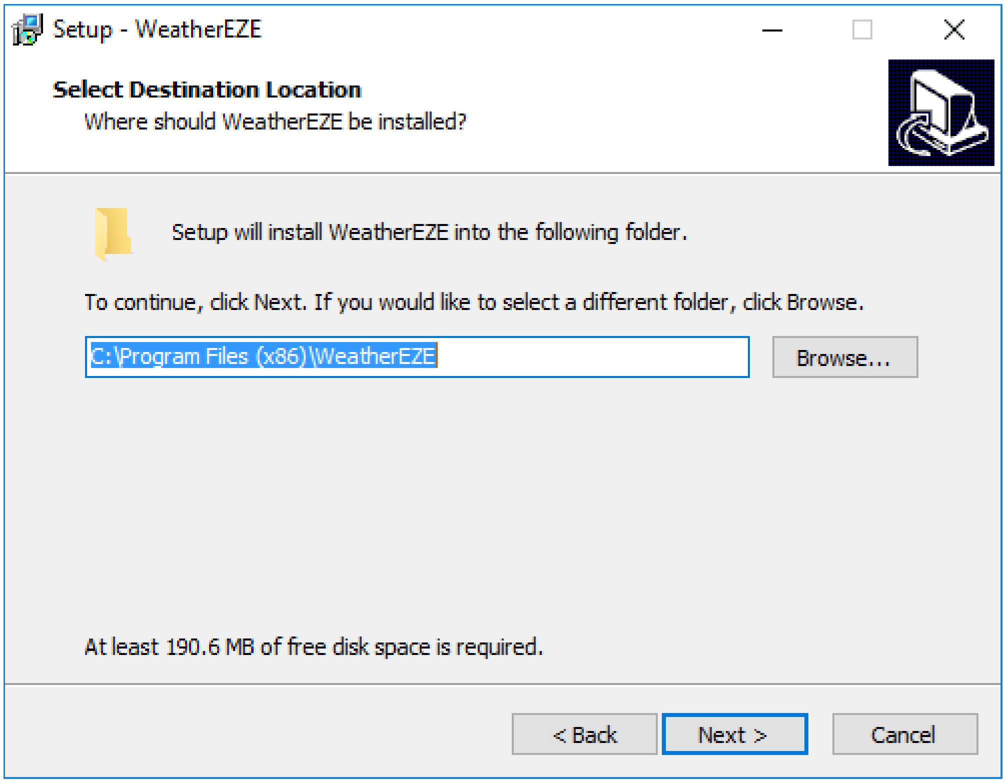


Figure 3 Installation directory

4. You can choose to input a desktop shortcut if you click the checkbox (Figure 4 Insert shortcut). Once you have decided, click next.

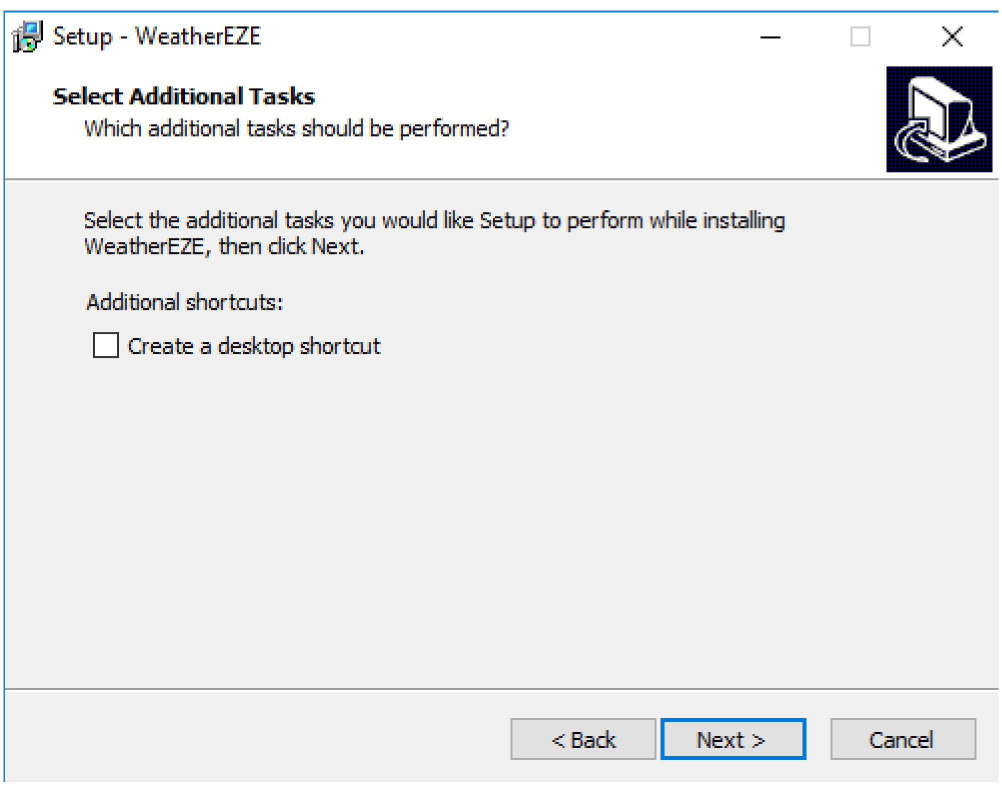


Figure 4 Insert shortcut

5. This screen (Figure 5 Installation confirmation) confirms the end of the installation wizard. Click Install to install WeatherEze™. During installation, the current progress of each installation module is shown on the screen. The installation process will take roughly 5-10 minutes to complete, depending on hardware and computer processing speed.

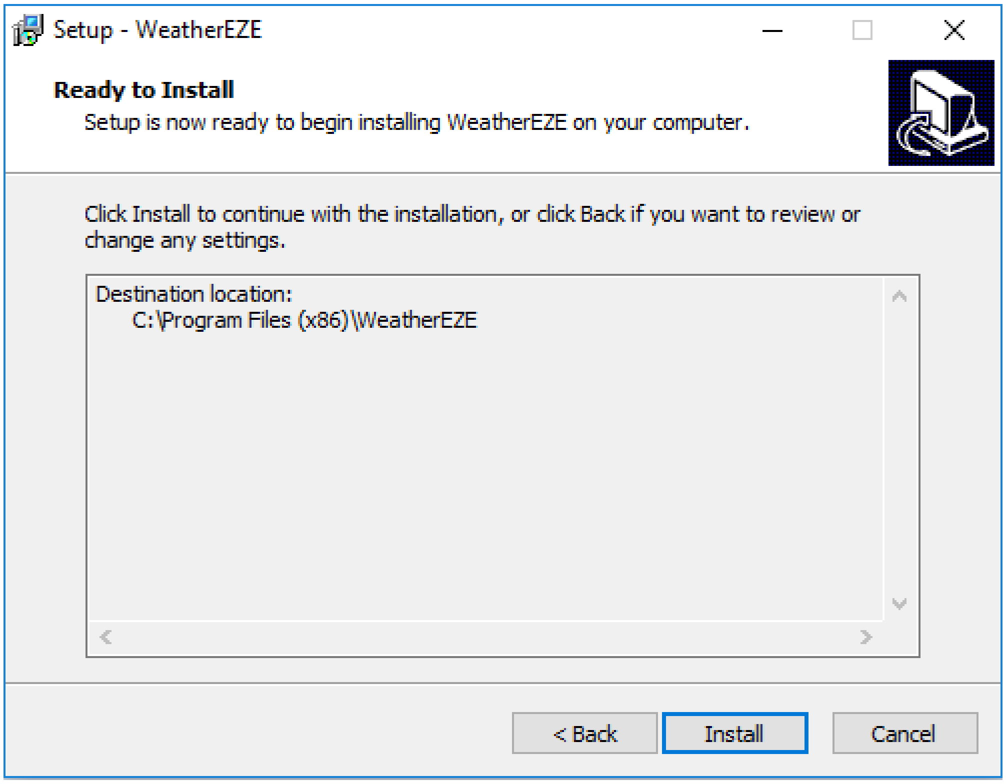


Figure 5 Installation confirmation

7. After installation a privacy policy is displayed (Figure 6 Privacy policy page). Take time to review this information.

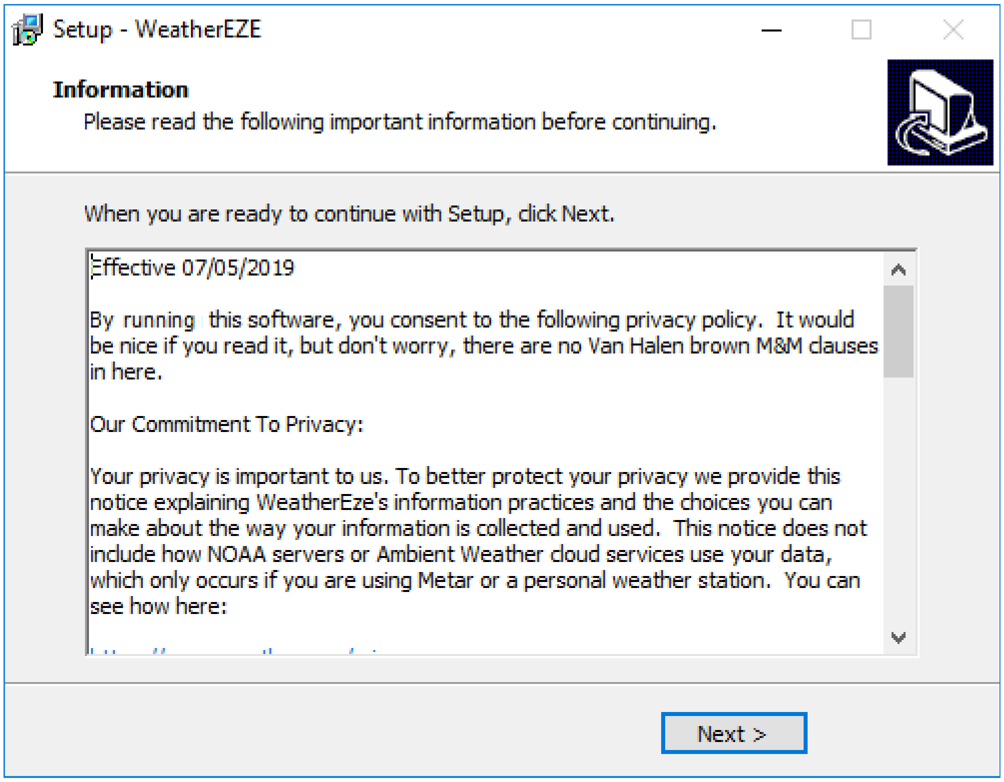


Figure 6 Privacy policy page

8. The final page (Figure 7 Installation completed screen) confirms that your installation of WeatherEze™ has completed. The software and required libraries are installed on your computer in the destination directory specified. The installation program added a shortcut to WeatherEze™ on the desktop of the computer if you chose. Click the checkbox and Finish if you want to run WeatherEze™ now.

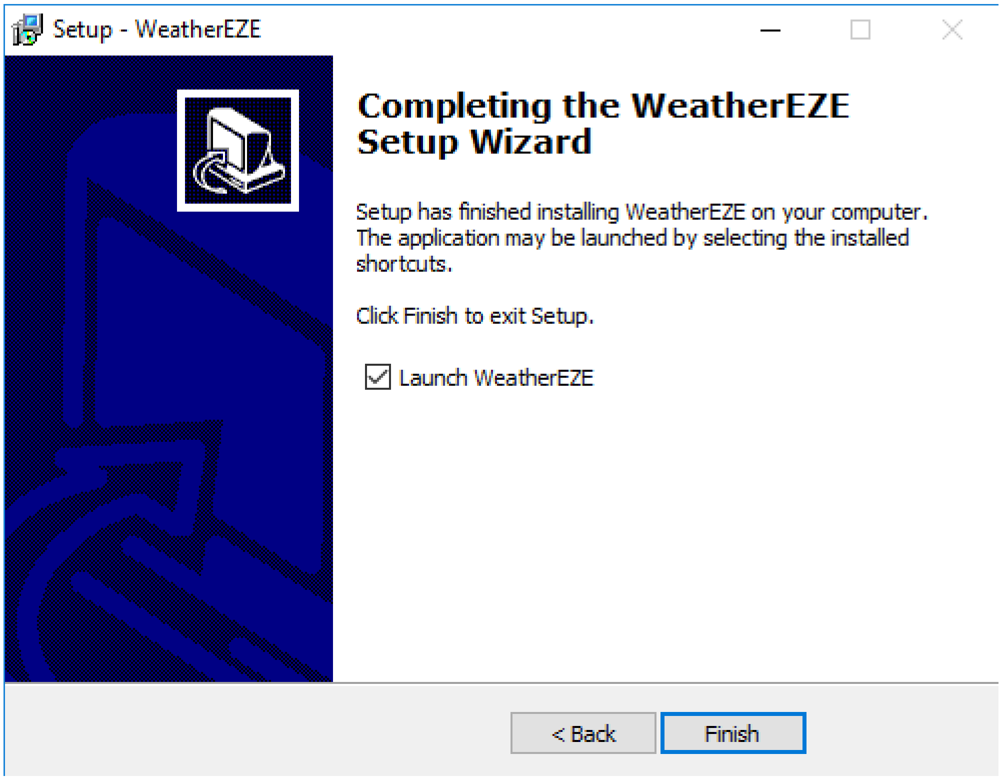


Figure 7 Installation completed screen

2.5 WeatherEze™ Recommendations

The following recommendations should be observed when running WeatherEze™:

1. A battery backup should be purchased for the computer running WeatherEze™.
2. It is recommended that WeatherEze™ be restarted at the end of an experiment or once a month if running an experiment longer than one month (see A.2 as to why). If running a simulation (3.8) be sure to note the current simulated date and time the software is running before shutting down the software. Before restarting the simulation, be sure the next simulation file being ran is consistent with the new date and time. If running a real-time system, this need merely be stopping the simulation, waiting at least two minutes, and then re running the simulation anew.

Please contact Percival Scientific with questions regarding these recommendations.

2.6 General Quick start Usage Guide

The following steps can be used as a general guide to using WeatherEze™ in general, the setup process follows linearly down this list:

- Assign an IP address to the chamber you wish to control. Any chamber you wish to control using WeatherEze™ must have an IP address assigned to it. This IP address must be visible on your network. The chamber IP address is set in the Intellus Web Server provided with the chamber. For information on configuring the IP address please refer to the section titled, "Connecting to the Intellus Web Server" in the separate Intellus Web Server manual provided.
- Add the chamber to the WeatherEze™ database. Please refer to 3.1 for information on adding a chamber to the database.
- Configure light settings. Please refer to 3.1 and A.1 for information on configuring light settings.
- Select the chamber from the available chamber list, please see 3.2. Once a chamber is added to the database you will need to select the chamber from the list.
- Configure experiment location. Please refer to 3.3 for information on configuring experiment location and lighting simulation.
- Create a simulation file if a simulation is desired (refer to 3.4-3.7). Otherwise, if a real-time simulation is desired, continue to the next step.
- Run experiment (3.8).

For setting up a personal weather station, in addition to the above, the following must be performed for installation first (the individual instructions of which can be followed in the corresponding components' manuals and guides):

- Install the Console and Weatherbridge Router.
    - Make sure that Weatherbridge TP-link Router's USB cable is plugged into the (Vue2, if you have a Davis weather station) console.
    - Connect the Weatherbridge router via Ethernet to an Internet-capable connection.
    - Connect the Weatherbridge router to power.
- Install the Weather Station
    - Install your weather station at most 300' away from the Vue2 console, or 300' from a repeater.
- Setup the Console
    - For more information about the particulars of the console, please see the guide from Davis Instruments: https://www.davisinstruments.com/product_documents/weather/manuals/07395-234_IM_06312.pdf
    - Make sure the console's USB connection is attached to the Weatherbridge router.
    - Turn your console on. The console will ask you a number of questions during setup, including the latitude, longitude, altitude, and rainy season of the location where you are setting up the weather station. Use the arrow and enter keys to input this information. After a few moments (and assuming there is sunlight if your weather station's batteries happen to be low), you should receive information from your weather station on the console.
- Setup the Weatherbridge
    - If you have issues at any phase during this step, please see https://p10.secure.hostingprod.com/@site.ambientweatherstore.com/ssl/Manuals/weatherbridge.pdf
    - Enter in the license key you obtained with your Weatherbridge guide.

- Go to magicip.weatherbridge.com , if you are not able to connect, please view the product manual for the Weatherbridge available here (in particular, chapter 4. If prompted for username and password, please enter:
  - Username: meteobridge
  - Password: meteobridge
  - Under the Weather Station tab, select Davis: Vantage Pro2, Vue and select "USB" from the drop down menu.
  - Enter the altitude at the bottom of the screen.
  - Check the "Live Data" tag to make sure you are grabbing data from your Davis weather station. If not, please see the manual for this section.
  - Go to "System," and note the MAC # for the next step.
- Setup Your Ambient Weather Account
  - Go to ambientweather.net and setup an account
  - Go to the "Devices" tab on the left-hand side.
  - Under "Connect your device" enter in the MAC address from the previous step.
  - Click on your profile image (the face in the upper-right hand corner of the screen)
  - Press "Create API Key," and keep note of this API key.
- Finish Setting Up Weatherbridge
  - Go back to weatherbridge page (magicip.weatherbridge.com).
  - Go to Weather Network tab. You should see a green checkmark beside the MAC address
  - Choose your upload interval as "every minute" under "Ambient Weather Network."
- Connect to WeatherEZE
  - Go to the "Run Simulation" tab in WeatherEZE.
  - Under the Weather Station option, put in your API key you generated in step 5.
  - Press "Run."
  - You're done, son.

3 General Usage

The overall order of the wizard screens is described in Figure 8 Order of wizard screens. Each of the wizard screens will be described separately in the following sections.

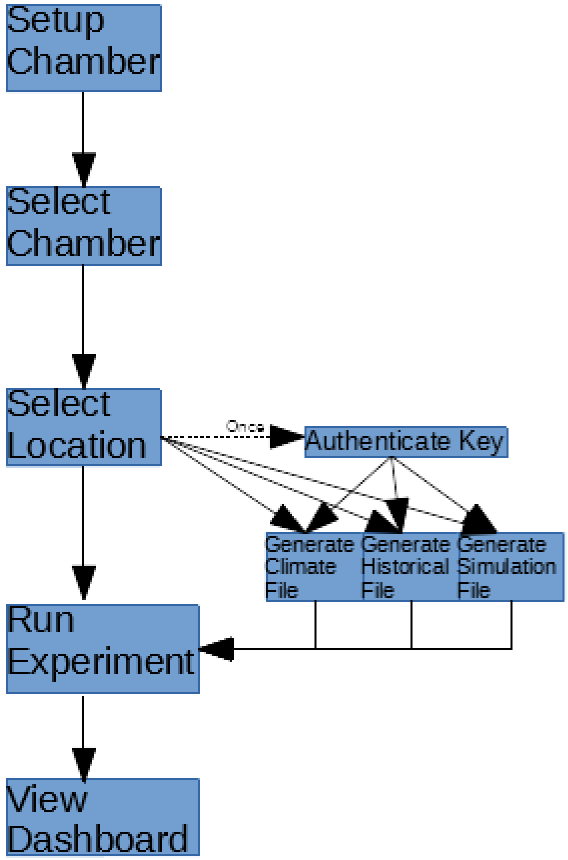


Figure 8 Order of wizard screens

3.1 Setting Up a Chamber

A pull-down menu will activate when "Chamber" is clicked on the left frame. Be sure to click "Setup" as highlighted in Figure 9 Chamber setup link

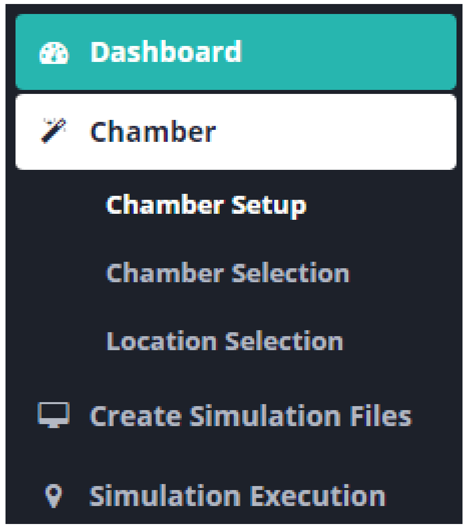


Figure 9 Chamber setup link

When the page loads, you will be prompted with a dialog box (Figure 10 Setting up a chamber connection). This dialog box allows the user to enter the IP address of the chamber. You should be able to determine the IP address of your chamber in the Diagnostics menu of your controller. There are some restrictions that must be adhered to:

Characters must be numeric in IP Address
There is a maximum of 3 digits between each period
There must be at least 1 digit (0-9) between each period
Example: 192.168.1.1

Once you have entered the IP address, click 

.

Figure 10 Setting up a chamber connection

The software queries the chamber to determine the number of available light banks. Once this process is completed, a list of available lighting events and sensors from the chamber is displayed (Figure 11 Setting up chamber lighting).

If you have a more common series of chamber, the software might be able to guess what intensities and bulbs should be set to each event. However, in many cases the software is unable to determine the type of light bulbs that are installed in each light bank, where these light bulbs are located, or the intensity that you desire for your experiment (if you have default intensities values that appear, the software will assume that the experiment is set at six inches from the lamp). Therefore, the type of light bulb in each light bank must be selected; but you should be able to find these values in the specifications of your chamber.

- Select the type of light bulb installed in your chamber for each enabled light bank. The type of light bulb(s) can typically be found on the lighting electrical diagrams provided with the chamber installation and operation manual. Currently, there are 47 different light bulb choices. The reference spectra for these light bulbs are shown in B. **Once this is done, the rest of the available options will display.**
- The “Location ID” setting is meant to help identify which lights act in unison. In general, if a light acts throughout the entire chamber, leave it as “0,” and enter a different integer for lights that only act in specific tiers in your chamber.
- The maximum intensity depends on how far away you wish to place your experiment from the light source, and you may want to use your own independent calibration tools. As such, it is

recommended that you use a light meter to determine the maximum UML intensity at the relevant median height of your experiment(s), or failing that, to use the maximum intensity according to your chamber manual's specifications.

If you are unsure of the type of light bulbs installed, their location control, or suggested maximum intensity, please double-check your chamber manual, the physical chamber itself, or contact Percival Scientific.

Otherwise, you may also install your own spectral graphs for your bulbs. To view the available spectra, and to edit them, please see B.

Figure 11 Setting up chamber lighting

After doing this for all the lights in your chamber, you will be prompted for a chamber profile name (Figure 12 Choosing a profile name). Place in either something descriptive to remember which chamber (the model or serial number of the chamber) or something that will help you troubleshoot any possible technical problems (the last 3 digits of the IP address, for example).

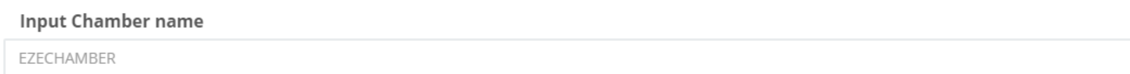


Figure 12 Choosing a profile name

Finally, you will be prompted for your preference in lighting control (Figure 13 Choosing a lighting preference). There are a fewer number of lights compared to the number of distinct lighting intensities at the many possible wavelengths from the Sun. Because of this, lighting control is a mathematically underdetermined problem, and some amount of approximation must take place. This is why so many methods of lighting control are provided, and why it is needed to ask for your preference in choosing between light intensity and spectral quality at this step. Choosing light intensity over spectral quality will try to make WeatherEze match only the total intensity of the lights to the Sun spectra. Choosing spectral quality will try to make WeatherEze ensure that the correct ratios of different wavelengths are matched. A more in-depth explanation of how the software uses your preference information to choose between different lighting algorithms is provided in A.1. When using a personal weather station, light intensity is given the utmost priority, due to the limitations in most weather stations' light sensors.

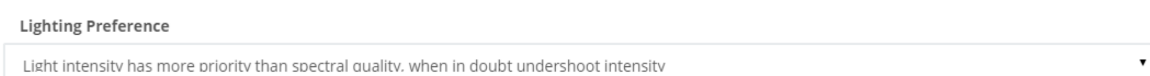


Figure 13 Choosing a lighting preference

Otherwise, you might wish to choose a simple Daily Light Integral (DLI) option. If you select "Use a plant-based Daily Light Integral" under lighting preference, then the following selection window (Figure 14 DLI selection) will appear.

Figure 14 DLI selection

The DLI selection includes a wide variety of plant species, including light values to try to match a propagative, vegetative, flowering, or fruit stage of the corresponding plant where applicable.

Once you've chosen a lighting method click the button at the bottom of the page to save the chamber.

When you've done so you should see the following message (Figure 15 Successfully added chamber).

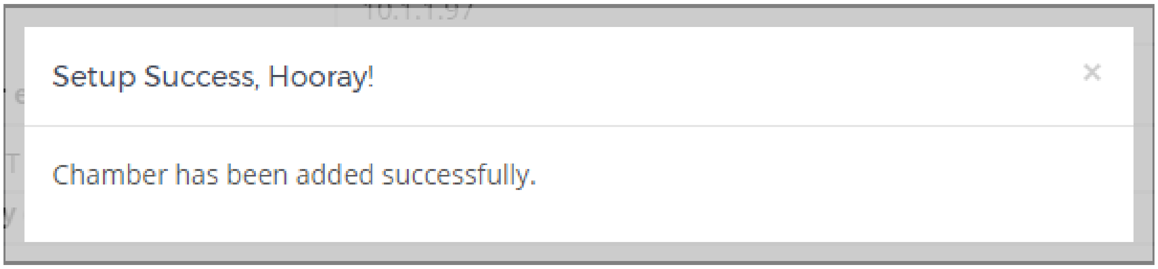


Figure 15 Successfully added chamber

Click anywhere for the message to go away and to continue.
Otherwise, you might see the following message (Figure 16 Message failure).

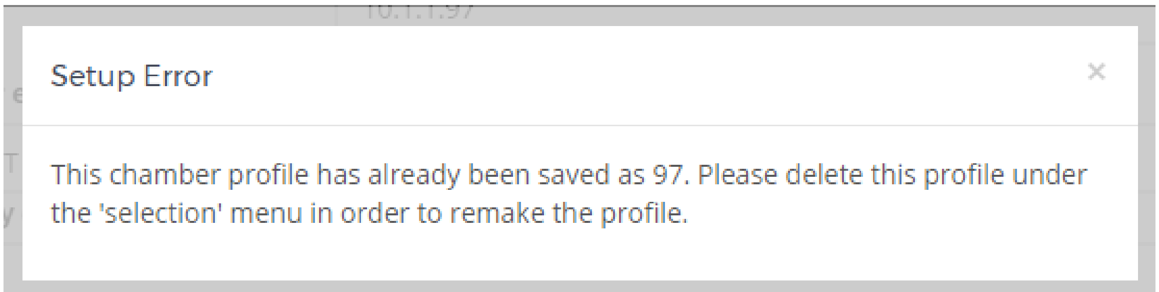


Figure 16 Message failure

This indicates that you already have a setup with the same name or IP address. Be sure to delete this profile (3.2) and then come back to the set-up page to try again.

3.2 Selecting and Resetting a Chamber

A pull-down menu will activate when "Chamber" is clicked on the left frame. Be sure to click "Selection" as highlighted in Figure 17 Chamber selection link

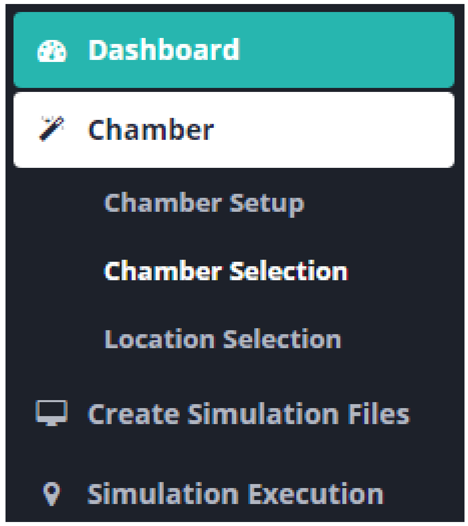


Figure 17 Chamber selection link

When the page loads, you should see a current chamber indication box (Figure 18 Chamber selection indication)

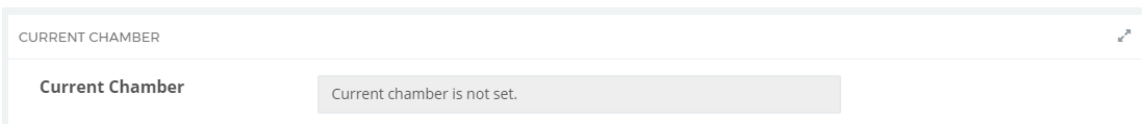


Figure 18 Chamber selection indication

This box is used to indicate which chamber you are currently working with in the program to either choose a location (3.3), viewing it remotely (3.9), or running a simulation (3.8). In Figure 18 Chamber selection indication, it shows that no chamber is currently selected. To change this, click the list below (Figure 19 Select a chamber)

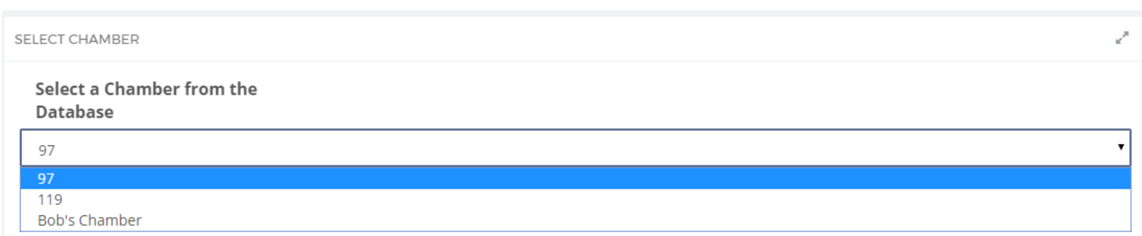


Figure 19 Select a chamber

Once you choose a chamber from this list, click the "Select" button. Once you have done so, the chamber selection should have changed (Figure 20 Chamber selection example)

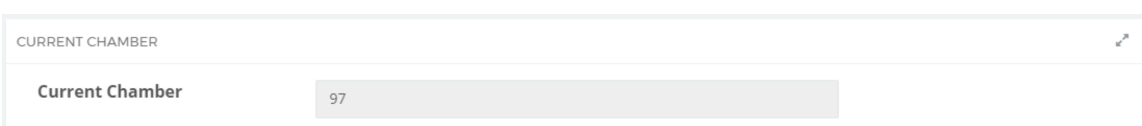


Figure 20 Chamber selection example

If you wish to delete a chamber, simply choose another chamber (Figure 20 Chamber selection example), and click the "Delete" button. You might have to click the link on the side of the page in order to see your changes to the chamber database.

3.3 Choosing a Location

A pull-down menu will activate when “Chamber” is clicked on the left frame. Be sure to click “Location Selection” as highlighted in Figure 21 Location selection link.

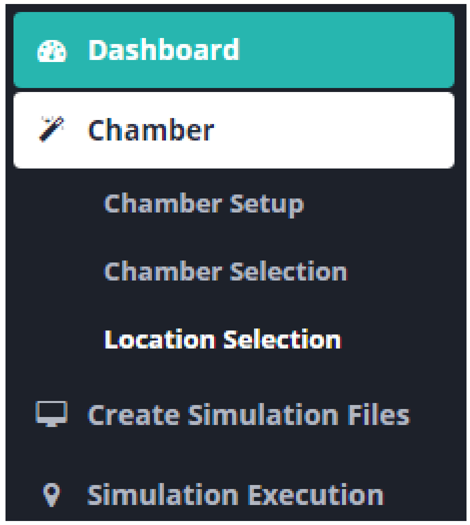


Figure 21 Location selection link

When the page loads, you should see a map (Figure 22 Location map)

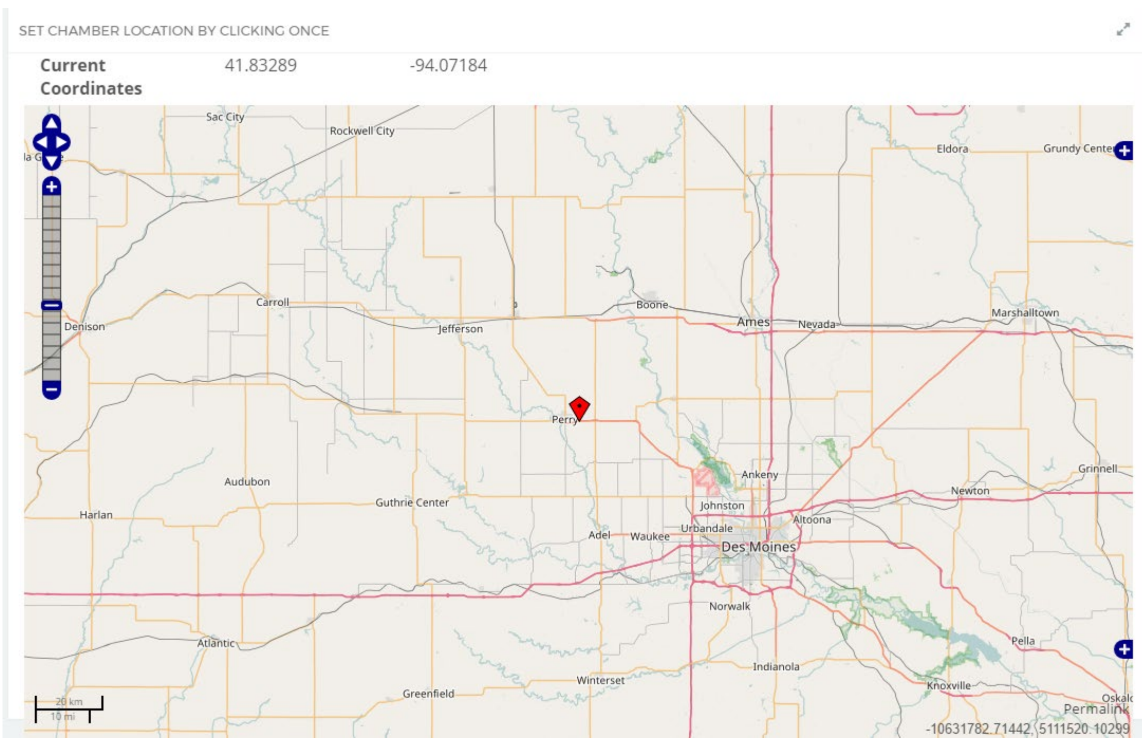


Figure 22 Location map

If you do not see this or your map is a blank blue, then double-check that you have selected a chamber (Section 3.2).

The marker indicates the current position that your selected chamber (3.2) will be simulated in. In order to change this, use the navigation tool (Figure 23 Map tool) on the left hand side of the screen in order to move to a different place on the map.

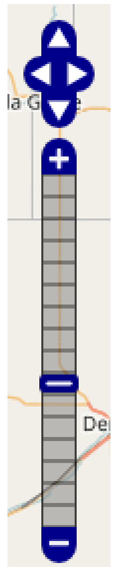


Figure 23 Map tool

When you have found the location you want to be placed at, click **ONCE** on the map. Once you have done so, a message will appear indicating your new latitude and longitude coordinates (Figure 24 New coordinates).

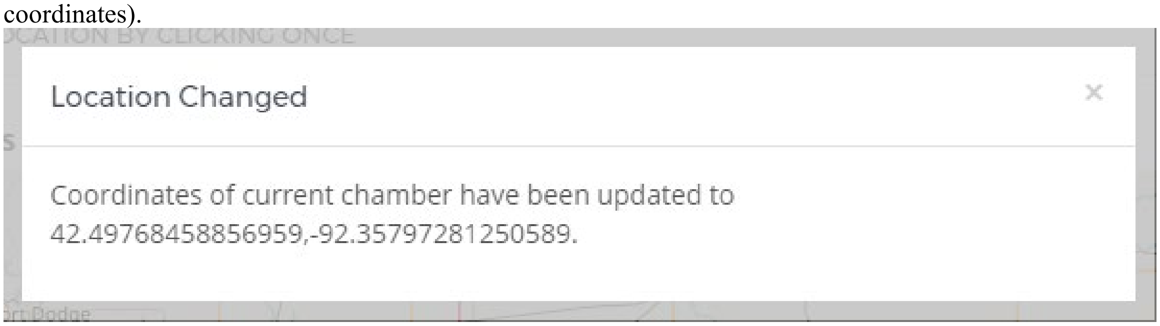


Figure 24 New coordinates

Your coordinates shown above the map (Figure 25 Shown coordinates example) should change as well.

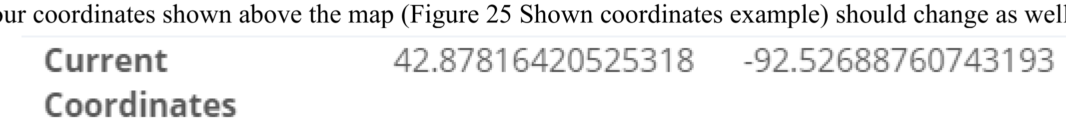


Figure 25 Shown coordinates example

In order to update your position on the map, however, it may be necessary to click the location selection page to (Figure 21 Location selection link) to reload the page. It is suggested you do this in any case to doublecheck that the location parameters have taken. If they have not, make sure that WeatherEZE has permissions in the folder where it was installed. Furthermore, *note that this must be done for each chamber*. The location selection screen is dependent on the chamber selected, it is not globally allocated to all chambers running on your instance of WeatherEZE.

Once you have chosen a location for your chamber, you are ready to either run a METAR simulation (3.8), or if you have already registered your WeatherEZE, a climate simulation file that you have generated (3.5-3.7) (in general, it is not necessary for personal weather stations). In order to generate a climate simulation file, if you have not already registered your version of WeatherEZE, please continue to 3.4, otherwise, you can generate a climate change, historical, or climatological study file (3.5-3.7).

3.4 Authenticating WeatherEZE

A pull-down menu will activate when "Create Simulation Files" is clicked on the left frame. Be sure to click "Key Authentication" as highlighted in Figure 26 Key authentication.

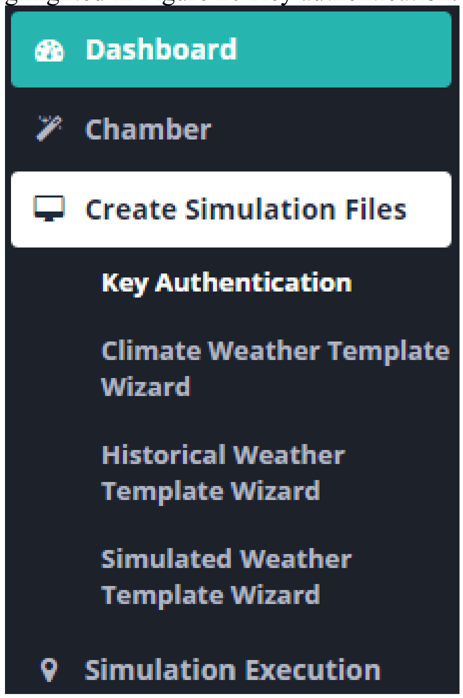


Figure 26 Key authentication

When the page loads, you should see a key entry dialog box (Figure 27 Key entry).

Figure 27 Key entry

You should have received this key when you purchased the software. If it did not (or if you lost it), please contact Percival Scientific. Otherwise, enter the key in the field and click the "Update Key" button. Once you have done so, a dialog box should come up, indicating that the key has been updated (Figure 28 Key success).

Figure 28 Key success

In order to verify that the key is working correctly, try generating a simulation file (3.5-3.7). If at any time you see this message appear on the screen (Figure 29 Key failure)

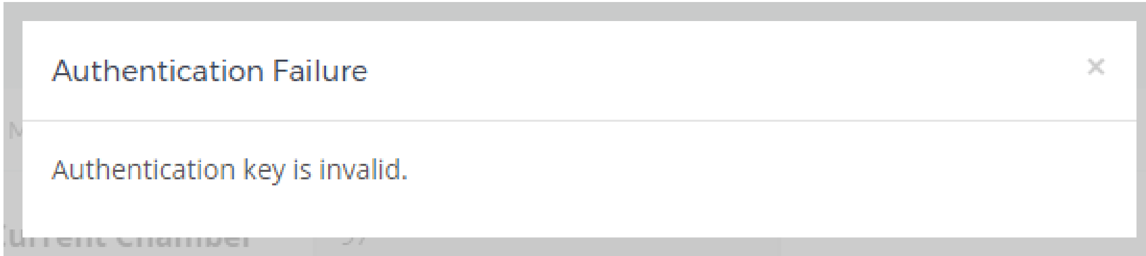


Figure 29 Key failure

Then make sure that your install is correct (e.g., you have permissions to use WeatherEze properly, see 2.4), and then try re-entering your key. If you still have issues, something might have happened to your account and you should contact Percival Scientific.

3.5 Generating a Climate Change Simulation File

A pull-down menu will activate when "Utilities" is clicked on the left frame. Be sure to click "Climate Weather Template Wizard" as highlighted in Figure 30 Climate weather template wizard link

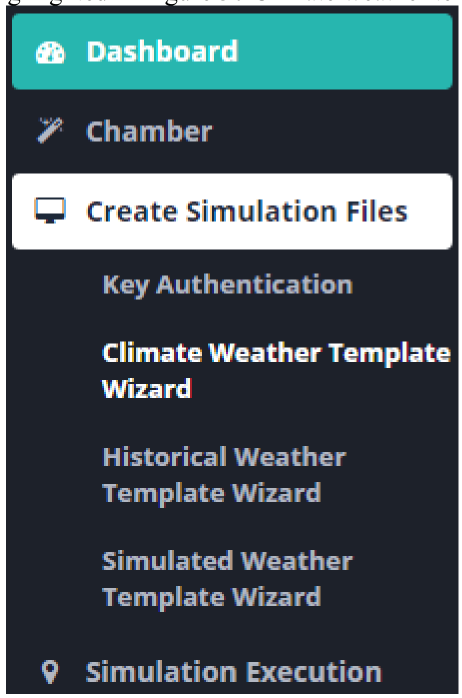


Figure 30 Climate weather template wizard

When the page loads, you should see your selected chamber and selected latitude and longitude of your chamber (Figure 31 Chamber setup review). If you don't, please revisit 3.2 and 3.3.

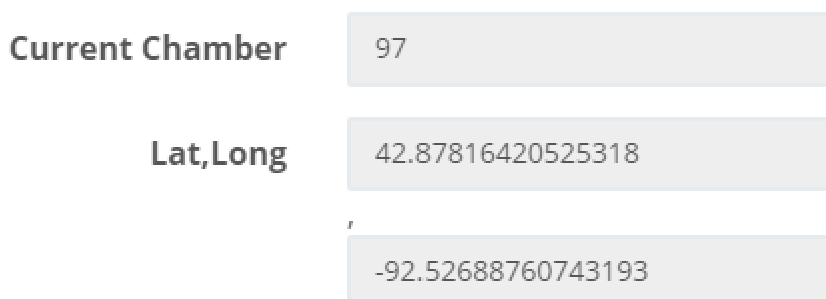


Figure 31 Chamber setup review

Climate change data creates a climatology model based on 30 year averages. So, if these values look correct, you can continue by choosing a date (Figure 32 Choosing a time period).
This involves first choosing a time range with a year. Click inside the text box to activate the calendar selection tool (Figure 32 Choosing a time period). When you are done, click "Apply."

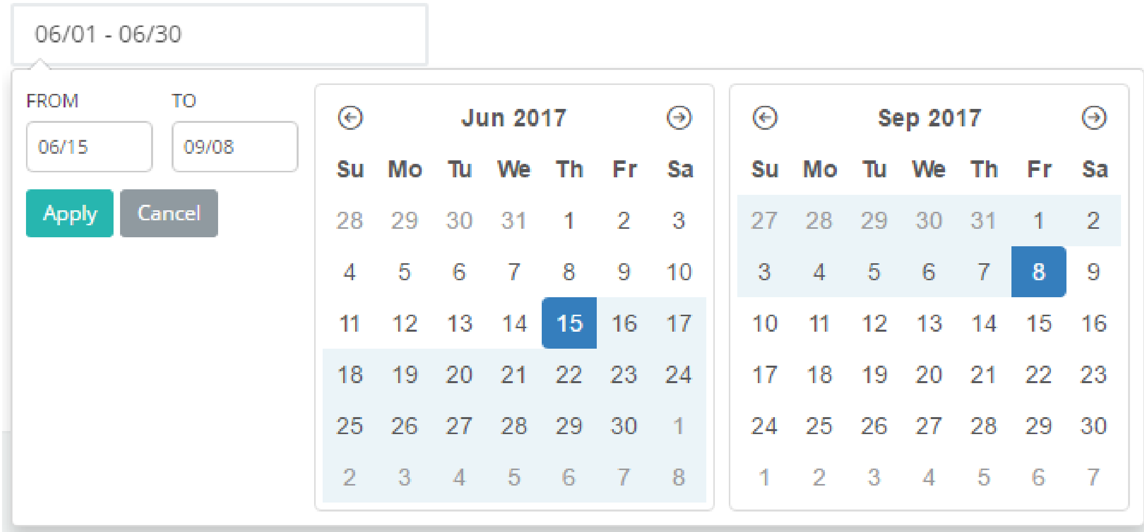


Figure 32 Choosing a time period

Now you can choose a 30-year climatological period (Figure 33 Climatological time period).

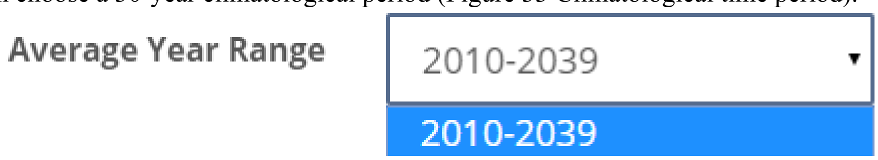


Figure 33 Climatological time period

Now we must choose how each day should be interpolated. Although the settings indicate the degree of accuracy of the daily calculation ("Fine" being the most computationally intensive, but also accurate, and "Coarse" being the least computationally intensive, but less accurate), this is for ease of interpretation. Each option uses a different algorithm to use the daily averages and interpolate throughout a given day. For more information about how this is done, see A.5. Otherwise, choose a level (Figure 34 Daily interpolation accuracy).

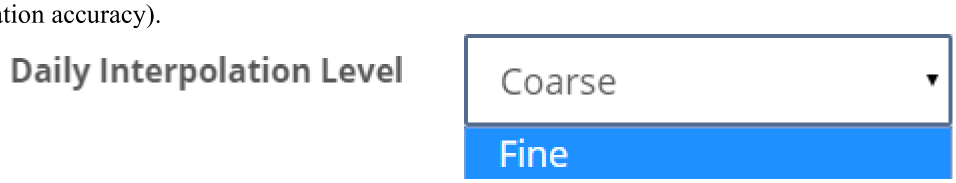


Figure 34 Daily interpolation accuracy

Next, choose a dataset (Figure 35 Climate change dataset). The datasets available here indicate which dataset from the IPCC the software will try to mimic. For information to help choose which dataset to use, please visit the IPCC climate change website, or see A.6. Please keep in mind that the grid spacing may change quite a bit between datasets. **This means that based on what dataset you choose and what you put at the latitude and longitude might get rounded a significant distance to the simulated latitude and longitude. If you think the data looks too cold or too hot, keep this in mind.**

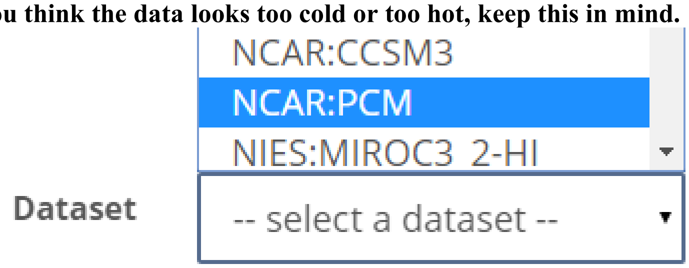


Figure 35 Climate change dataset

Once you have chosen a dataset, the climate change scenarios available for that dataset is shown (Figure 36 Climate change scenario). The difference between these scenarios as far as this software is concerned mainly have to do with the predicted CO_2 emissions. If you have CO_2 control on your chamber, this will influence the amount of CO_2 you use greatly. For more information, again, please visit the IPCC website or see A.6.

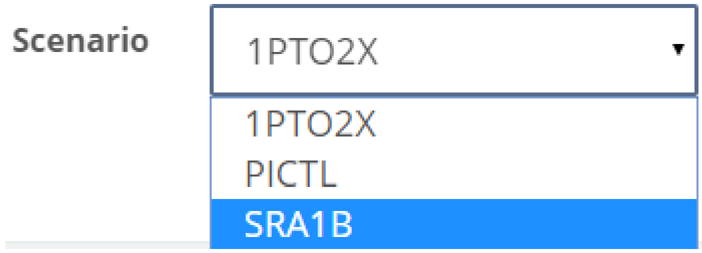


Figure 36 Climate change scenario

When you are ready, click the "Generate Program" button. **BE WARNED, WHEN YOU DO THIS, IT WILL TAKE SOME TIME TO GENERATE THE CLIMATE CHANGE SIMULATION FILE**. Once you have done so, the following message (Figure 37 Template generation notification) should appear.

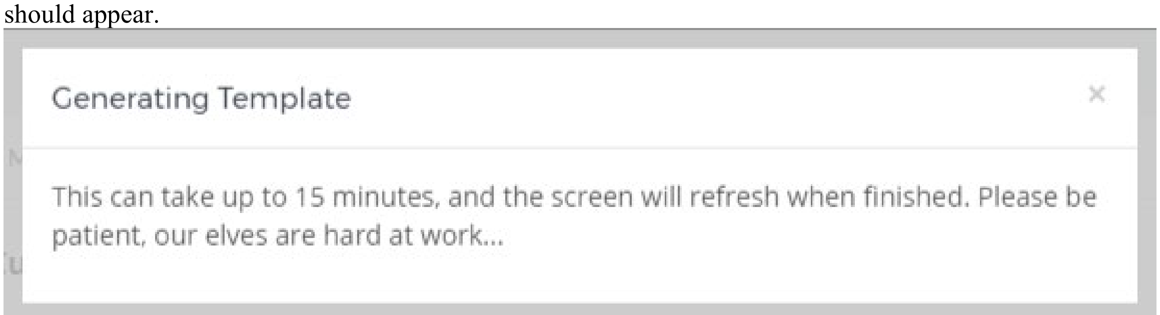


Figure 37 Template generation notification

Please wait for the elves. They are hard workers. When it's done, the page will refresh, and the file should be in your templates folder to run (3.8).

3.6 Generating a Historical Simulation File

A pull-down menu will activate when “Utilities” is clicked on the left frame. Be sure to click “Historical Weather Template Wizard” as highlighted in Figure 38 Historical weather template wizard link

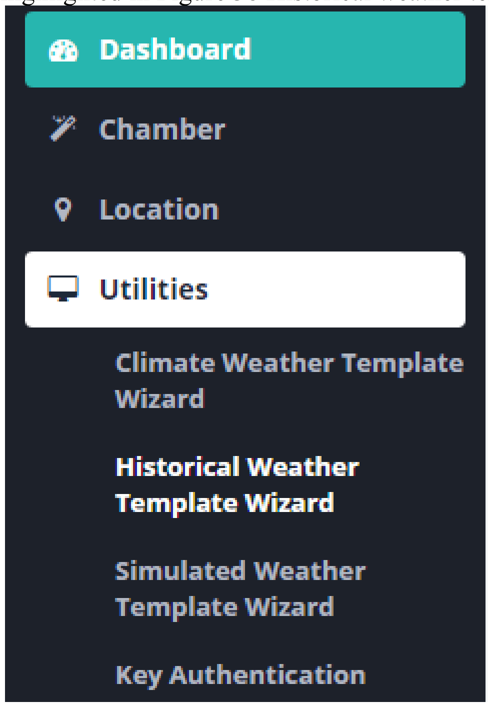


Figure 38 Historical weather template wizard

When the page loads, you should see your selected chamber and selected latitude and longitude of your chamber (Figure 31 Chamber setup review). If you don’t, please revisit 3.2 and 3.3.
After these options, you should see an option to choose a time range (Figure 32 Choosing a time period) and year of the simulation (Figure 39 Historical Year). Unlike in the climate change simulation (3.5), the historical year is simply the actual data from that given year.

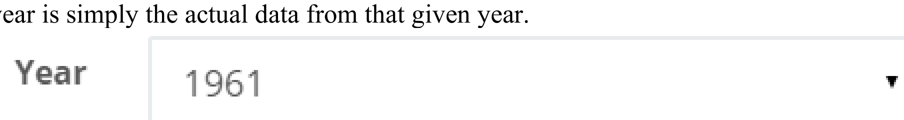


Figure 39 Historical Year

Be aware that the years and locations available change drastically depending on your choices (e.g., the early 1940s will probably not be available for Europe).
Because of this, a “generation preference” option is given (Figure 40 Generation preference) to balance data availability concerns yet maintain exact historical data. This gives you the option to prioritize by year or location. Some locations may have a long yearly historical record, but the recording station may have moved many times over the years. This is a case in which you will want to make sure to choose the exact year. Other locations may have sparse recording stations, and therefore you will want to choose the nearest one to avoid dramatic location shifts.

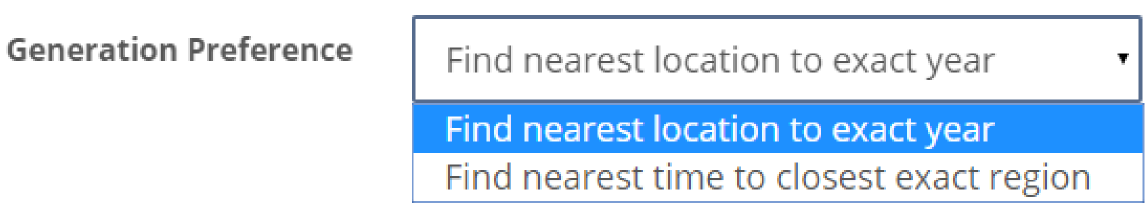


Figure 40 Generation preference

If you are not satisfied with the year range available, be aware of what might have been happening in that location in history, and try choosing areas near large population centers. Also keep in mind that although there is data going as far back as 1806, that it gets much sparser as you go back to these periods in time.

Once you have chosen a year range, you must choose an interpolation level (Figure 34 Daily interpolation accuracy). The instructions to do so are the same as in 3.5.
With this completed, you must now choose a humidity option (Figure 41 Humidity option).

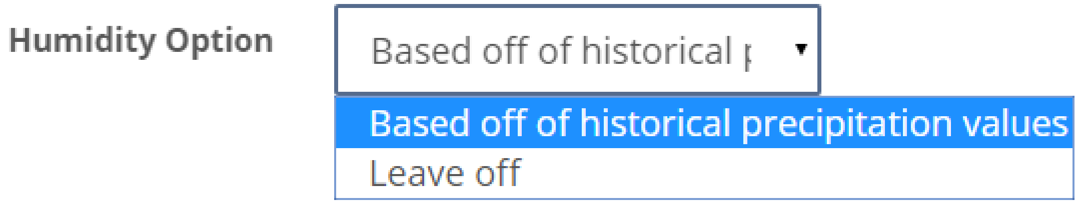


Figure 41 Humidity option

Because many historical weather stations did not and still to this day do not have RH data, we allow an RH calculation to take place based on the historical precipitation data. If you do not like this approximation, or wish to ignore the RH calculations, then choose "Leave off" in order to ignore humidity control and focus solely on temperature control for your simulated run. For more information on manipulating the resulting simulation files, see 3.8.
When you are done, press the "Generate Program" button. **BE WARNED, WHEN YOU DO THIS, IT WILL TAKE SOME TIME TO GENERATE THE CLIMATE CHANGE SIMULATION FILE**. Once you have done so, the generating template message (Figure 37 Template generation notification) should appear. Again, please wait for the elves. They are hard workers. When it's done, the page will refresh, and the file should be in your templates folder to run (3.8).

3.7 Generating a Climatology Simulation File

A pull-down menu will activate when "Utilities" is clicked on the left frame. Be sure to click "Simulated Weather Template Wizard" as highlighted in Figure 42 Simulated weather template wizard link

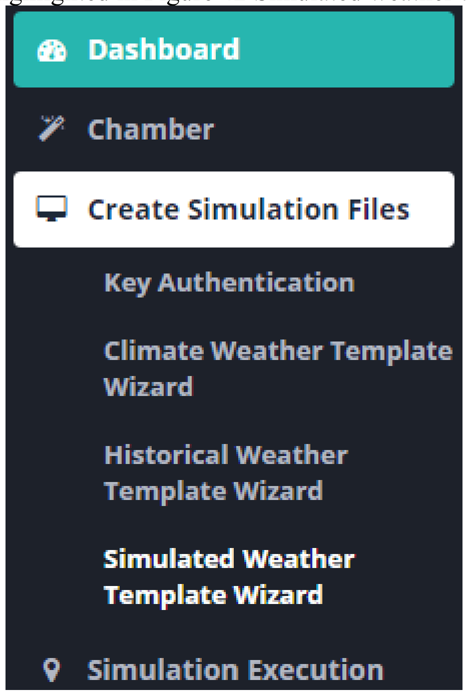


Figure 42 Simulated weather template wizard

When the page loads, you should see your selected chamber and selected latitude and longitude of your chamber (Figure 31 Chamber setup review). If you don't, please revisit 3.2 and 3.3.
The simulated weather calculates an average climatology based on the location you chose. Therefore, you need only to choose a date range within the year to simulate (Figure 32 Choosing a time period).
Like in the historical weather template generation (3.6), once you have chosen a date range, you must now choose an interpolation level (Figure 34 Daily interpolation accuracy) and then a humidity option (Figure 40 Humidity option).
Because the climatological calculations are based off of historical data, the same caveats apply as in 3.7. Many places do not have access to RH data, and calculations may take place based on precipitation data instead. If you do not like this approximation, or wish to ignore the RH calculations, then choose "Leave off" in order to ignore humidity control and focus solely on temperature control for your simulated run.
For more information on manipulating the resulting simulation files, see 3.8.
When you are done, press the "Generate Program" button. **BE WARNED, WHEN YOU DO THIS, IT WILL TAKE SOME TIME TO GENERATE THE CLIMATE CHANGE SIMULATION FILE**.
Once you have done so, the generating template message (Figure 37 Template generation notification) should appear. Yet again, these poor elves, please wait for them. We're their only source of employment when Santa is not employing them. They are hard workers. When it's done, the page will refresh, and the file should be in your templates folder to run (3.8).

3.8 Running WeatherEze

Be sure to click “Simulation Execution” as highlighted in Figure 43 Simulation run link

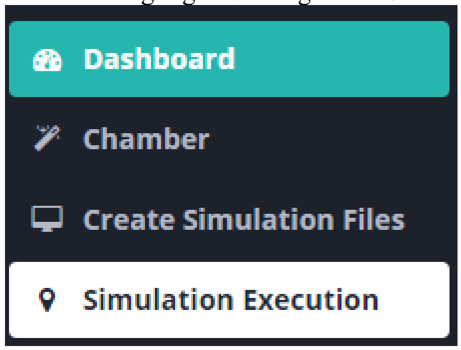


Figure 43 Simulation run

When the page loads, if you see the following message (Figure 44 Simulation connection error), you should revisit 3.2, or check the physical communications to the chamber.

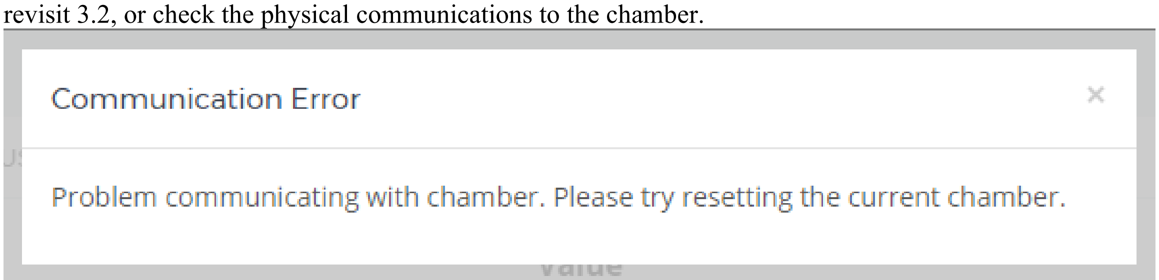


Figure 44 Simulation connection error

If you see the following message (Figure 45 Simulation mode error), **check that you have no valuable experiments running on the chamber’s controller’s program**. This signals that WeatherEze is overrunning your program mode and switching to manual mode.

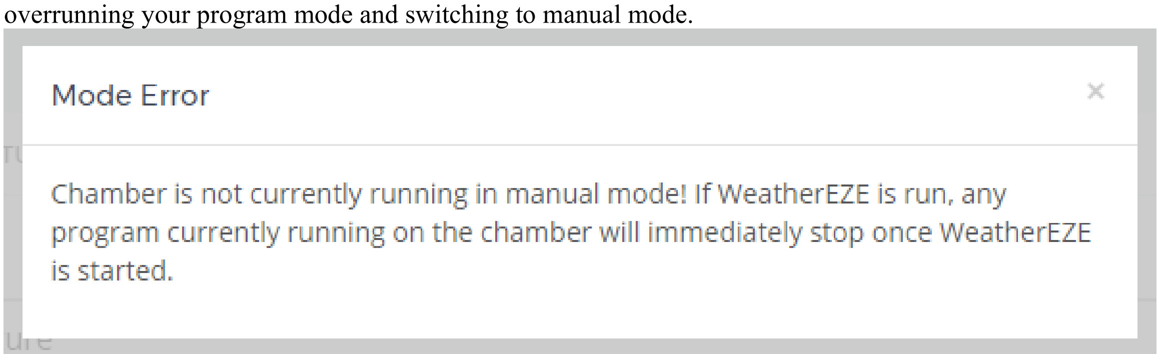


Figure 45 Simulation mode error

Otherwise, you should see three icons (Figure 46 Simulation type icons).

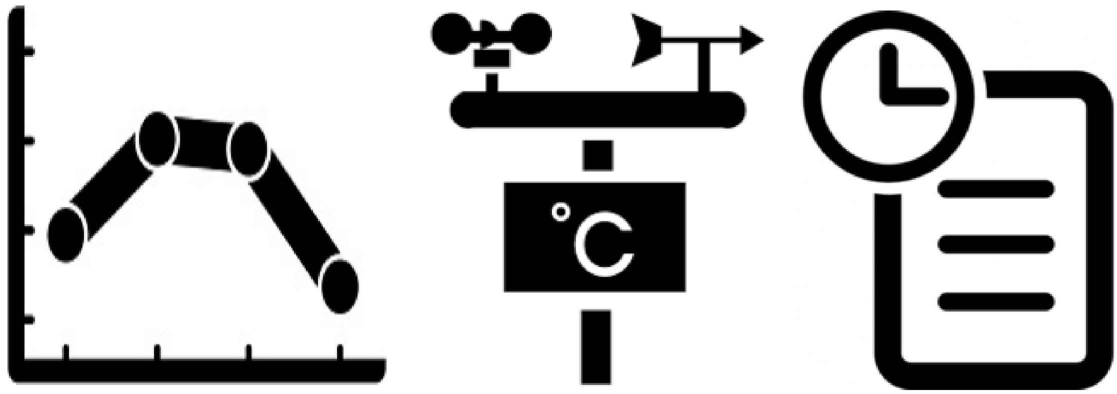


Figure 46 Simulation type icons

These are meant to indicate whether you want to run a real-time METAR simulation, a personal weather station retransmit, or load a simulation from one of the weather simulation files you generated (see 3.5-3.7) respectively.

Figure 47 Run real-time simulation

If you wish to run a real-time weather simulation, then make sure no other simulations are currently running, that the button underneath "Real-time METAR" is green, and that the button says "Run Real-Time Simulation" (Figure 47 Run real-time simulation) before clicking the button, and wait sixty seconds for the chamber to initialize. Once you have done so, you should be redirected to the Dashboard (32).

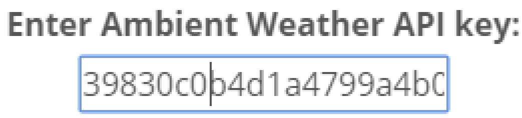


Figure 48 Insert API key

Likewise, if you wish to run a personal weather station retransmit, click on or edit the API key box (Figure 48 Insert API key), and enter in the API key that you should have obtained from the weather station setup in section 2.6. The default API key you see is using a personal weather station beside Percival Scientific's factory if you wish to run a test.

Figure 49 Run personal weather station

After clicking on this box, the real-time METAR button should gray out, and you should see the button change to "Retransmit Weather Station" (Figure 49 Run personal weather station).

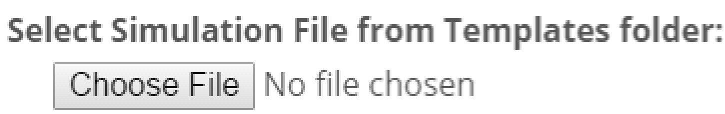


Figure 50 Choose simulation file

If you wish to run a simulation, click the "Choose file" button (Figure 50 Choose simulation file), and navigate to your WeatherEZE folder path, then to "www" then to "Templates." This should have the templates you've generated. **If there are other csv files you wish to run, place them into this folder**. For computer security reasons, the application is only permitted to run out of this folder.

Figure 51 Run simulation file

After selecting a simulation, the real-time METAR button should gray out, and you should see the button change to "Run Model Simulation" (Figure 51 Run simulation file).

Figure 52 Stop simulation

Once you have a simulation running, if you wish to stop it navigate back to the "Simulation Execution" page (Figure 43 Simulation run). You should see the same screen only with the "Stop Simulation" button displayed on the bottom (Figure 52 Stop simulation). This indicates that you are currently running one of any of the three simulations.

For more data about your run, you can either view your chamber data through our PercivalConnect solution, or a more limited view is available on the dashboard (see 3.9). **During the time the chamber is running, a flag will be switched which will disable commands on the panel overlay of the chamber, if at any time you wish to reset this flag and/or stop the simulation, come back to this page of the software and click the "Stop Simulation" button**. WeatherEZE will spawn a process that actually continues running in the background, so if you wish you can actually X out of the program to save system resources.

If you wish to use one of the simulation files you have generated, then click the "Choose File" button. Once you have done so, navigate to either where you installed WeatherEze (see 2.4) and in the www/Templates folder, or go to the Templates folder shortcut that should have been installed in your Documents folder (Figure 53 Opening a simulation file).

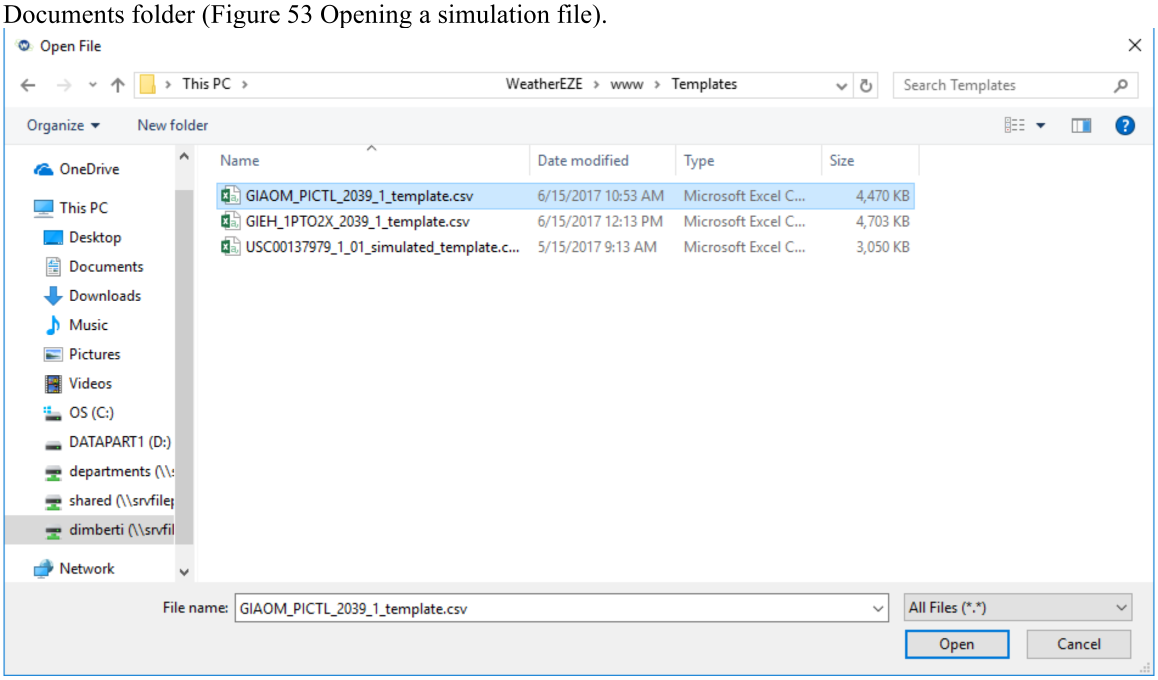


Figure 53 Opening a simulation file

Be sure to choose one of the templates you have generated, and click the Open button.

Once you have done so, the "Run Real-Time Simulation" button should have disappeared and been replaced by the "Run Model Simulation" button. Click this to run your simulation.

It should be noted that if any part of the simulation file does not appeal to you, even though it is a nonstandard procedure you can change it manually. You can open the simulation files with Libre Office (or any spreadsheet editor of your choice) since they are csv files (Figure 54 Editing a simulation file).

A	B	C	D	E	F	G	H	I
-8.02669	81.47549	172.1733	1023.707	-10.6349	0	0	0	0.001661

Figure 54 Editing a simulation file

Each row controls one minute, and each column controls a specific value as follows:
A is temperature (°C)
B is RH (%RH)
C is CO2 (ppm)
D is pressure (hPa, this is used in the light calculations)
E is the dew point (°C, which seems redundant given A and B, but is used in light calculations)
F is the hour (24 hour clock)
G is the minute
H is the day
I is the absolute humidity (g/m^3, but is functionally unused when running a simulation, it is a column used during template generation as a way to doublecheck humidity calculations)
If you have events (e.g., for watering), then they could be controlled using columns J onwards, otherwise leave them blank.

If you see an 'x' value in the RH or CO2, this means that those values are not being simulated in the chamber, and left to their ambient values. Otherwise, if you wish to merge two months together, or manually edit your simulation files, you may do so as long as they remain in this format; but keep in mind that wrapping around from December 31st to January 1st has not been thoroughly tested and it would probably be best to split such a test into two separate runs.
It should also be noted that although this does not have the ~1000 program steps limit of the controller, that if you like this feature, it might be advisable to use the programs features directly on the Intellus, and instead use the uploader that comes with Percival Connect.

3.9 Dashboard Overview

To access the dashboard, click the dashboard icon on the menu on the left hand side (Figure 55 Dashboard link).

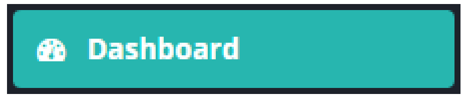


Figure 55 Dashboard link

When the page loads, if you see the following message (Figure 56 Dashboard communication error), you should revisit 3.2, check the physical communications to the chamber, or try again as often it can be just a momentary error as multiple devices are trying to communicate with the controller at once.

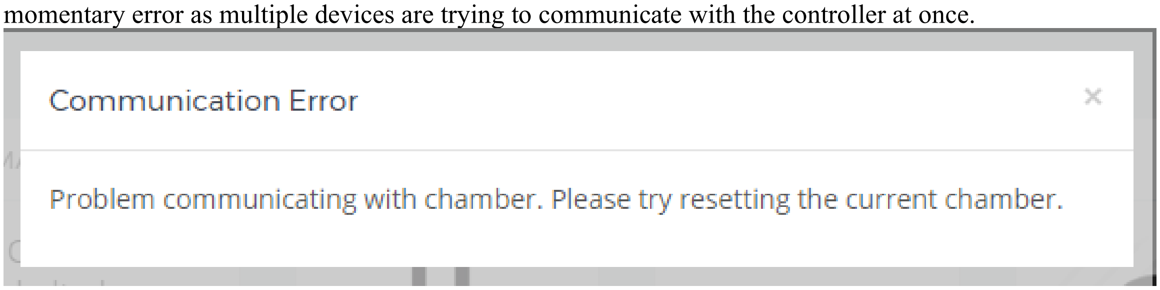


Figure 56 Dashboard communication error

This message is coupled with the chamber information box (Figure 57 Dashboard communication box) giving a similar message.

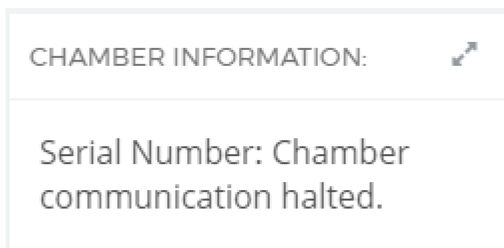


Figure 57 Dashboard communication box

Otherwise, along the top line of your dashboard you should see current information regarding your chamber (Figure 58 Dashboard information).

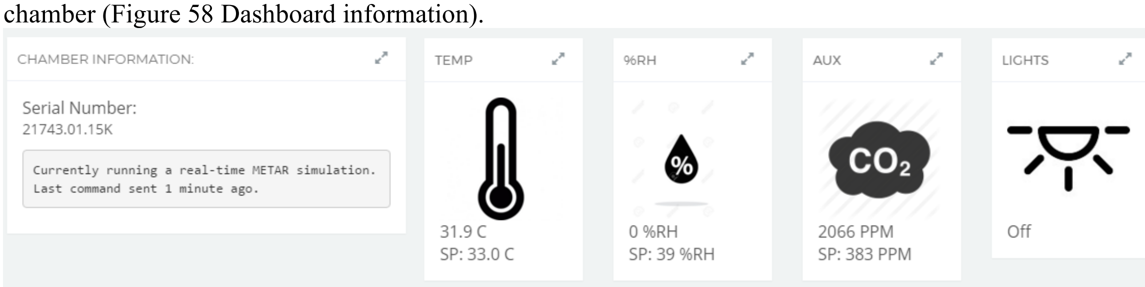


Figure 58 Dashboard information

The first panel (Figure 59 Chamber serial number) displays the serial number of the currently selected (3.2) chamber, as well as giving an indication of when the last command was sent. **If this value is >15 minutes, then doublecheck your network connectivity**.

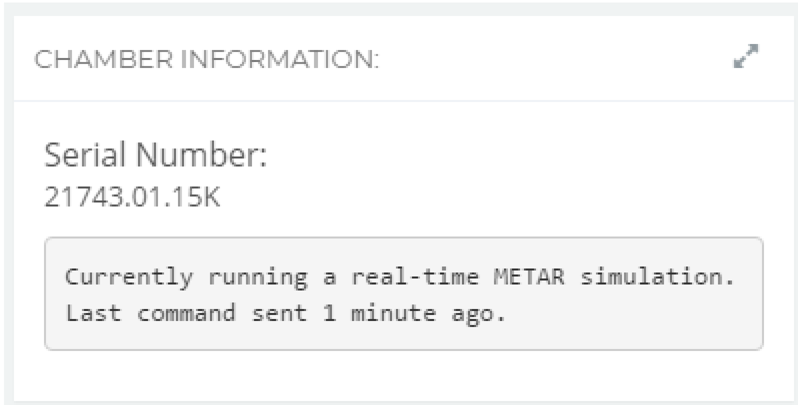


Figure 59 Chamber serial number

The next panel to the right displays current temperature information (Figure 60 Chamber temperature). Above the SP label is the current temperature in the chamber, and beside the SP label is the current Temperature Set Point of the chamber.

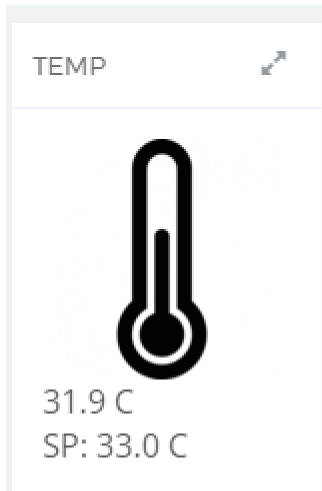


Figure 60 Chamber temperature

The next panel to the right displays current RH information (Figure 61 Chamber RH) if available. Above the SP label is the current RH in the chamber, and beside the SP label is the current RH Set Point of the chamber.

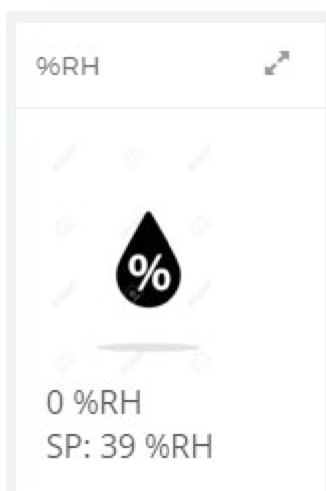


Figure 61 Chamber RH

The next panel to the right displays current CO_2 information (Figure 62 Chamber CO_2) if available. Above the SP label is the current CO_2 in the chamber, and beside the SP label is the current CO_2 Set Point of the chamber.

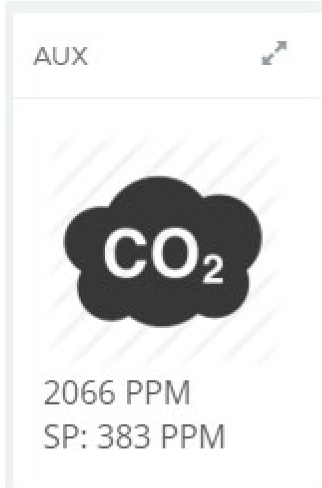


Figure 62 Chamber CO_2

The next panel to the right displays the current lighting information (Figure 63 Chamber lighting, currently all off). It simply indicates whether all lights are on, off, or some light events are on/partially dimmed.

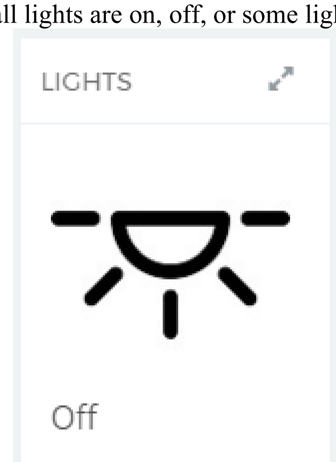


Figure 63 Chamber lighting, currently all off

Finally, below this row of information is a quick overview graph of roughly the past day of information or when the simulation started, whichever is shortest. If you do not see the graph, you might need to run a simulation, or wait a few more minutes for the first few updates from the controller. Otherwise, simply try reopening the dashboard page to see if the graph loads. Otherwise, the PercivalConnect option maintains a separate and permanent running database of chamber outputs.
Otherwise, the graph should look something like Figure 64 Chamber graph

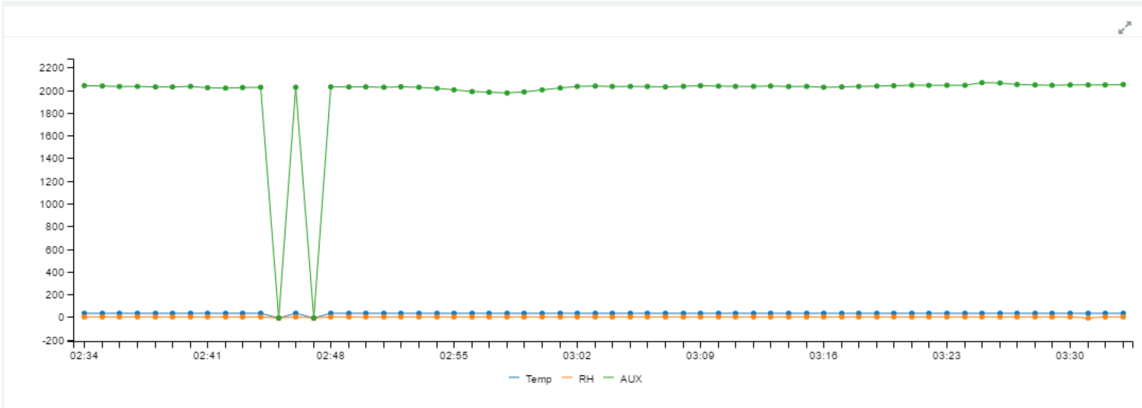


Figure 64 Chamber graph

Universal '-10' values indicate a communication hiccup in the system. For example, in Figure 64 Chamber graph the chamber was turned off twice so there was no data available for that period of time. Otherwise, separate graphs are displayed for Temperature, RH, and whatever you happened to have installed on your Aux sensor if you happen to have one (for the chamber in Figure 64 Chamber graph, we have CO_2 hooked up to our Aux). In order to filter out and select only one graph, click on the line(s) you want to hide (Figure 65 Selecting a subset).

Figure 65 Selecting a subset

Once you have done so, you will only see graphs of whichever sensor you want (Figure 66 Temperature selection only).

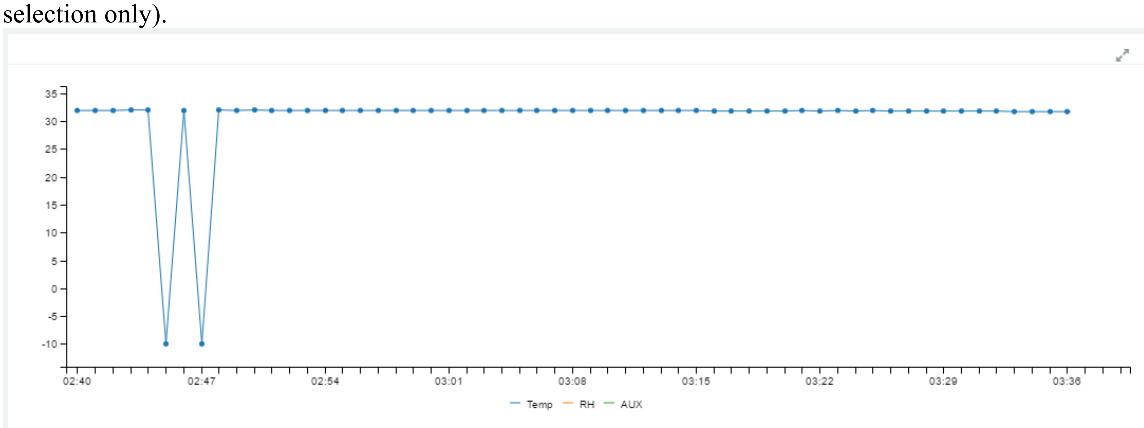


Figure 66 Temperature selection only

4 References

Bolin, B. and Keeling, C. D. (1963) Large-scale atmospheric mixing as deduced from the seasonal and meridional variations of carbon dioxide. *J. Geophys. Res.* **68**, 3899-3920.

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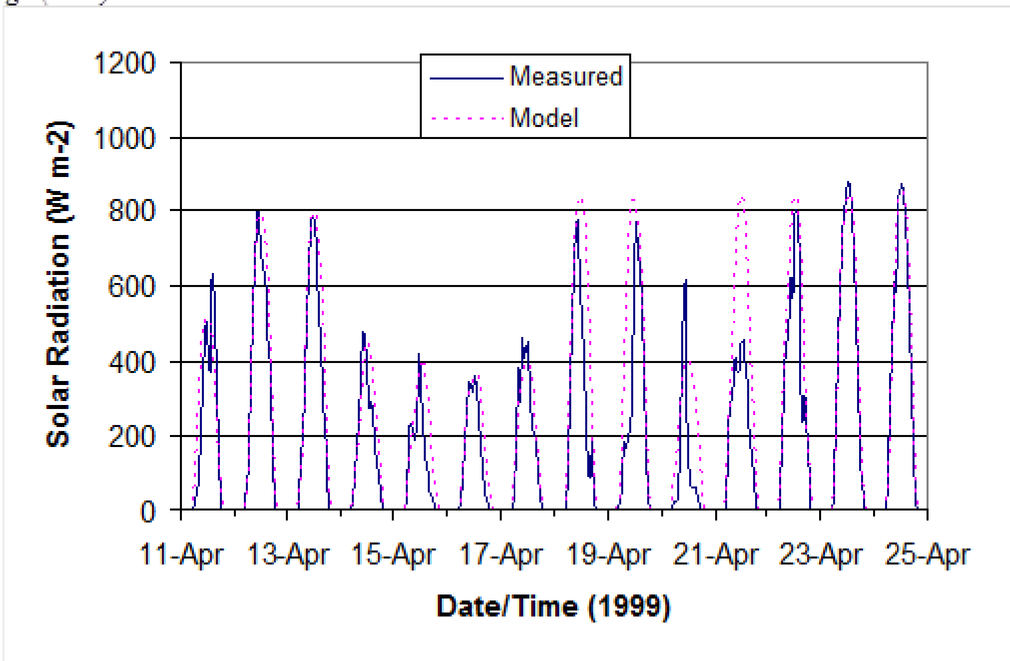
A Additional Information

A.1 Introduction to Lighting Quality/Intensity

A.1.1 Calculating Solar Spectra

The most important factor for plant growth is light quantity and quality. The main models utilized within this software were SolarCalQ and SolarCalc (Spokas and Forcella, 2006). SolarCalQ simulates the spectral quality of incident solar radiation for any location on the globe, down to one-minute intervals. SolarCalQ is an adaptation of existing NREL (National Renewable Energy Laboratory) solar spectral quality (Bird and Riordan 1984, 1986) and solar position models (Reda and Andreas, 2003), with significant modifications that are outlined below. The solar position model of Reda and Andreas (2003) has been shown to be accurate within the time period from the year -2000 to 6000, with uncertainties of +/- 0.0003 degrees in the solar zenith and azimuth angles based on the date, time, and location on the Earth. The daily temperature variability (either simulated or real-time) was used within the SolarCalc program to calculate the intensity of the incident radiation. SolarCalc provides a more realistic approximation of total incident radiation, as shown in Figure 67 Comparison of hourly SolarCalc prediction of total incoming radiation for two sites: a) Fargo, ND and b) North Ryde, Sydney Australia. Other comparisons and further statistical validation can be found in Spokas and Forcella (2006). Other comparisons and further statistical validation can be found in Spokas and Forcella (2006). This calculated intensity was then utilized to correctly scale the output of the solar quality model (SolarCalQ). An empirical model for total precipitable water vapor based upon the Liebe (1989) model for estimating total water vapor from surface relative humidity and surface temperatures (either simulated or real-time) was utilized to predict the value of the precipitable water vapor as input into the spectral quality model. Additional empirical models for ozone concentration and atmospheric optical depth (or aerosol optical depth) were also utilized as inputs into the spectral calculation. Spectral intensity is predicted in raw intensity units ($W\ m^{-2}\ um^{-1}$). The wavelength spacing is irregular, covering 52 wavelengths from 305 nm to 800 nm.

a) Fargo (1999)



b) Australia (2000)

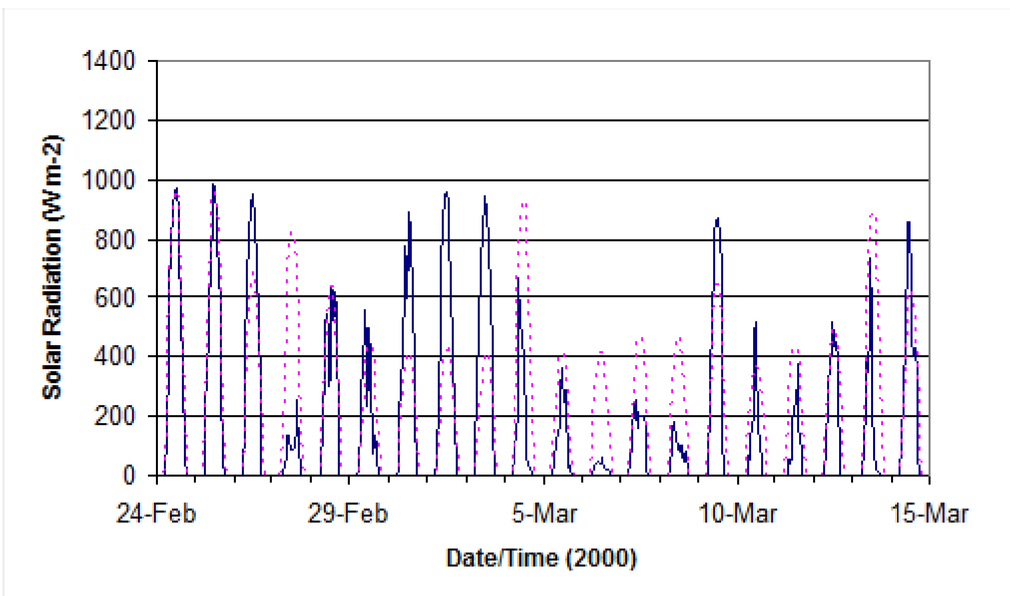


Figure 67 Comparison of hourly SolarCalc prediction of total incoming radiation for two sites: a) Fargo, ND and b) North Ryde, Sydney Australia. Other comparisons and further statistical validation can be found in Spokas and Forcella (2006).

A.1.2 Light Fitting Algorithms

With the spectrum to be matched made, all is left is the calculation to try to match that spectrum. A brief explanation of each method we use to match the spectra, and their advantages and disadvantages are as follows:

1- Peak

This method attempts to fit the local maxima (peaks) of the constructed light curve to the Sun's light curve. The fit is done in order of the variability of each light source, and due to this variability, an exact peak match is still not possible. However, it will try to do so. Also, because the peak of the constructed curve is fitted to the Sun's light spectra, the overall light intensity will tend to be underestimated.

2- Trough

This method does exactly what the peak algorithm does, except instead of trying to fit the local maximas, it tries to fit the local minimas (troughs) of the constructed light curve to the Sun's spectra. Because of this, it will tend to overestimate the light intensity.

3- LEDPeak

Unlike the Peak algorithm, this method does not take into account the different spectras' variability, and does a very straightforward matching of the global maxima of each light source spectra to the sun's spectra at the wavelength where the global maximum is obtained. Because LED light spectra tend to have one very clearly defined peak, it is suggested to use this method if you have LED lighting controls, as it will automatically be called if you have any LEDs.

4- L1

This method attempts to minimize the L1 norm error between the constructed light source spectra and the Sun's spectrum using a linear programming approach. It tends to match the overall intensity a little better, but the quality of the spectra at each point not so much.

5- L2

This method attempts to minimize the L2 norm error between the constructed light source spectra and the Sun's spectrum using a linear programming approach. It tends to match the overall spectral quality a little better, but the intensity of the spectra at each point not so much.

6- LLS

This method attempts a straightforward truncated Linear Least Squares solution to the problem. It is suggested to not use this method if you have two of the same type of bulb in different events, or if you have two different lights of very different intensities.

7- Spectral Ratio

This method applies a dot product of the normalized spectral quantities of the light bulb and Sun spectra in order to determine dimming percentages. Because of this, it emphasizes the quality of the light spectra much more than the intensity over any other method listed here.

8- Simple Scaling

This method ignores the spectral information in the software, and simply scales every light (after which a rounding is applied for on/off lights), given their maximum intensity information, to try to match the µmol intensity of the Sun in the PAR.

In general the software uses the following flowchart for deciding which lighting control to use (Figure 68 Lighting algorithm flowchart), with an exception for the personal weather station, which always defaults to simple scaling:

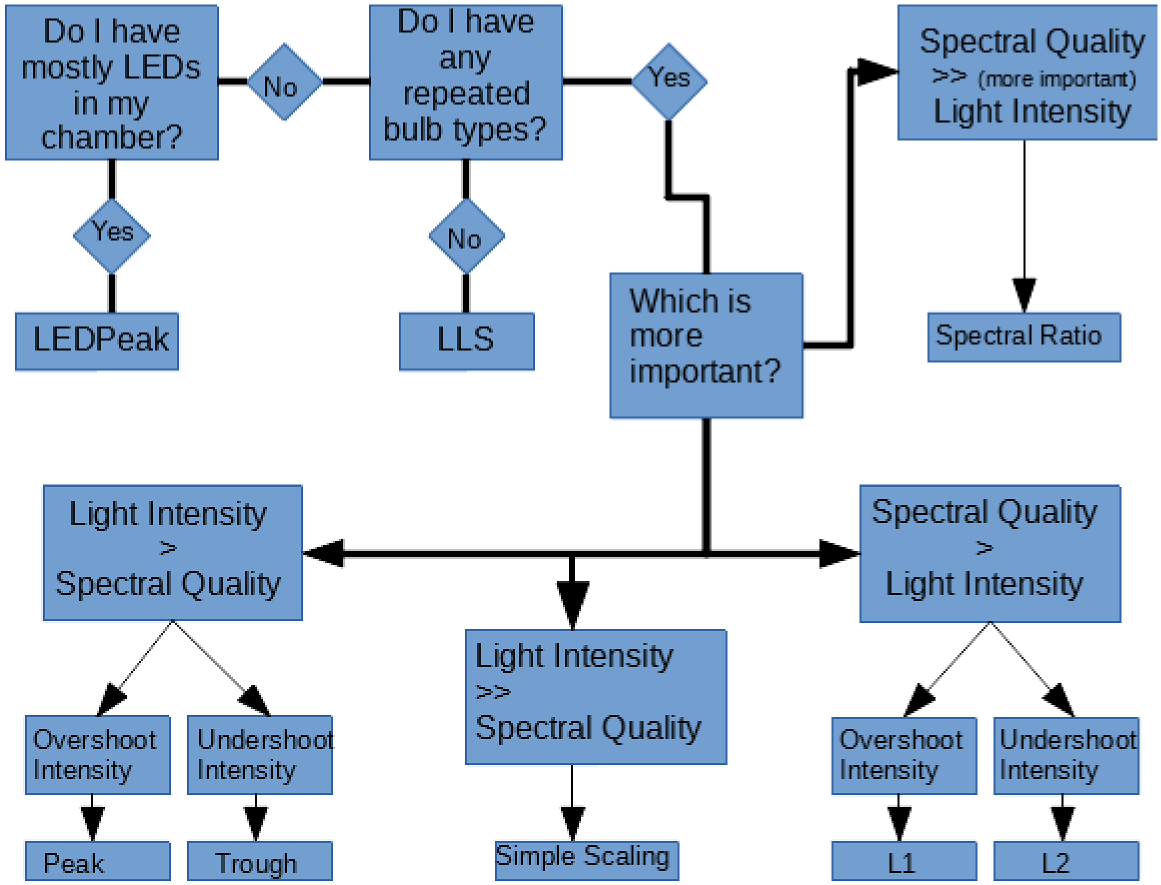


Figure 68 Lighting algorithm flowchart

A.1.3 Light Measurement

There can be a lot of confusion about the various methods of measuring light irradiance as well as the spectral quality of incident radiation. This section outlines some of the common units (as well as the units used in within this software) to provide an overview on these topics.

Visible light is a particular region of the electromagnetic (EM) spectrum, which is the range of all possible electromagnetic radiation, from radio waves (wavelength ≈1000 meters) to gamma rays (wavelength ≈ 10^{-12} meters). Scientifically, light refers to the entire EM spectrum, whereas visible light refers to the region of the EM spectrum that our human eye is sensitive to (between approximately 400 nm and 700 nm). An interactive-graphical overview of the EM spectrum can be found at:

http://www.e-builds.com/EM%20spectrum/.

Several measurement devices exist for light irradiance (intensity) measurements. This is in part due to the historical development of the various light measuring devices. Consequentially, different light meters measure in different units and each device can be measuring different portions of the solar spectrum.

A very comprehensive glossary of solar irradiance terms can be found at:

1) http://rredc.nrel.gov/solar/glossary/ and
2) http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html.

Below is a summary of some of the major units of solar irradiance that are typically encountered:

Footcandle - A footcandle is the measure of the amount of light projected on the inside of a sphere one foot from a standard wax candle. A foot candle is assigned equal to one lumen per square foot. Devices that measure footcandles are typically sensors that are used to determine building lighting needs and sensors that are used in the photography industry. Therefore, these devices are sensitive to the spectrum that the human eye is able to detect (visible spectrum). These measurement devices are still used in the greenhouse industry.

Watts per Meter Squared ($W \cdot m^{-2}$) - This is a total energy of the incident radiation. This unit unlike Footcandle and PAR (below) measures the entire spectrum of sunlight.

PAR – Photosynthetically Active Radiation - Refers to the portion of the solar spectrum that is important to photosynthesis in plants. The sensor measures radiation between 400 and 700 nm, and outputs the irradiance in units of $\mu mole\ m^{-2}\ s^{-1}$. Different plant species can have different absorption spectrums depending on the mix of photoreceptors present in the leaves, but a majority of the absorption is within the 400 to 700 nm region.

A.1.4 Spectral Quality (i.e. Spectral Colors)

Spectral quality of incident radiation refers to the wavelength (color) distribution of the radiation (light). The typical unit of measure for wavelength is the nanometer (nm). Artificial light bulbs emit radiation with various unique spectral quality signatures (or colors, see Appendix B) as a function of the mechanism used to produce the light. The solar radiation from the sun emits all known wavelengths from a single source, but humans can see only a small portion of this total spectrum (visible light). The wavelength of radiation is related to the amount of energy each wavelength possesses. In other words, the higher (longer) the wavelength results in EM radiation of lower energy compared to the shorter wavelengths. So, the short wavelengths contain a “bigger punch” (more energy) and hence the danger from UV radiation to human skin.

A.2 Timing Issues when Running a Long-Term Simulation (Longer than 6 months)

Every effort has been made in the programming of WeatherEze™ to provide the most accurate chamber control. However, with each update there are milliseconds that are lost due to software execution delays. These keep adding up during the course of a simulation. The user can visualize if the chamber is updated every minute, this could lead to larger timing differences between the real-world time and the simulation time as days, weeks and months elapse. As an example, the simulator could be off by some seconds (or more) each day. This therefore could add up to more significant delays the longer the simulation is running. There is currently no remedy for this delay.

A.3 Introduction to CO_2 Control

The longest continual record of CO_2 observations has been made at the Mona Loa observation site located in Hawaii at an elevation of 3397 m above mean sea level (Figure 69 Mona Loa CO2 data. Graphic taken from source: NOAA http://www.esrl.noaa.gov/gmd/ccgg/trends/). The current value for this station is considered the average CO_2 concentration in the middle layers of the troposphere.

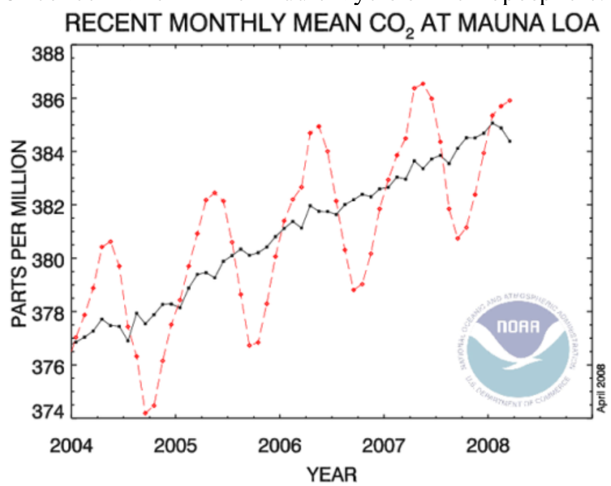


Figure 69 Mona Loa CO2 data. Graphic taken from source: NOAA
http://www.esrl.noaa.gov/gmd/ccgg/trends/

However, this value may or may not be representative of surface conditions. Local building (laboratory) CO_2 concentrations may be higher, particularly if the building is highly occupied or if additional sources of CO_2 are present (e.g. propane/natural gas heaters). Guidelines in the US state that an indoor value of 800-1000 ppm above outside air indicates poor building circulation (approximately 1200 – 1500 ppm absolute concentration). It is important to note that OSHA's permissible exposure limit for CO_2 is 5000 ppm for an 8 hour day.

Variations in CO_2 are larger in the northern hemisphere than in the southern hemisphere (Keeling *et al.,* 1968). Empirical relationships were established for the latitudinal variability of the seasonal trends for global CO_2 concentrations (Bolin and Keeting, 1963). An example of this seasonal variation is shown in Figure 70 Seasonal variability of CO2 concentration from Bolin and Keeting (1963) for the 45N latitude..

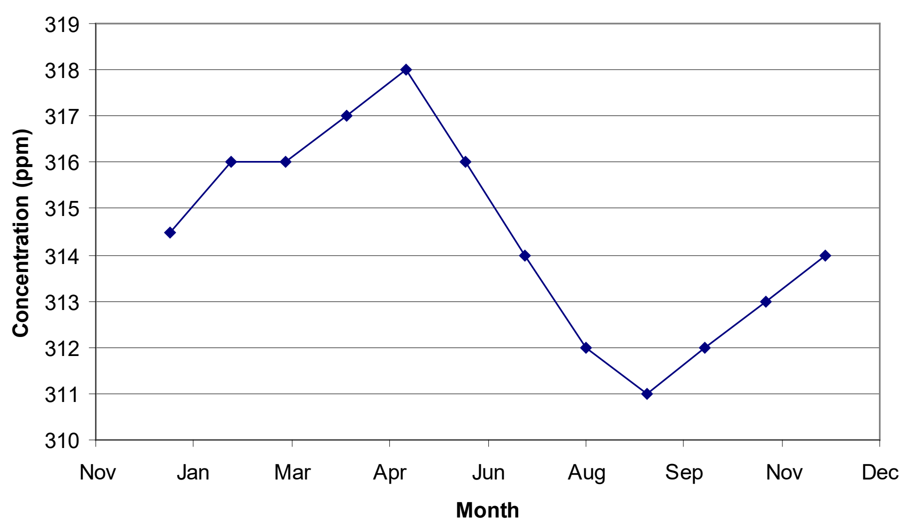


Figure 70 Seasonal variability of CO_2 concentration from Bolin and Keeting (1963) for the 45N latitude.

These geographical relationships are embedded within WeatherEze™. Please refer to Section 4.4 (CO_2 Tab) for information on adjusting diurnal variability. Diurnal fluctuations in excess of 300 ppm CO_2 have been reported (e.g. Keeling, 1961).
Figure 71 illustrates changes in the curve utilizing a variety of diurnal variability settings.

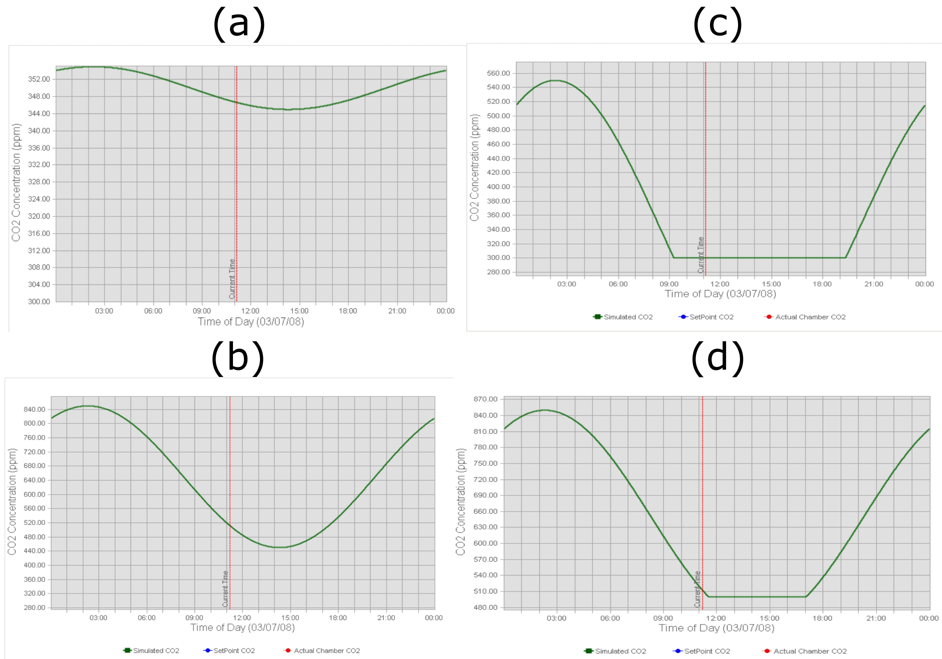


Figure 71 Illustrations of different CO_2 scenarios: (a) average CO_2= 350 ppm, minimum CO_2 value = 300 ppm, amplitude = 5 ppm, (b) average CO_2 = 600 ppm, minimum CO_2 value = 300 ppm, amplitude = 200 ppm, (c) average CO_2 = 350 ppm, minimum CO_2 value = 300 ppm, amplitude = 200 ppm, and (d) average CO_2 = 600 ppm, minimum CO_2 value = 500 ppm, amplitude = 200 ppm.

A.4 METAR Information

Meteorological Aeronautical Report (METAR) data from surface stations is the source of real-time weather data. METAR is the international standard code format for surface weather observations, typically taken at airports throughout the world. METAR data allows real-time data (typically with hourly updates) to be used for temperature control of the chamber. Figure 72 Location of METAR reporting locations worldwide below illustrates the distribution of METAR stations worldwide. As seen in the figure, the density of stations is the highest in the United States and Europe. For additional information on METAR data and its format, please see the following link:
http://www.ncdc.noaa.gov/oa/wdc/metar/index.php?name=faq.

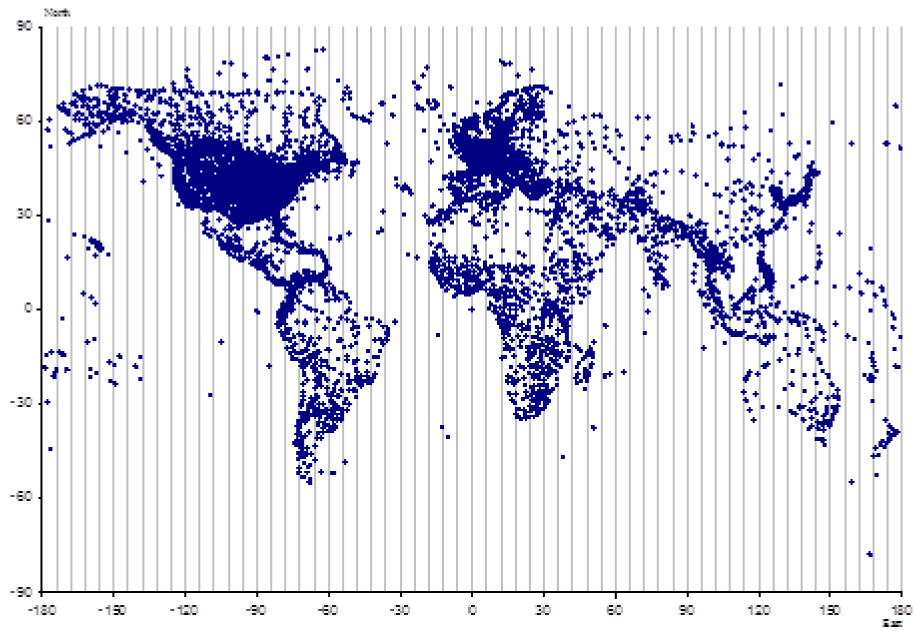


Figure 72 Location of METAR reporting locations

A.5 Weather Interpolations

Many things in nature are periodic. Air temperature is a good example, both on annual and daily time scales. Often air and soil temperatures are represented by simple sinusoidal functions (Hilel, 1982; Marshall and Holmes, 1988).

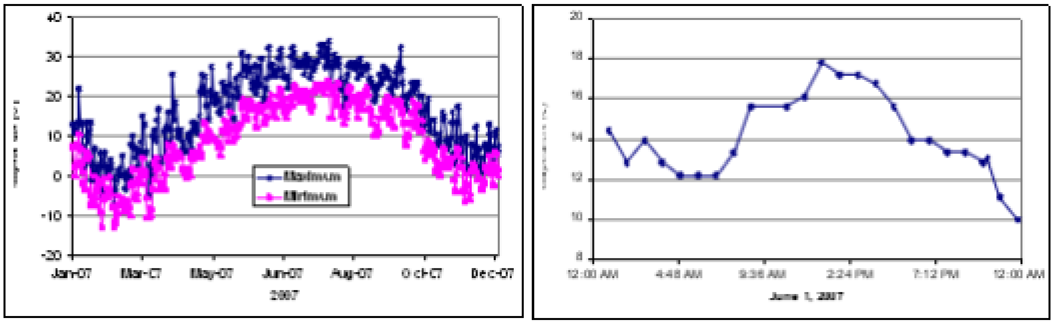


Figure 73 Illustration of annual temperature wave for New York JFK, New York (Airport) for 2007 and the daily temperature wave for June 1, 2007

For a daily time scale. There are three options within WeatherEze™ to extrapolate values for air temperatures. These are denoted in the software as "Coarse" to "Fine" in order to aid in everyday use. However, each level uses a slightly different formula with different pros and cons.

1. <u>Sinusoidal Temperature Wave (Coarse)</u>
   A sinusoidal temperature pattern was established through the following formula:

$$Temp_{current} = T_{avg} - \sin(Time_{\min} * 0.0000727 * 60)$$

   Where T_{avg} is the average daily temperature and $Time_{min}$ is the elapsed minutes since midnight. The first is a very simplistic sinusoidal estimation for maximum temperature at noon, and the minimum temperature occurring at 6am at the site, regardless of the sunrise/sunset timings at the site. This is a very crude estimation of the diurnal temperature cycle for a site, which makes it simple to understand and compute.
2. <u>Cesaraccio et al. (2001) Model (Inbetween)</u>
   Within WeatherEze™, the model of Cesaraccio et al. (2001) was chosen to represent a more accurate diurnal temperature pattern. Daily temperature cycles are not truly symmetric sinusoidal curves. Cesaraccio et al. (2001) developed an empirical model that estimates hourly temperatures from daily maximum and minimum temperatures. The Cesaraccio model depicts the diurnal temperature wave as a sine function from the minimum temperature at sunrise to the time the maximum temperature is reached, followed by a subsequent sine wave that starts at the maximum temperature occurrence until sunset. A square-root function is used for describing the temperature fluctuation occurring between sunset and sunrise the next morning.
   This model has proved to be superior to other existing models for degree-day calculations. The maximum error in the extrapolation of hourly temperatures from the daily records did not exceed 3°C, and a majority of times the root mean square error was below 2°C for the sites evaluated (Cesaraccio et al., 2001).
3. <u>Newton Cooling (Fine)</u>
   The model of Parton et al. (1981) was chosen to represent surface and soil cooling. This model follows a daily sinusoidal pattern, but at night follows an exponential heat decay pattern. This has issues with achieving the same kind of thermal matching that the Cesaraccio model achieves, but may be used to better model an exponential heat loss decay.

The comparison of the three simulations in WeatherEze™ is shown in Figure 74 from 505 Research Dr., Perry, IA (June 2, 1961), comparing the temperature simulations for extrapolation of minutely temperatures from daily maximum and minimum values.

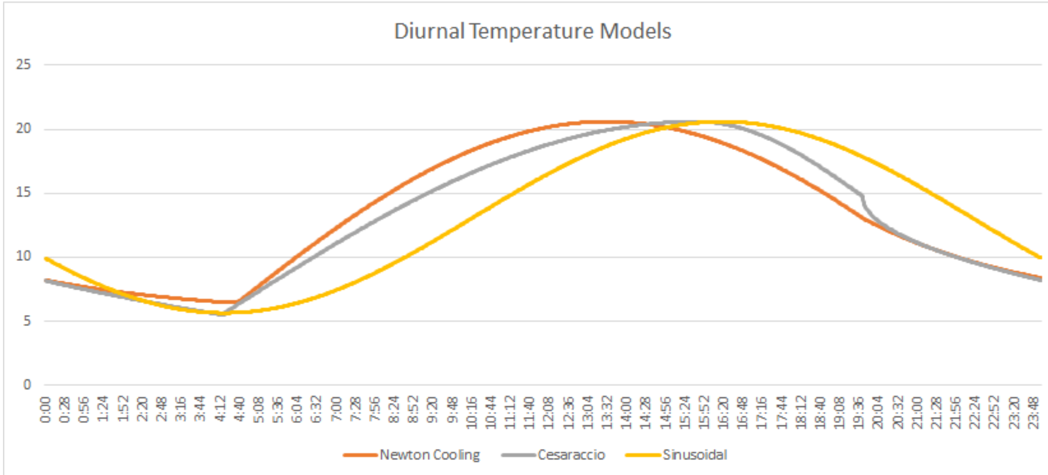


Figure 74 Illustration of air temperatures from Perry, IA (June 2, 1961), comparing the temperature simulations for extrapolation of minutely temperatures from daily maximum and minimum values.

Often times, a different type of interpolation is needed for annual time scales. Because weather data can be so numerous or infrequent, typically only monthly averages will be given (e.g., many IPCC datasets). Therefore, a different kind of interpolation is needed to extract the individual daily averages. One kind of seasonal interpolation was already discussed in A.3. For other weather phenomena, we use the fact that seasonal variations are periodic, and therefore we assume the phenomena follows the form of some trigonometric polynomial of the form

$$a_0 + \sum_{k=1}^{K} a_k \cos(kx) + \sum_{k=1}^{K} b_k \sin(kx)$$

and use a trigonometric interpolation algorithm so that December 31st data will merge into January 1st data as best as possible. The most common trigonometric interpolation algorithms assume equispaced nodes, therefore the 365 days of the year are divided into 12 equally spaced points and at those points it is assumed that the monthly averages take place.

A.6 Climate Change Data

The climate change data is based mainly off of the IPCC AR4 data available here: http://www.ipcc-data.org/sim/gcm_clim/SRES_AR4/index.html
However, where possible, AR3 data may be used to fill in gaps in the data and when available (if available to the public), AR5 SRES scenario data can be incorporated into the software in the future. As of this writing, there are 21 different models, and each of these models have the following main differences:

- Originary agency
- Resolution of the latitude/longitude grid
- Availability of SRES scenarios
- Availability of pressure/specific humidity/precipitation data

We will go through each of these in turn to help you make your choice. If you have any particular agency preference, Table 1 is a table indicating the model with the corresponding participating agency or agencies responsible for that model. Percival Scientific does not vouch for the accuracy of any one agencies' model over any other.

BCCR:BCC-CM1	Beijing Climate Center-China
BCCR:BCM2	Bjerknes Centre for Climate Research-Norway
CCCMA:CGCM3_1-T63	Canadian Centre for Climate Modeling and Analysis-Canada
CONS:ECHO-G	Meteorological Institute of the University of Bonn (Germany)-Institute of KMA (Korea)-Model and Data Group
CNRM:CM3	Centre National de Recherches Meteorologiques-France
CSIRO:MK3	Australia
GFDL:CM2	Geophysical Fluid Dynamics Laboratory NOAA-U.S.A.
GFDL:CM2_1	Geophysical Fluid Dynamics Laboratory NOAA-U.S.A.
INM:CM3	Institute of Numerical Mathematics Russian Academy of Science-Russia
IPSL:CM4	Institut Pierre Simon Laplace-France
LASG:FGOALS-G1_0	Institute of Atmospheric Physics Chinese Academy of Sciences-China
NASA:GISS-AOM	Goddard Institute for Space Studies National Air and Space Administration-U.S.A.
NASA:GISS-EH	Goddard Institute for Space Studies National Air and Space Administration-U.S.A.
NASA:GISS-ER	Goddard Institute for Space Studies National Air and Space Administration-U.S.A.
NCAR:CCSM3	National Center for Atmospheric Research-U.S.A.
NCAR:PCM	National Center for Atmospheric Research-National Science Foundation-Department of Energy-National Air and Space Administration-NOAA-U.S.A.
NIES:MIROC3_2-HI	CCSR/NIES/FRCGC Japan
NIES:MIROC3_2-MED	CCSR/NIES/FRCGC Japan
MPIM:ECHAM5	Max Planck Institute for Meteorology-Germany
MRI:CGCM2_3_2	Meteorological Research Institute Japan Meteorological Agency-Japan
UKMO:HADCM3	Hadley Centre for Climate Prediction and Research-Met Office-United Kingdom

Table 1 Participating AR4 IPCC Agencies

The resolution of the grid is a very subtle factor. Because the software uses the nearest grid points available from the model, you may end up placing your simulation in a different spot than you expect. For example, if you place your experiment in Iowa but the nearest resolution of grid point is in Minnesota, you will end up with colder temperatures than you might have been expecting. Table 2 is a table roughly indicating the maximum resolution of each model in terms of degrees longitude by degrees latitude.

BCCR:BCC-CM1	1.875x1.875
BCCR:BCM2	1.5x1.5
CCCMA:CGCM3_1-T63	1.4x0.9
CONS:ECHO-G	2x2
CNRM:CM3	1x2
CSIRO:MK3	0.84x1.875
GFDL:CM2	1x1
GFDL:CM2_1	1x1
INM:CM3	2.5x2
IPSL:CM4	2.5x3.75
LASG:FGOALS-G1_0	2.8x2.8
NASA:GISS-AOM	3x4
NASA:GISS-EH	4x5
NASA:GISS-ER	4x5
NCAR:CCSM3	1.125x1
NCAR:PCM	0.26x1
NIES:MIROC3_2-HI	0.1875x0.28125
NIES:MIROC3_2-MED	1.4x1.4
MPIM:ECHAM5	1.5x1.5
MRI:CGCM2_3_2	2x2.5
UKMO:HADCM3	1.25x1.25

Table 2 Model Resolutions

Each model studies a certain selection of the available emission models. The different emissions scenarios are discussed in further detail on the IPCC website here http://www.ipcc-data.org/sim/gcm_clim/SRES_TAR/ddc_sres_emissions.html . Aside from the fact that these different scenarios will influence air temperature, specific humidity, and air pressure measurements from each model, as far as the chamber is concerned, this will have the most immediate impact on your CO_2 usage. In order to have some idea of the CO_2 levels in the chamber for each of the currently seven different emissions scenarios available, please refer to Table 3.

	2039	2069	2099
SRA2	419.33	534	701.33
SRB1	412.33	486.67	535.67
SRA1B	421.67	531.67	648.33
1PTO2X	398	536	540
1PTO4X	398	536	723
PICTL	270	270	270
COMMIT	369	369	369
No scenario	400	400	400

Table 3 Average CO_2 ppm use by chamber

In order to note which models use which scenarios, please note Table 4.

Model	SRA2	SRB1	SRA1B	1PTO2X	1PTO4X	PICTL	COMMIT
BCCR:BCC-CM1	No	Yes	No	Yes	Yes	No	No
BCCR:BCM2	Yes	Yes	Yes	Yes	No	Yes	Yes
CCCMA:CGCM3_1-T63	No	Yes	Yes	No	No	Yes	No
CONS:ECHO-G	Yes	No	Yes	Yes	Yes	Yes	Yes
CNRM:CM3	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CSIRO:MK3	Yes	Yes	Yes	Yes	No	Yes	Yes

GFDL:CM2	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GFDL:CM2_1	Yes	Yes	Yes	Yes	Yes	Yes	Yes
INM:CM3	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPSL:CM4	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LASG:FGOALS-G1_0	No	Yes	Yes	Yes	No	Yes	Yes
NASA:GISS-AOM	No	Yes	Yes	No	No	Yes	No
NASA:GISS-EH	No	No	Yes	Yes	No	Yes	No
NASA:GISS-ER	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NCAR:CCSM3	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NCAR:PCM	Yes	No	Yes	Yes	Yes	Yes	No
NIES:MIROC3_2-HI	No	Yes	Yes	Yes	No	Yes	No
NIES:MIROC3_2-MED	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MPIM:ECHAM5	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MRI:CGCM2_3_2	Yes	Yes	Yes	Yes	Yes	Yes	Yes
UKMO:HADCM3	Yes	Yes	Yes	No	No	Yes	Yes

Table 4 Scenario availability

Finally, we note the availability of specific humidity and pressure data. This is probably the most immediately important factor. Specific humidity will modify RH controls in your chamber if you have them, and air pressure will subtly influence lighting events in your chamber. If either do not exist, the software will default to the NASA:GISS-EH model and standard atmospheric pressure unless you edit your files manually or choose to not include RH controls. Table 5 is a table indicating whether all scenarios that are available to that model has pressure and specific humidity, some available scenarios have either, or whether it has neither.

Model	Specific Humidity Availability	Pressure Availability
BCCR:BCC-CM1	None	All
BCCR:BCM2	All	All
CCCMA:CGCM3_1-T63	All	All
CONS:ECHO-G	None	All
CNRM:CM3	All	All
CSIRO:MK3	None	All except SRA2
GFDL:CM2	None	All
GFDL:CM2_1	None	All
INM:CM3	All	All
IPSL:CM4	All except 1PTO4X	All
LASG:FGOALS-G1_0	All	All
NASA:GISS-AOM	All	All
NASA:GISS-EH	All	All
NASA:GISS-ER	All except SRB1	All
NCAR:CCSM3	All	All
NCAR:PCM	None	All
NIES:MIROC3_2-HI	All	All
NIES:MIROC3_2-MED	All	All
MPIM:ECHAM5	None	All
MRI:CGCM2_3_2	All	All
UKMO:HADCM3	All except PICTL and SRA2	All

Table 5 Auxiliary Model Data Availability

B Spectral Library within WeatherEze

This appendix lists the included light bulb reference spectra within WeatherEze™. At the end of this section, we list graphs of the light spectra of each of our most common bulb types at the 52 discrete wavelengths according to the Bird model. To begin with, we give a quick primer if you want to add your own bulbs or tailor and calibrate your own spectral bulb spectra.

Adding a bulb spectra is meant for advanced users, and may have unknown effects on solar calculations. Custom set-ups are run at your own risk.

To add a bulb spectra, navigate to the www/backgroundScripts folder of your installation. There you should see a csv file entitled "birdLightDatabase." If you open this file, you should see something like Figure 75 Custom bulb table.

	A	B	C	D	E	F
1	Wavelength (nm)	0.3	0.305	0.31	0.315	0
2	FLUORESCENT T8 - WHITE 841 (ELA-039-041-056)	2.36973204506786E-05	1.79902495827214E-05	0.000561471813519	7.64641931007533E-05	7.58473408542649E
3	FLUORESCENT T5 - WHITE F54T5HO 841 BY GE (ELA-100)	0.000159012	7.90869E-05	0.00120003	0.000109628	0.0002099
4	FLUORESCENT T5 - WHITE F54T5HO 841 WHITE BY PHILIPS (ELA-096)	0.000108748	0.000109579	0.000366797	0.000216116	0.0001047
5	INCANDESCENT FROSTED 15 W	0	4.00716E-05	3.54395E-05	0	
6	LED (PERCIVAL BAR) COOL WHITE	0.000930829	0.000930829	0.000930829	0.000930829	0.0009308
7	LED (PERCIVAL BAR) RED	0	0	0	0	
8	LED (PERCIVAL BAR) BLUE	0.000819967	0.000936509	0.000971993	0.000992866	0.0010158
9	LED (PERCIVAL BAR) FAR RED	0.00064689	0.00064689	0.00064689	0.00064689	0.000646
10	LED (PERCIVAL BAR) GREEN	5.37E-07	0.000213128	0.000252456	0.000250499	0.0002602
11	LED CLF GROLED (REDnFAR RED)	8.96209E-05	8.67369E-05	0	0	
12	Halogen Clear (29W)	9.76765E-05	0.000103305	6.09283E-05	2.94644E-05	5.95087E
13	Halogen Clear (43 W)	1.9E-05	1.69E-05	9.67E-06	3.93311E-05	4.03452E
14	CMH 315W Philips Agro	0	0	0	0	
15	CMH 315W VENTURE 38821	6.62179335853832E-06	7.16661064963178E-06	1.40746052533799E-05	7.31563255574514E-06	1.95814441134327E
16	COMPACT FLUORESCENT - BLACK 13W FEIT BPESL15TBLB	8.13956328035056E-06	7.18496691631774E-05	0.000190027650743	1.2994712303394E-06	
17	COMPACT FLUORESCENT - BLUE 13W FEIT BPRSL13TB	8.09E-05	0.000101764496705	0.000106568838029	0.000106553697575	7.83353323997696E
18	COMPACT FLUORESCENT - ORANGE 13W FEIT BPRSL13TO	0.0001674393517	0.000161121689665	0.000238750804217	0.000237750613963	0.0002019156839
19	COMPACT FLUORESCENT - RED 13W FEIT BPRSL13TR	0.000207841180831	0.000286992855787	0.000263255091773	0.000302531708319	0.0001601127337
20	COMPACT FLUORESCENT - UVA SYLVANIA CF13ELSUPERBLACK	0.000147899711774	0.000139493837034	9.61431990542197E-05	0.000159455820157	9.46944066803918E
21	COMPACT FLUORESCENT - UVB REPTISUN 10	0.000812142353393	0.002182792690667	0.004843130587099	0.005944362778416	0.006064976277
22	COMPACT FLUORESCENT - WHITE REVEAL 20W GEFLE20HT326HRVL	0	1.18243916673718E-05	4.78605227250539E-06	1.79229587318316E-06	7.22672023596639E
23	COMPACT FLUORESCENT - YELLOW 13W FEIT BPRSL13TR	0.000173	0.000181	0.000142	0.000258	0.0001
24	FLUORESCENT T5 - AGROMAX F54T5HO BLOOM SPECTRUM	0.000227145	0.00022023	0.002984931	0.000876063	0.0008037
25	FLUORESCENT T5 - BLUE F54T5HO BLUE BY SUNLITE	0.000201515	0.000190172	0.000284764	0.000265826	0.0002384
26	FLUORESCENT T5 - GREEN F54T5HO GREEN BY SUNLITE	0.000130546	5.81189E-05	0.001268795	0.00013113	0.0003816
27	FLUORESCENT T5 - MARINE BLUE F54T5HO (BLUE) BY GLO	0.000175332	0.000138131	0.000351968	0.000191172	0.0001579
28	FLUORESCENT T5 - RED F54T5HO RED BY SUNLITE	0.000277441	0.000311119	0.000355525	0.000241655	0.0002124
29	FLUORESCENT T8 - BLUE PERCIVAL LAMP	0.000205251	0.000190481	0.001156971	0.000531304	0.0002192
30	FLUORESCENT T8 - FAR RED PERCIVAL LAMP	0.000256603	0.000184483	0.003108556	0.00112107	0.0001385
31	FLUORESCENT T8 - GROLITE NS	0.000191549	0.000159487	0.001376413	0.000592191	0.000203
32	FLUORESCENT T8 - RED PERCIVAL LAMP	9.74193E-05	0.000114475	0.000786897	0.000352457	0.0001789
33	FLUORESCENT T8 - UVA F32T8BLB BY PROLUME (ELA-111)	0.000264709	0.000525562	0.000224677	0.000522754	0.0032547
34	FLUORESCENT T8 - UVB	0.034723356	0.049089173	0.070438516	0.067002989	0.0650909
35	FLUORESCENT T8 - WHITE WITH UVB REPTISUN 5 (ELA-105)	0.001142017	0.003351171	0.009785686	0.014217682	0.0176254
36	FLUORESCENT TWIN T5 - WHITE FT55W840 WHITE BY OSRAM (ELA-054)	0.000250857	0.000166224	5.82935E-05	0.000116457	0.0001600
37	HPS 200W (LU200 SYLVANIA 67576)	4.49134E-05	0.000101625	8.95577E-05	8.66036E-05	0.0001937
38	LED T8 PHILIPS INSTANT FIT CODE 433086	0.000102603	0.000113584	0.000130594	0.000124312	0.0001156
39	LED T8 PHILIPS INSTANT FIT CODE 456913	7.32504E-05	9.26546E-05	0.000119625	0.000123878	9.70587E
40	Plasma Lighting	0.000275813	0.000395241	0.000629019	0.000722237	0.0009966
41						
42						
43						
44						

Figure 75 Custom bulb table

To add another bulb type, simply add in the name of your bulb to the bottom of the first column, and then corresponding to the wavelength along row 1 input. These wavelengths entries should be in terms of the *relative* spectra measured in UML totals between that column's wavelength and the next nearest column's wavelength (or the next 10 nm in the case of the final column).

Once these are entered, go up one folder in the directory, and you should see a csv file entitled "lightDatabase" that will simply be one row consisting of the names of the available lamps. **Add the exact same name you used in the birdLightDatabase file** and add it to the end of the row.

You may also recalibrate or set your own measurements to the other bulbs that are already default options in the birdLightDatabase file.

We conclude this section with a list of the relative spectra of our available bulbs. **It should be noted that these spectragraphs may seem highly skewed.** This is because we use the same resolution as the Bird spectral model (A.1.1) in these graphs. For fuller spectrographs of your chamber's lights, contact Percival-Scientific.

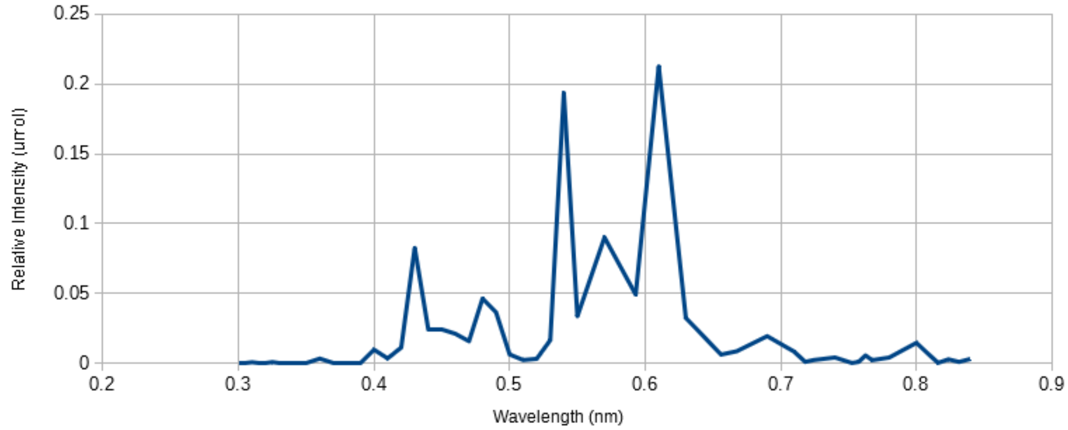


Figure 76 FLOURESCENT T8-WHITE 841

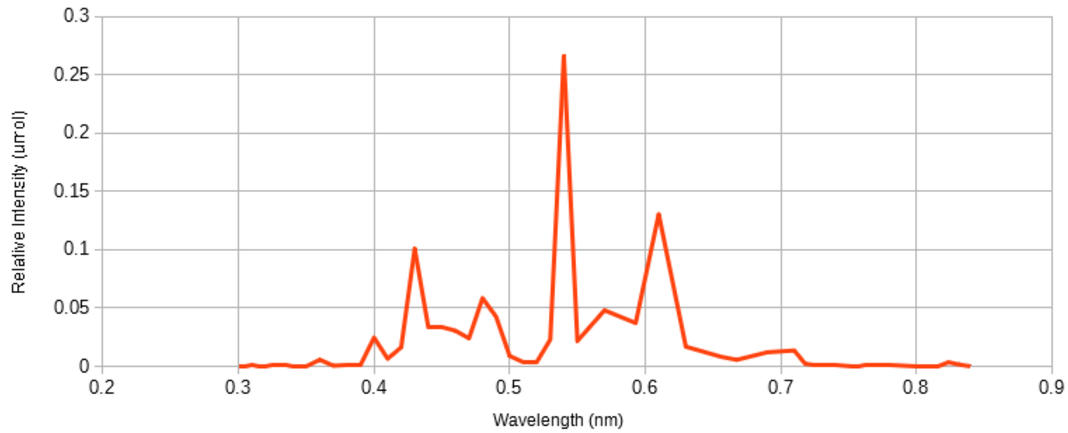


Figure 77 FLOURESCENT T5-WHITE F54T5HO 841 BY GE

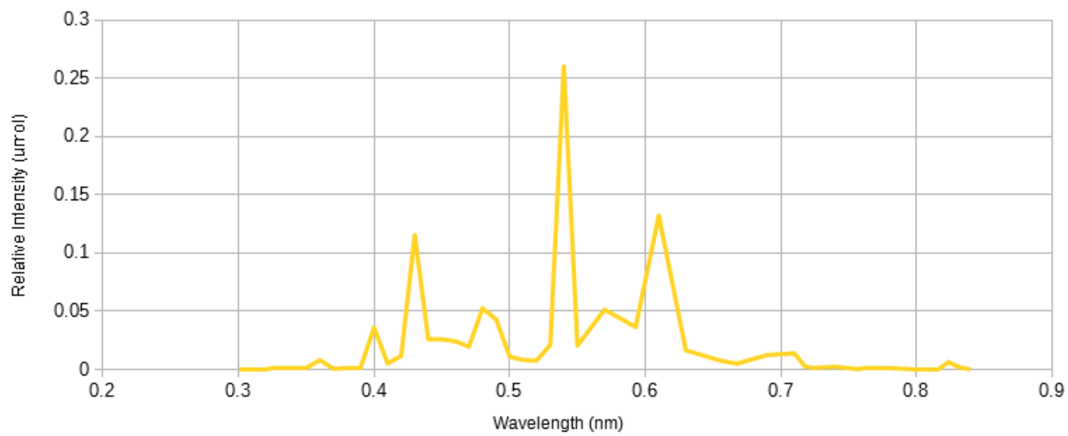


Figure 78 FLOURESCENT T5-WHITE F54T5HO 841 BY PHILIPS

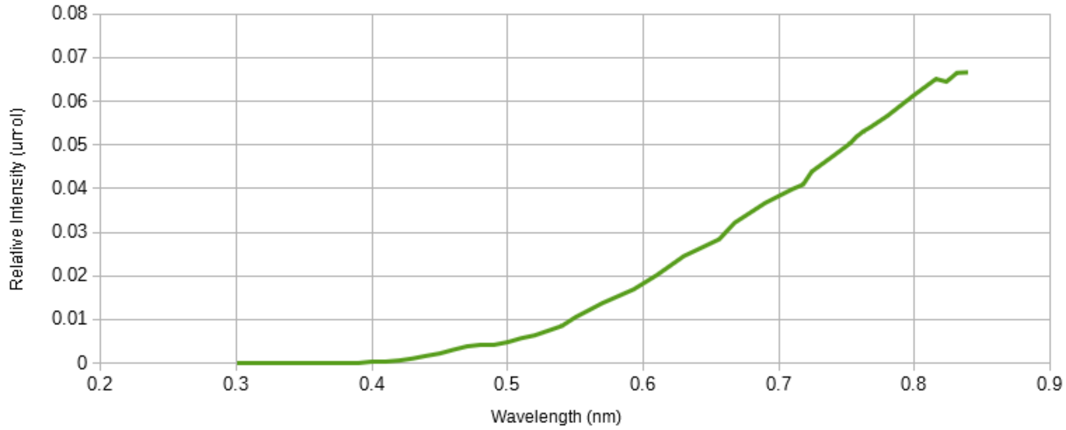


Figure 79 INCANDESCENT FROSTED 15W

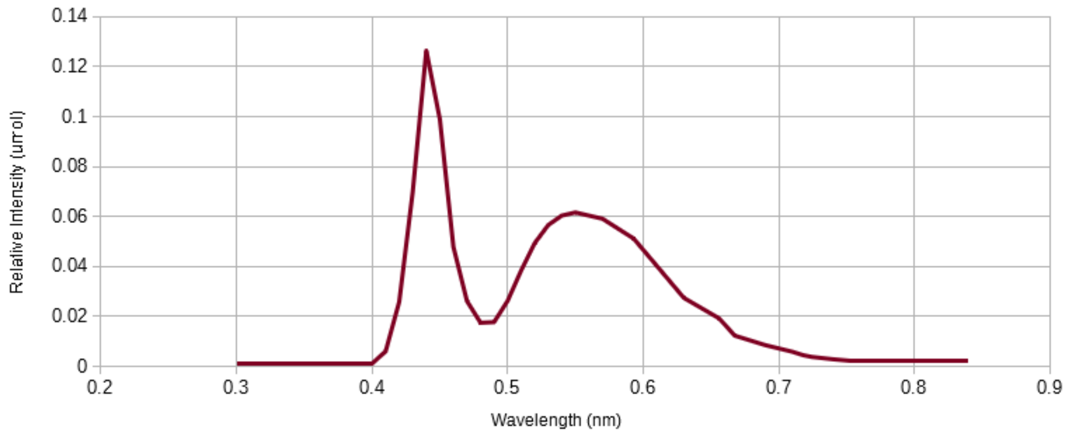


Figure 80 LED (PERCIVAL BAR) COOL WHITE

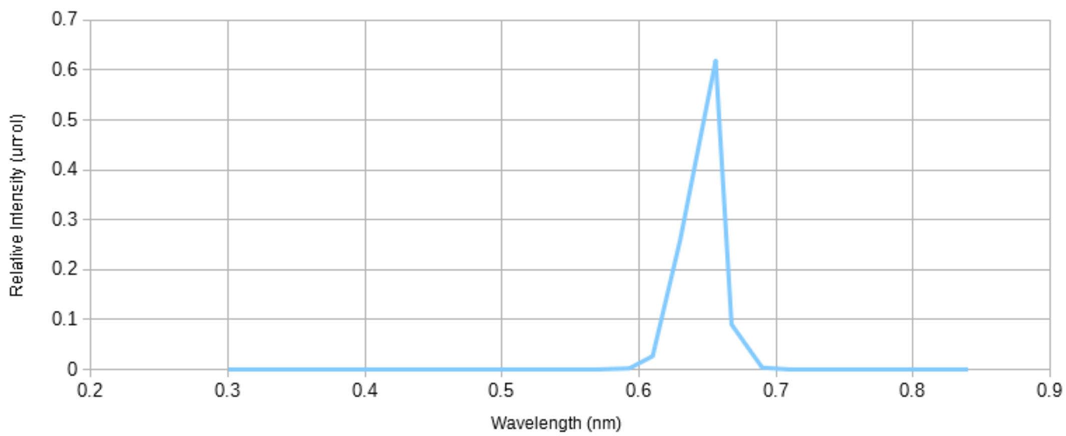


Figure 81 LED (PERCIVAL BAR) RED

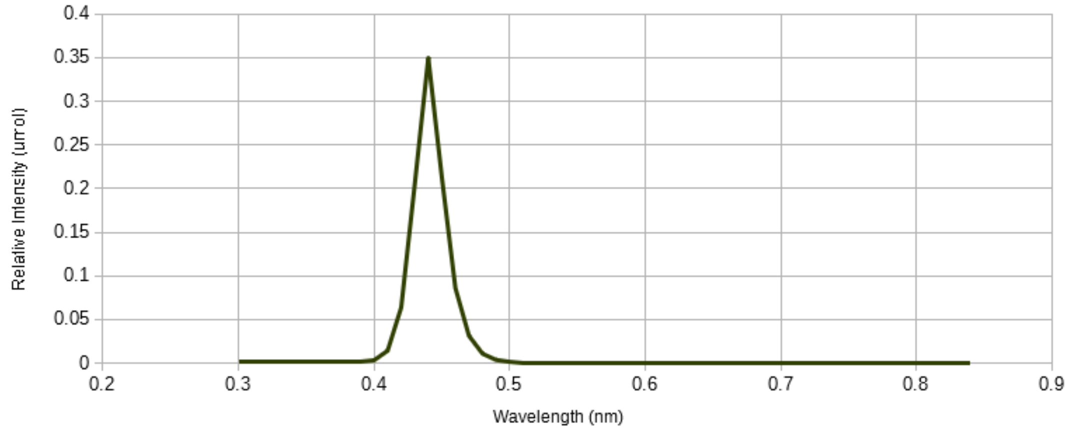


Figure 82 LED (PERCIVAL BAR) BLUE

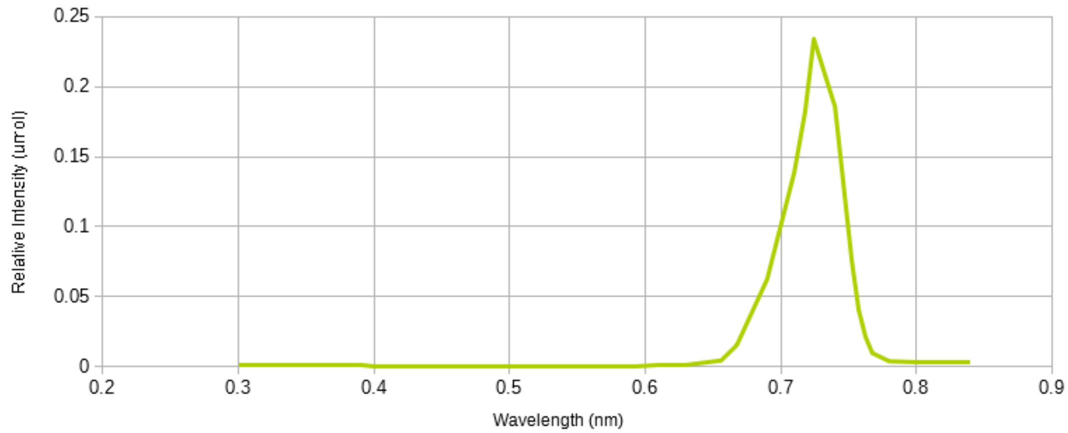


Figure 83 LED (PERCIVAL BAR) FAR RED

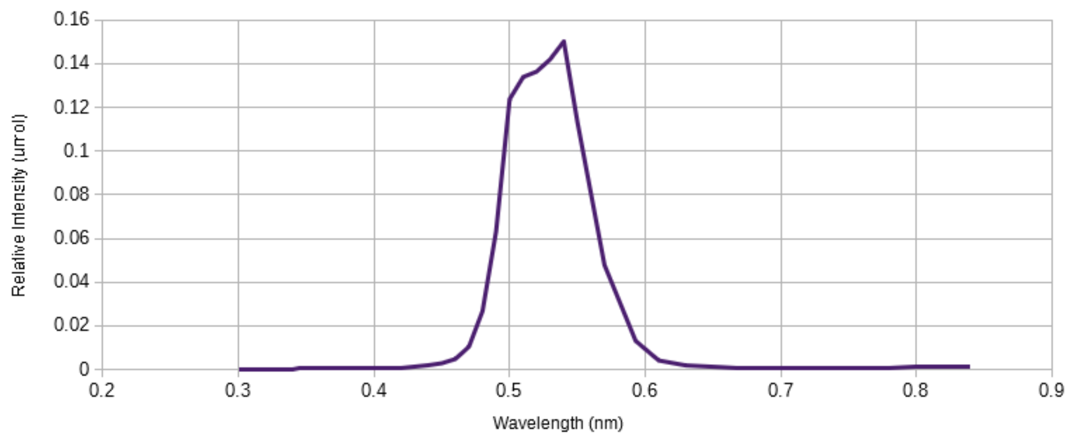


Figure 84 LED (PERCIVAL BAR) GREEN

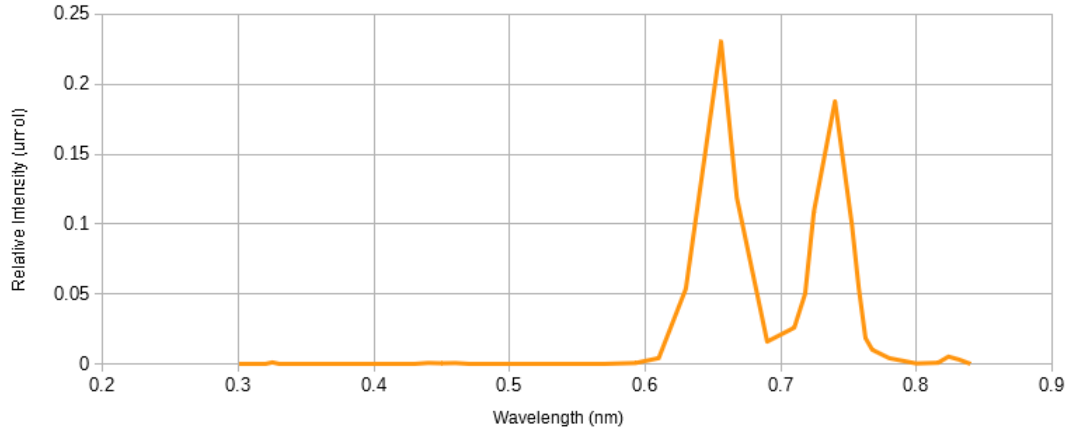


Figure 85 LED CLF GROLED (RED&FAR RED)

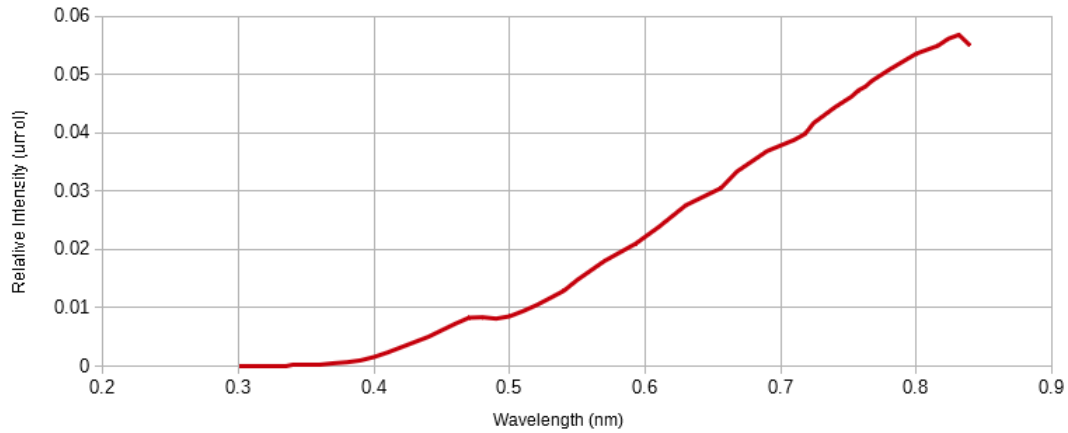


Figure 86 HALOGEN CLEAR (29W)

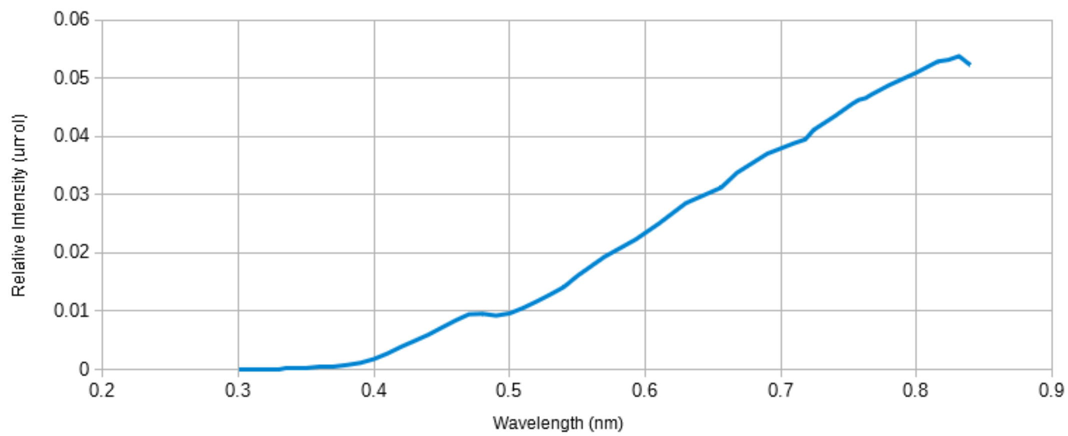


Figure 87 HALOGEN CLEAR (43W)

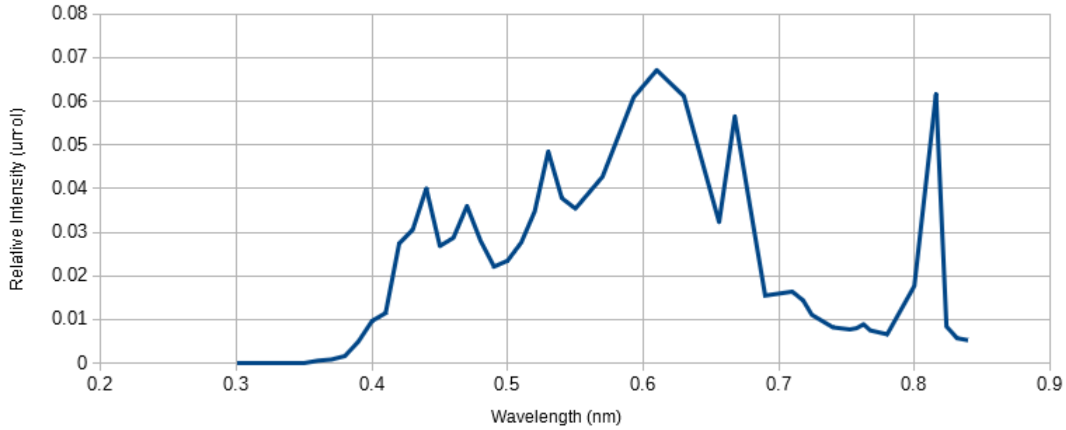


Figure 88 CMH 315W PHILIPS AGRO

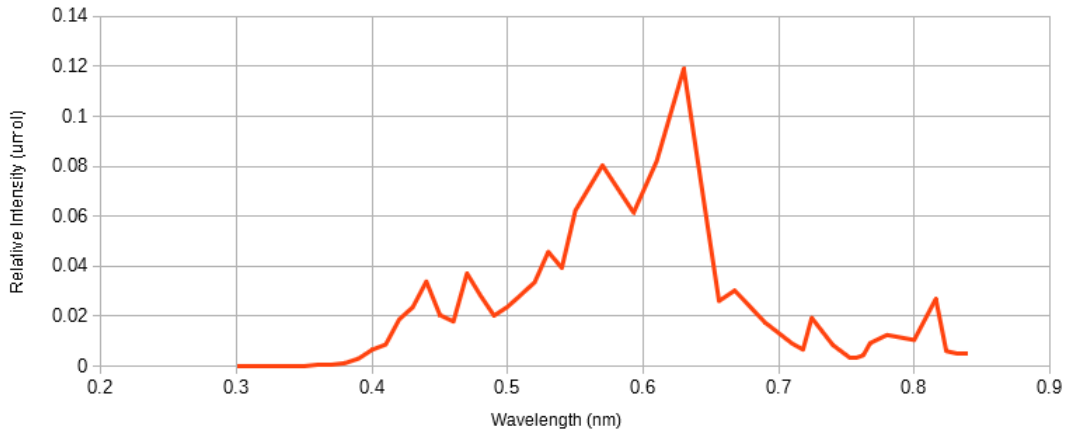


Figure 89 CMH 315W VENTURE 38821

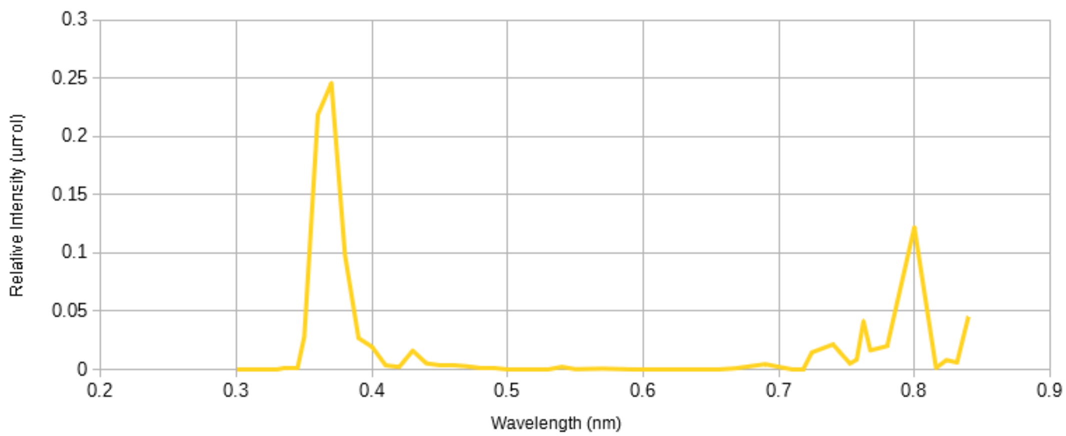


Figure 90 COMPACT FLOURESCENT-BLACK 13W FEIT BPESL15TBLB

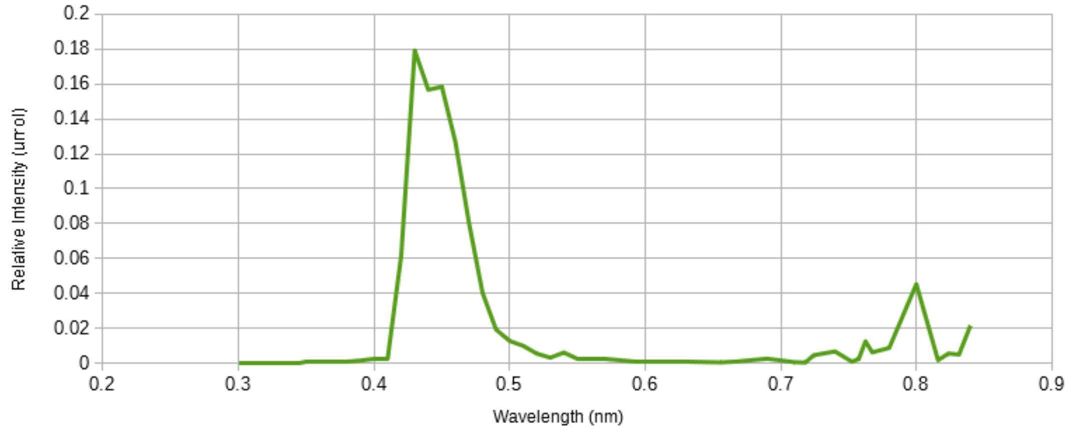


Figure 91 COMPACT FLOURESCENT-BLUE 13W FEIT BPESL13TBLB

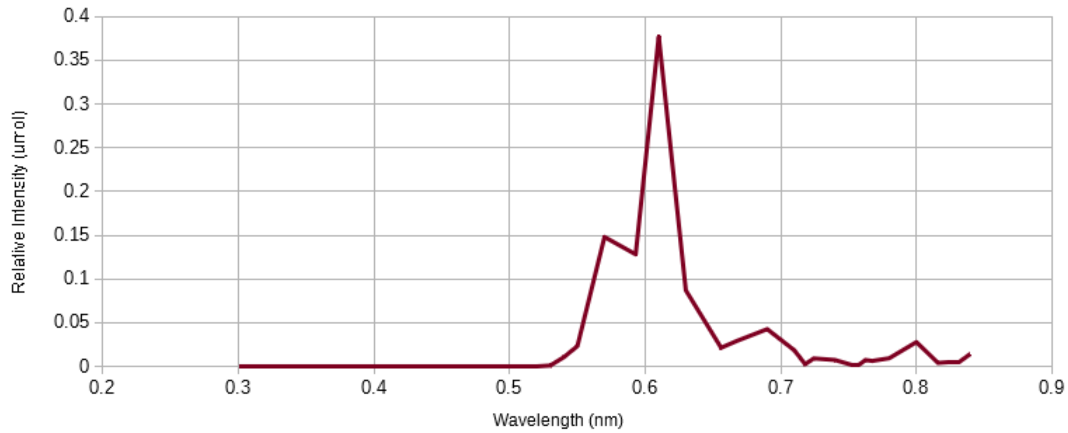


Figure 92 COMPACT FLOURESCENT-ORANGE 13W FEIT BPRSL13TO

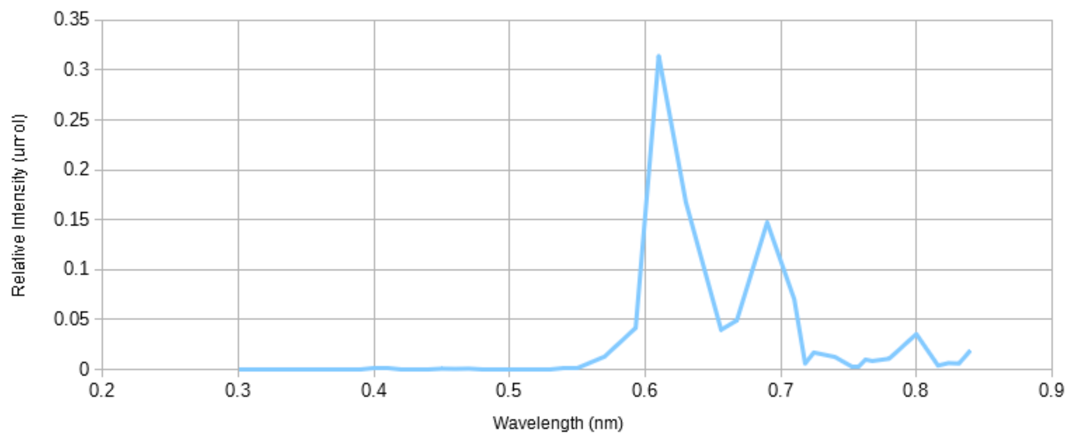


Figure 93 COMPACT FLOURESCENT-RED 13W FEIT BPRSL13TR

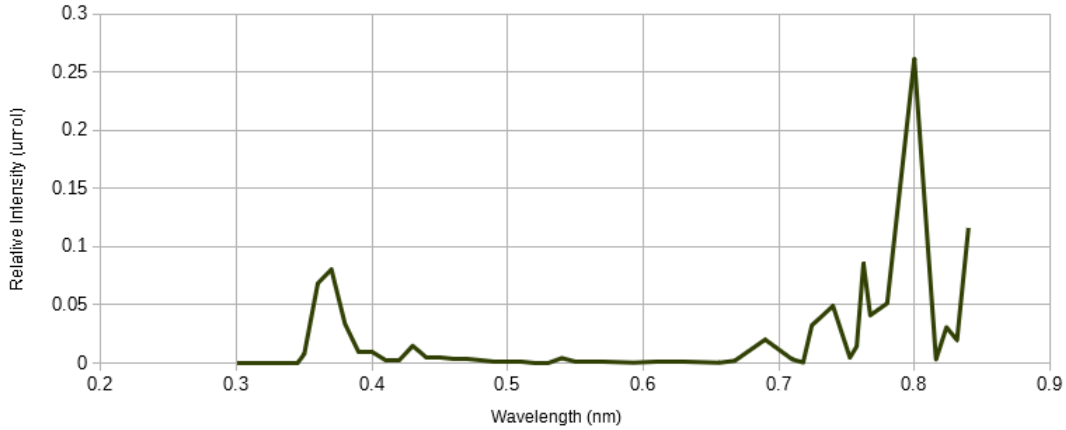


Figure 94 COMPACT FLOURESCENT-UVA SYLVANIA CF13ELSUPERBLACK

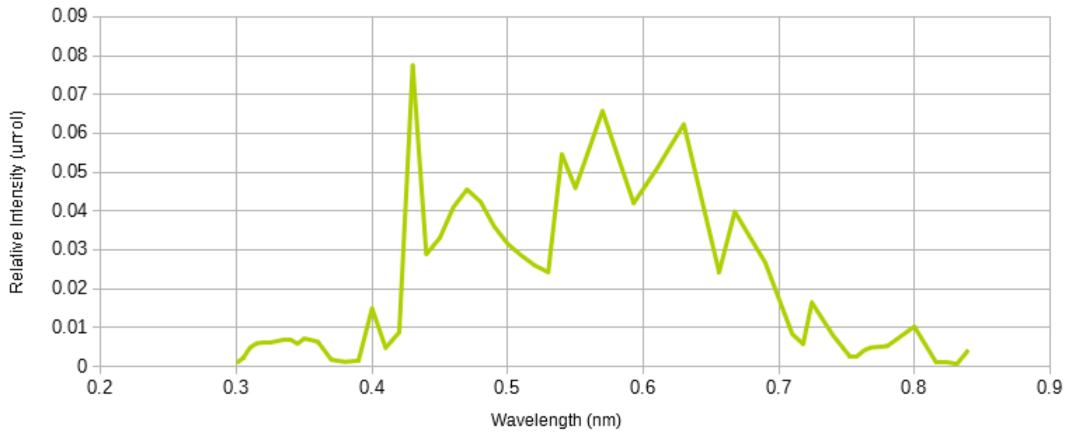


Figure 95 COMPACT FLOURESCENT-UVB REPTISUN 10

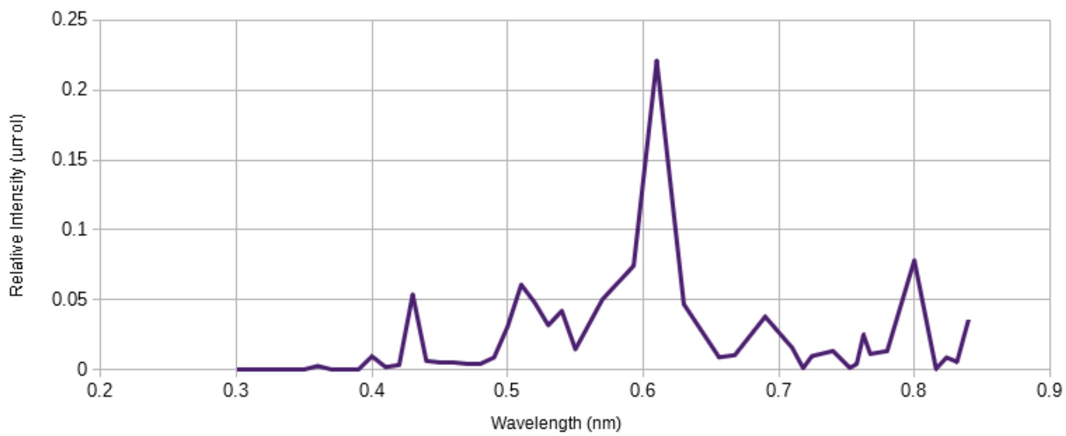


Figure 96 COMPACT FLOURESCENT-WHITE REVEAL 20W GEFLE20HT326HRVL

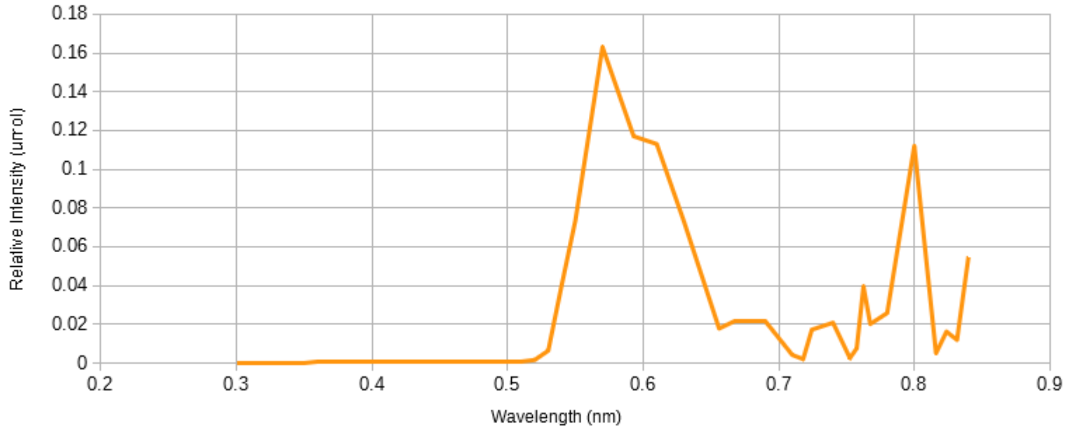


Figure 97 COMPACT FLOURESCENT-YELLOW 13W FEIT BPRSL13TR

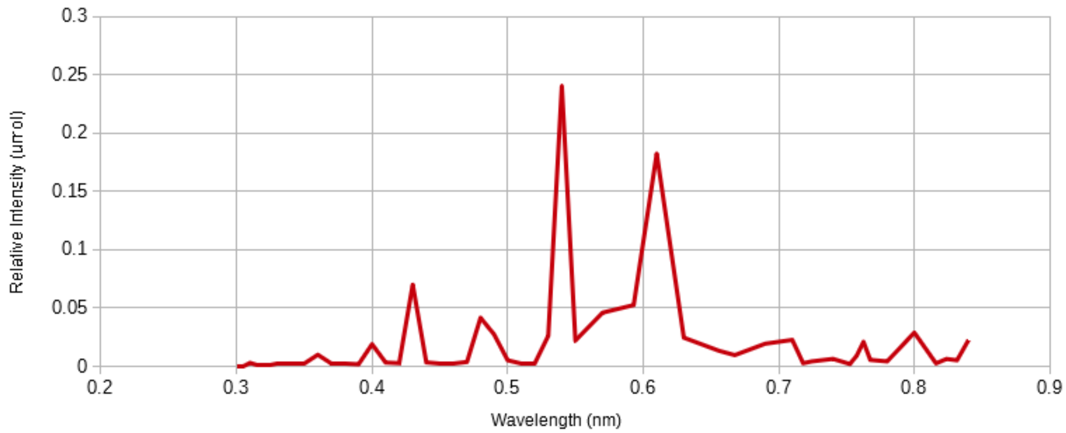


Figure 98 FLOURESCENT T5-AGROMAX F54T5HO BLOOM SPECTRUM

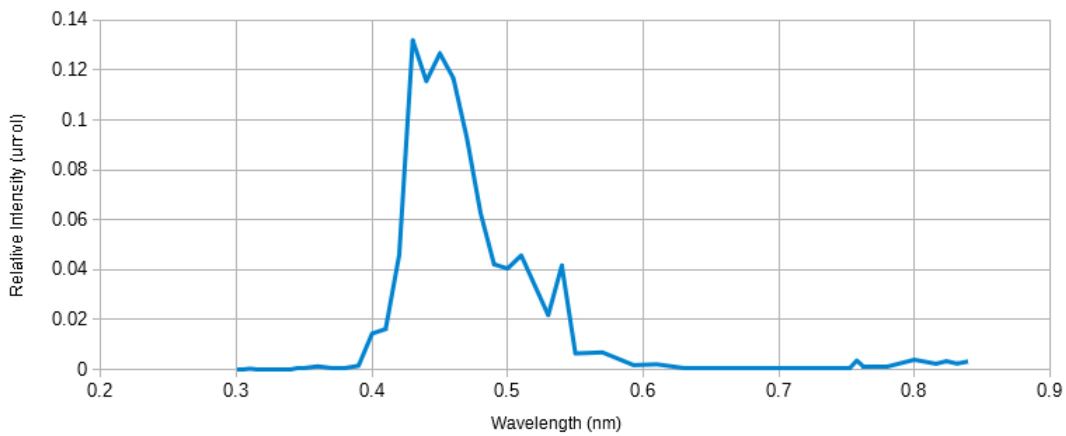


Figure 99 FLUORESCENT T5 - BLUE F54T5HO BLUE BY SUNLITE

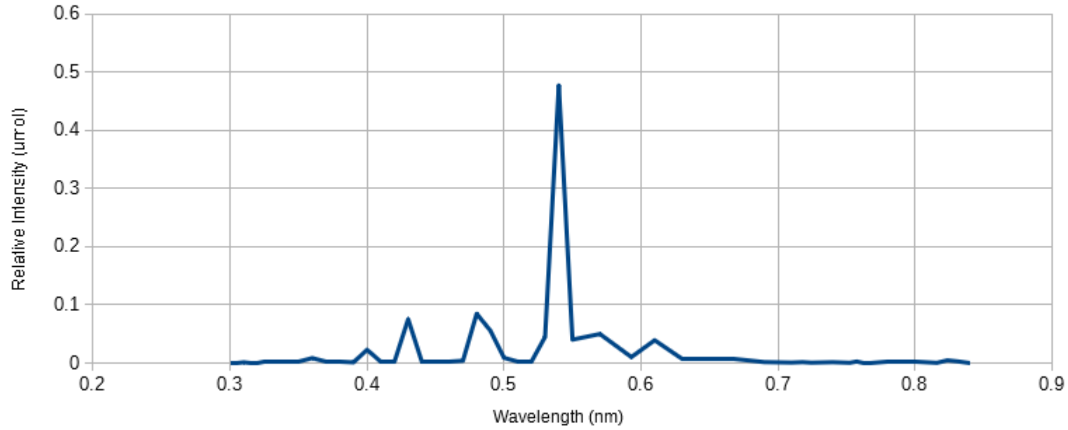


Figure 100 FLUORESCENT T5 - GREEN F54T5HO GREEN BY SUNLITE

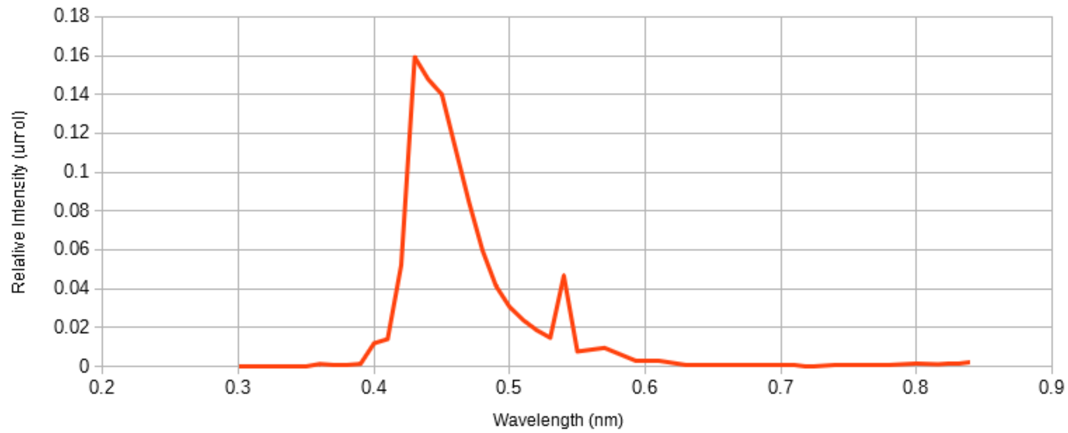


Figure 101 FLUORESCENT T5 - MARINE BLUE F54T5HO (BLUE) BY GLO

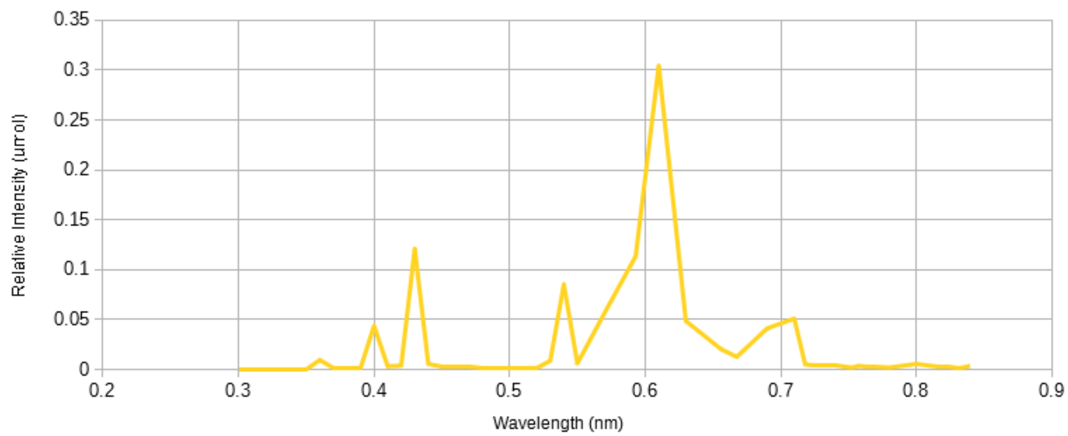


Figure 102 FLUORESCENT T5 - RED F54T5HO RED BY SUNLITE

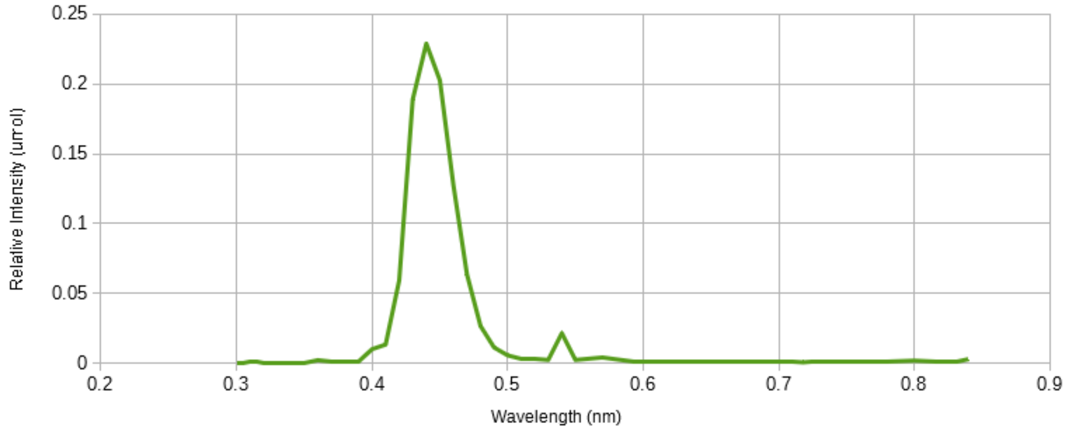


Figure 103 FLUORESCENT T8 - BLUE PERCIVAL LAMP

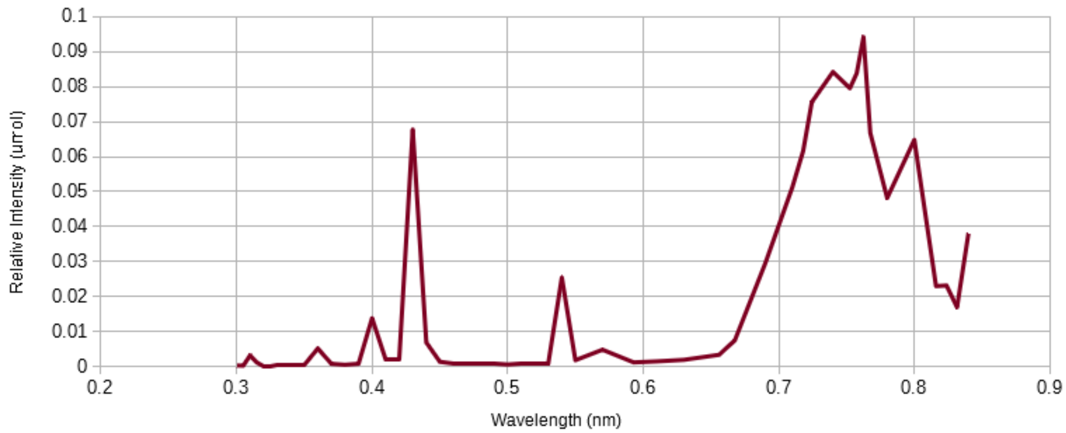


Figure 104 FLUORESCENT T8 - FAR RED PERCIVAL LAMP

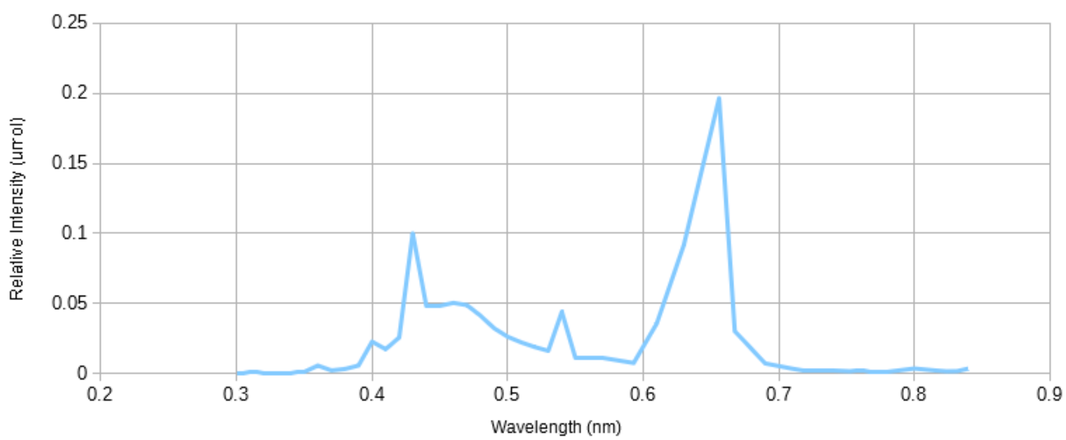


Figure 105 FLUORESCENT T8 - GROLITE NS

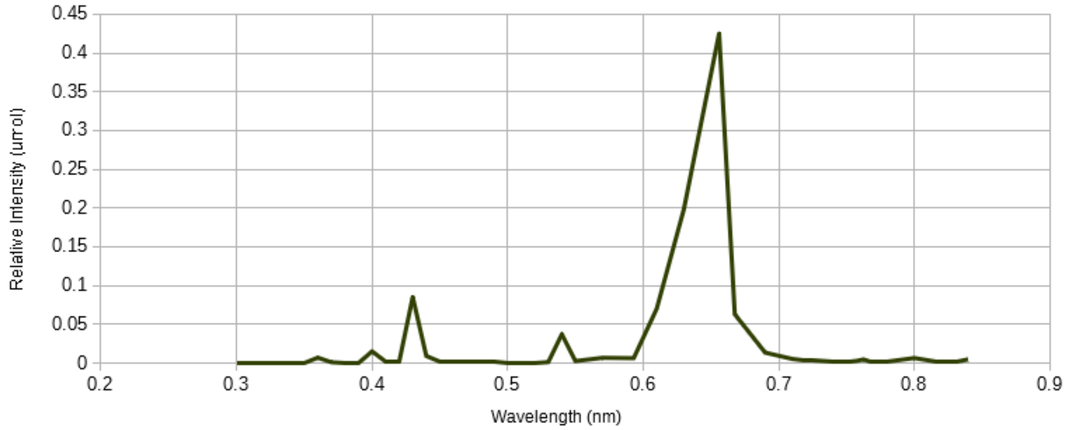


Figure 106 FLUORESCENT T8 - RED PERCIVAL LAMP

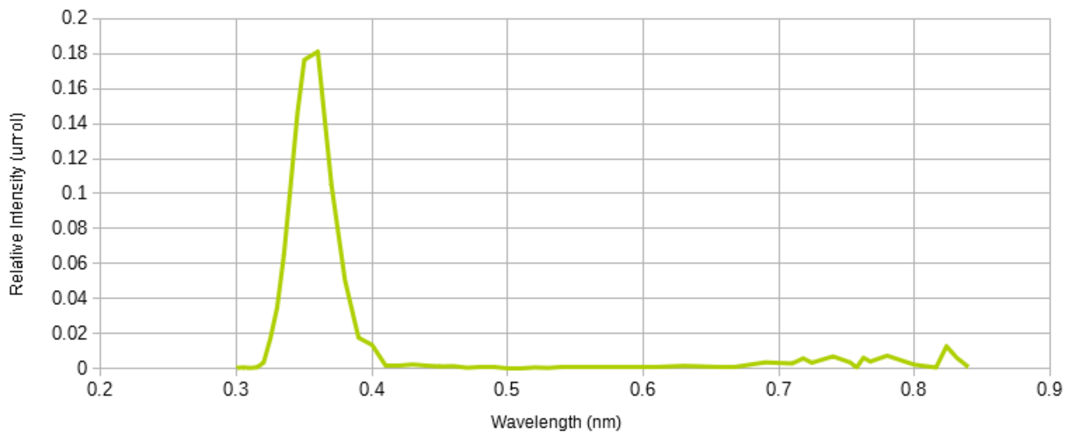


Figure 107 FLUORESCENT T8 - UVA F32T8BLB BY PROLUME

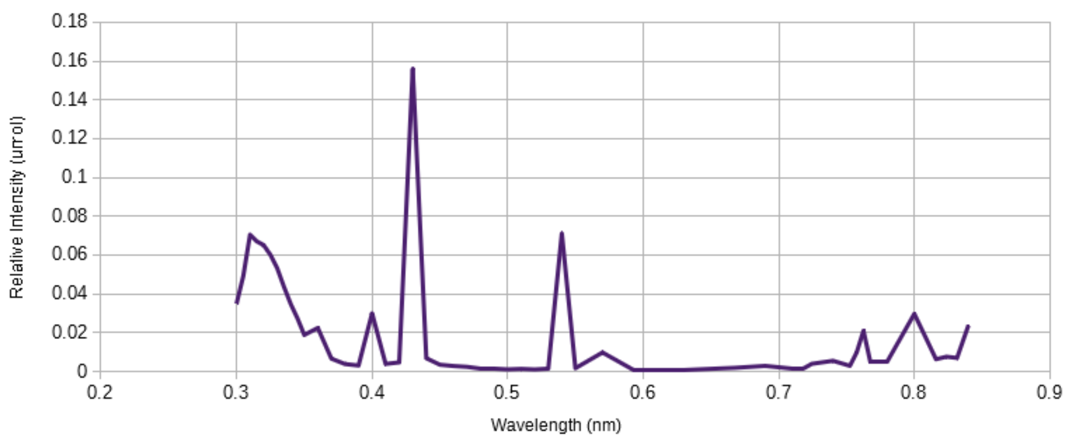


Figure 108 FLUORESCENT T8 - UVB

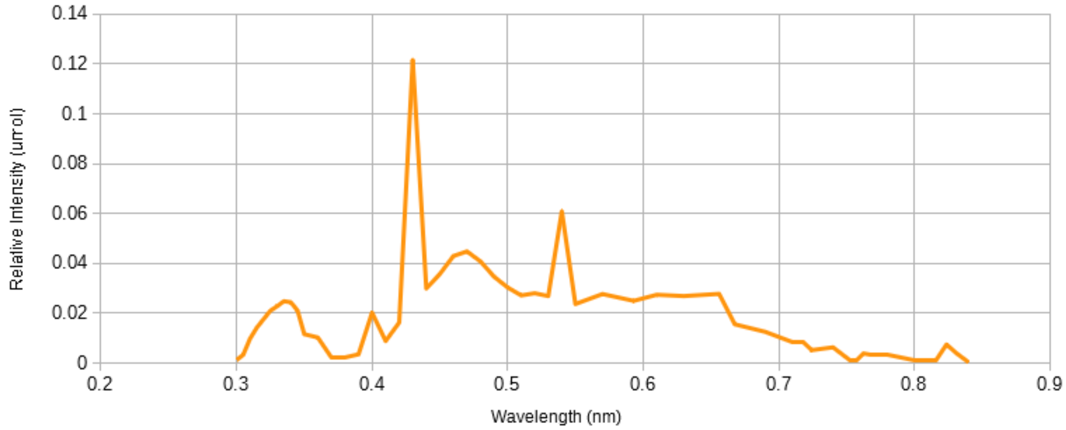


Figure 109 FLUORESCENT T8 - WHITE WITH UVB REPTISUN 5

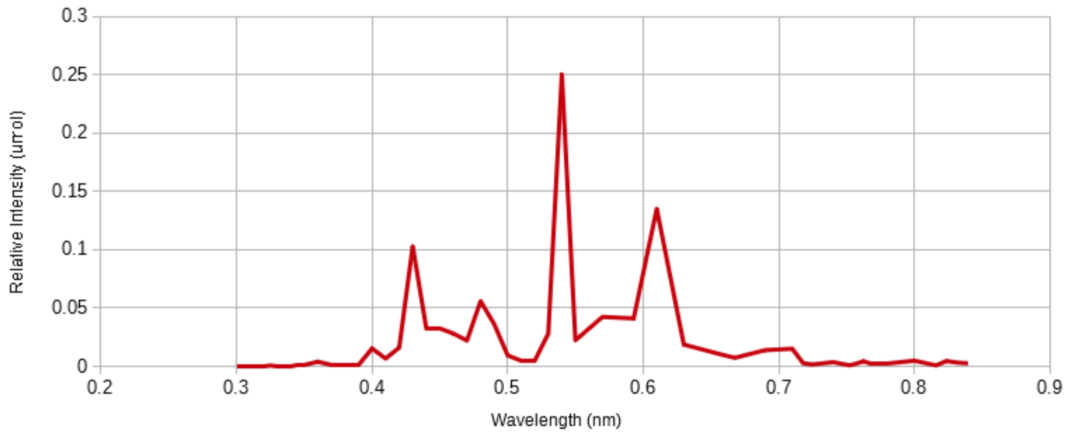


Figure 110 FLUORESCENT TWIN T5 - WHITE FT55W840 WHITE BY OSRAM

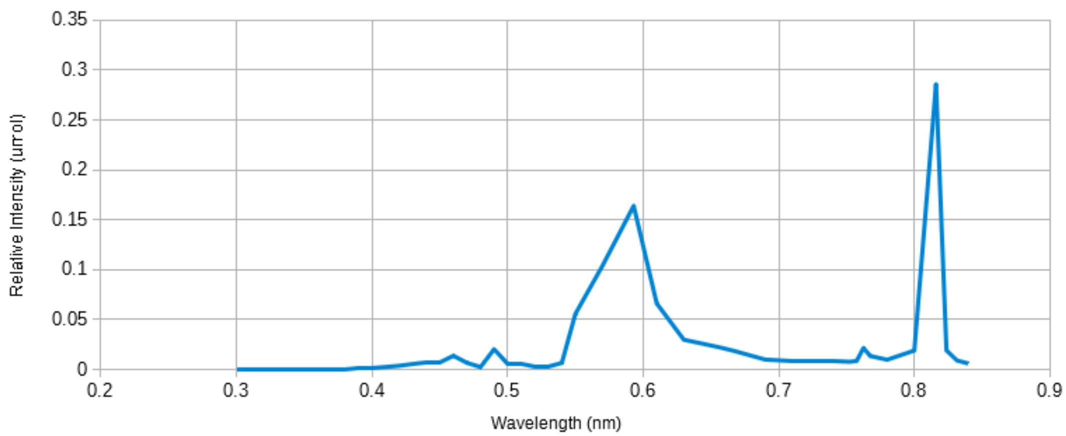


Figure 111 HPS 200W (LU200 SYLVANIA 67576)

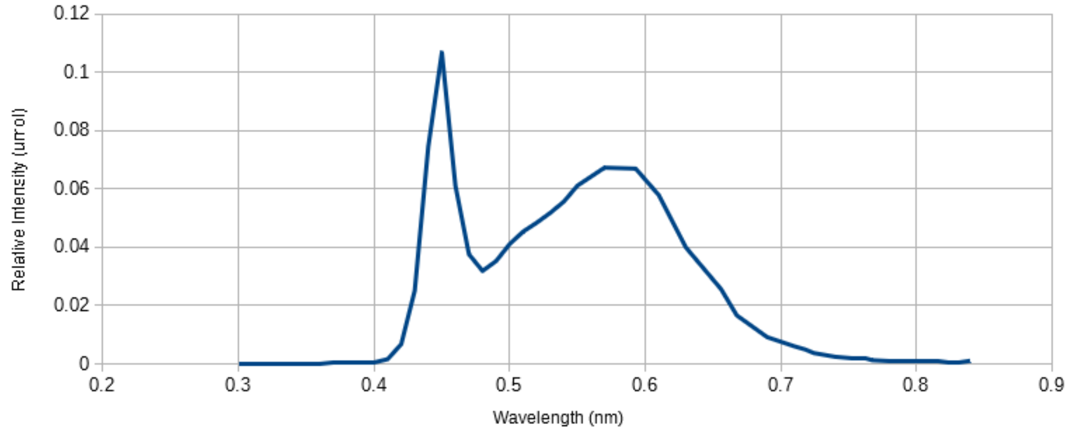


Figure 112 LED T8 PHILIPS INSTANT FIT CODE 433086

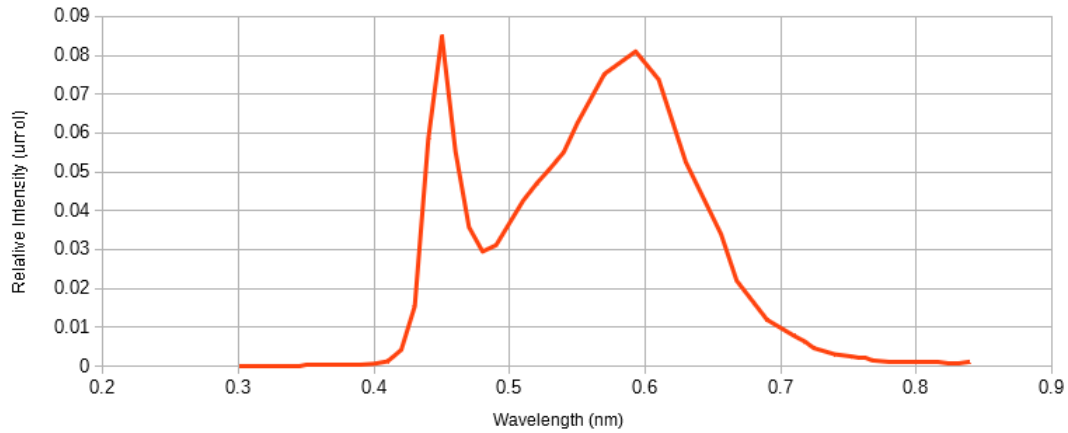


Figure 113 LED T8 PHILIPS INSTANT FIT CODE 456913

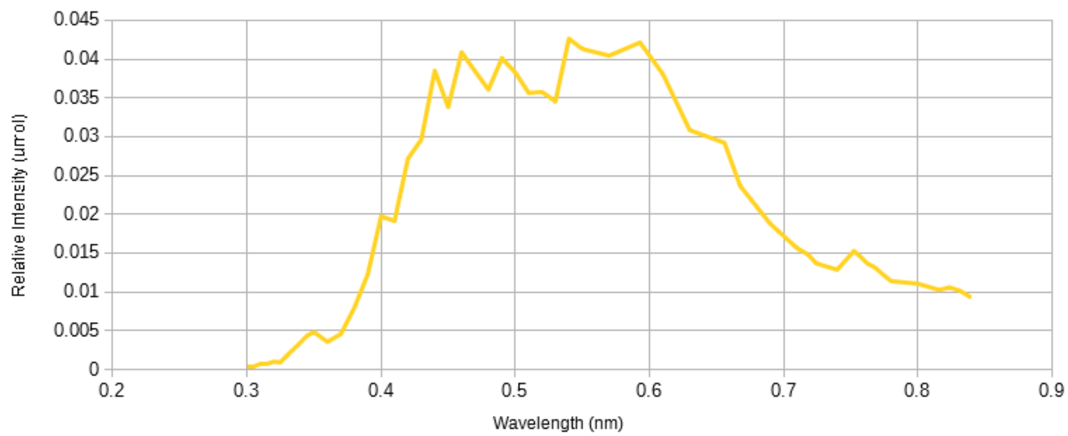


Figure 114 Plasma Lighting

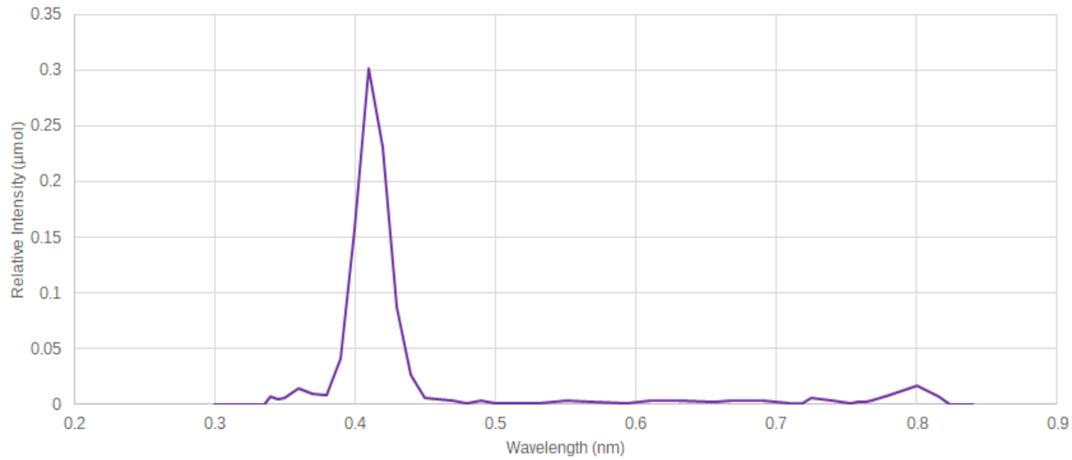


Figure 115 SciBrite Violet

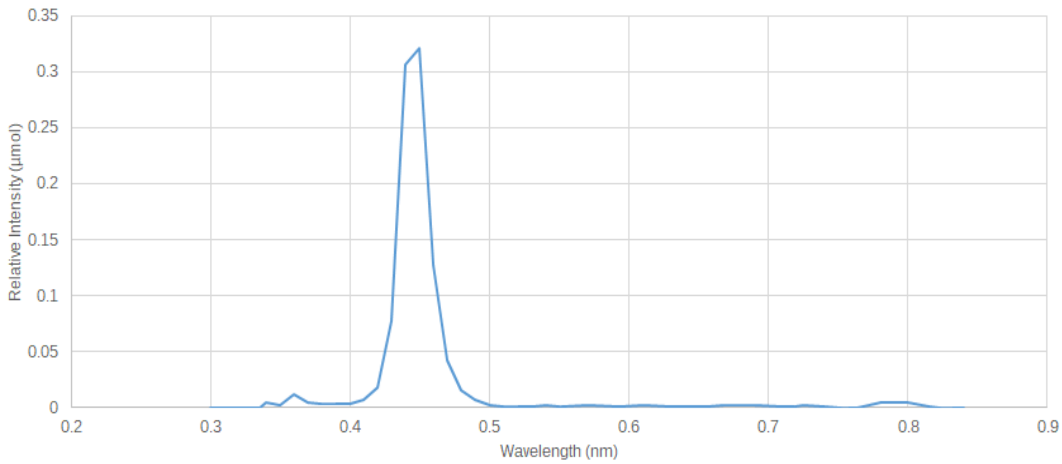


Figure 116 SciBrite Blue

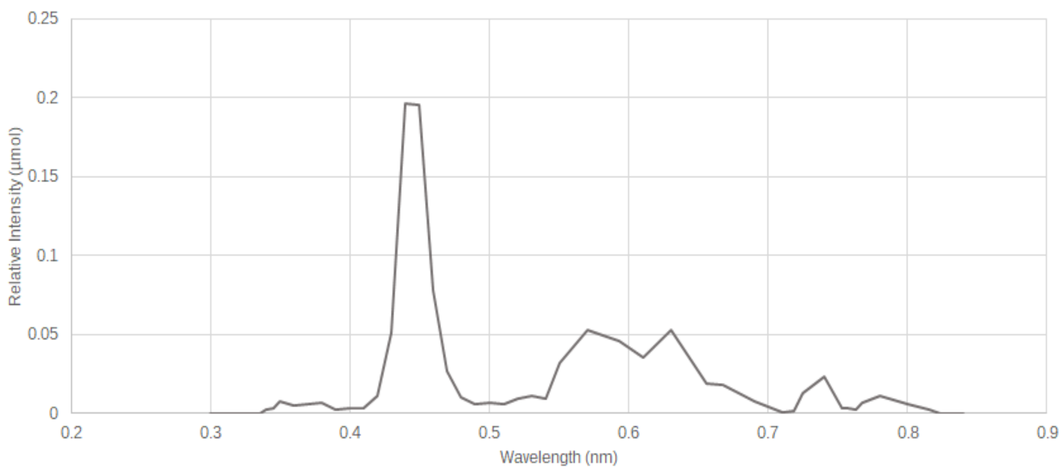


Figure 117 SciBrite Cool White

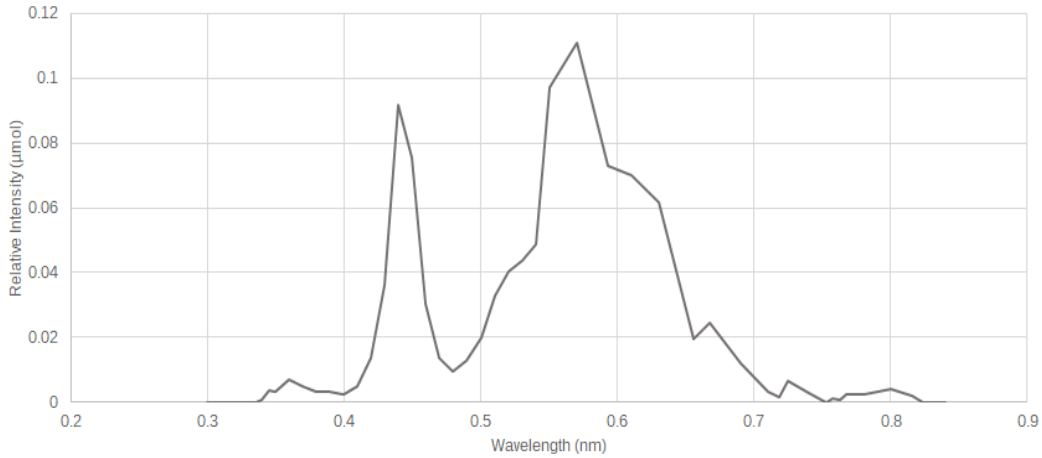


Figure 118 SciBrite Warm White

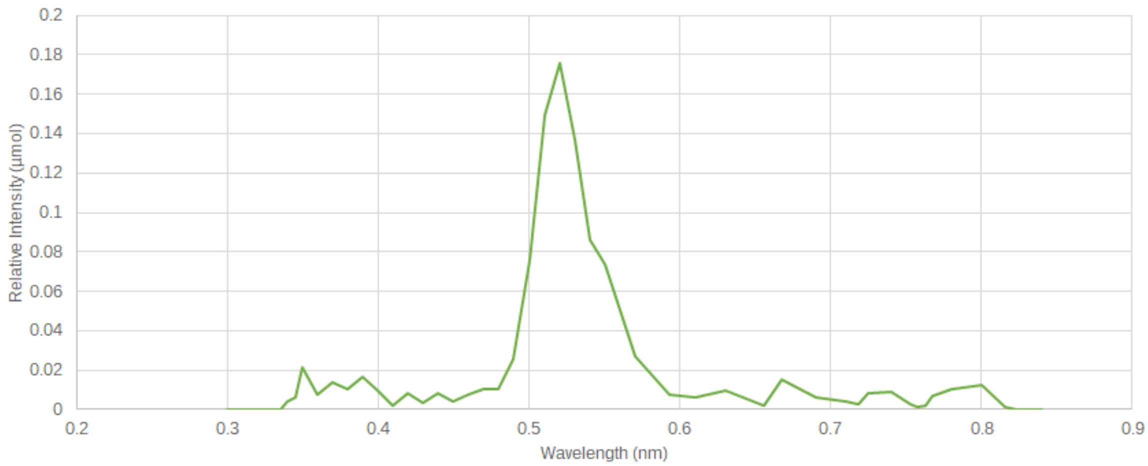


Figure 119 SciBrite Green

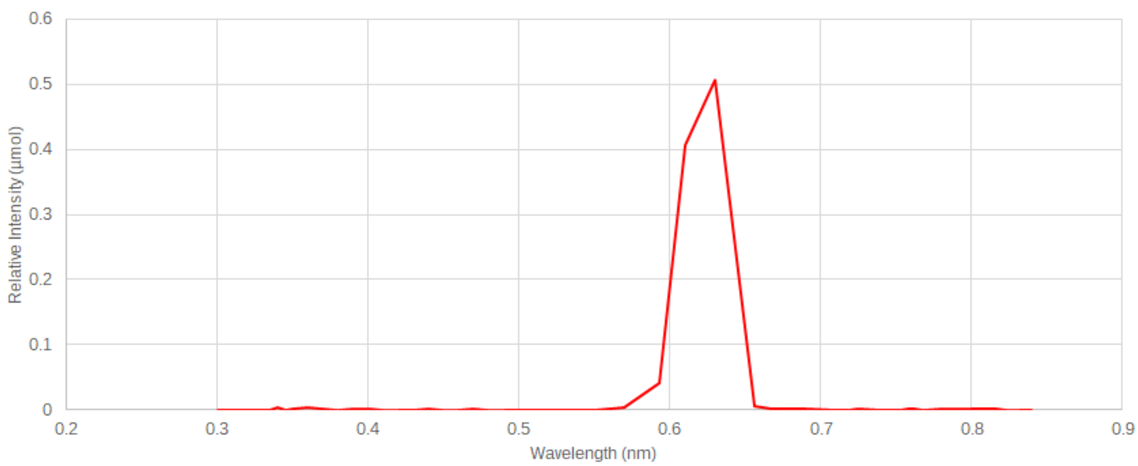


Figure 120 SciBrite 620 Red

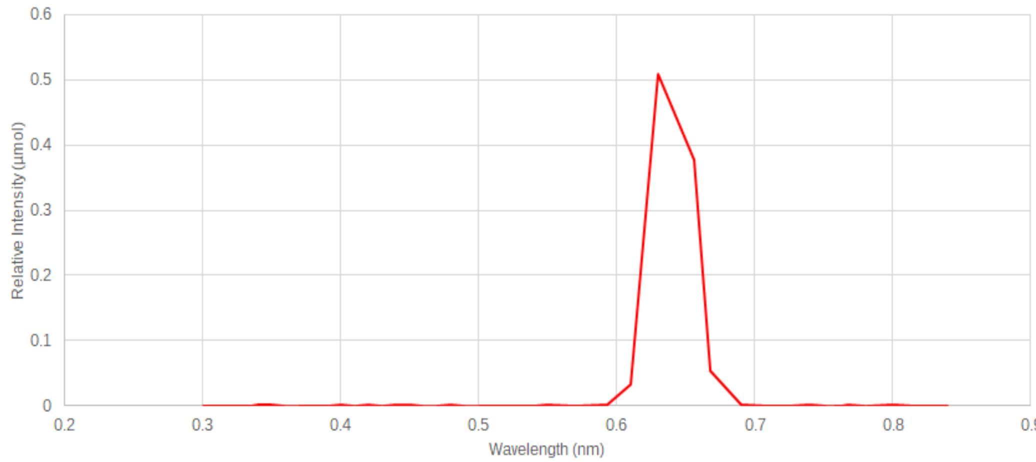


Figure 121 SciBrite 660 Red

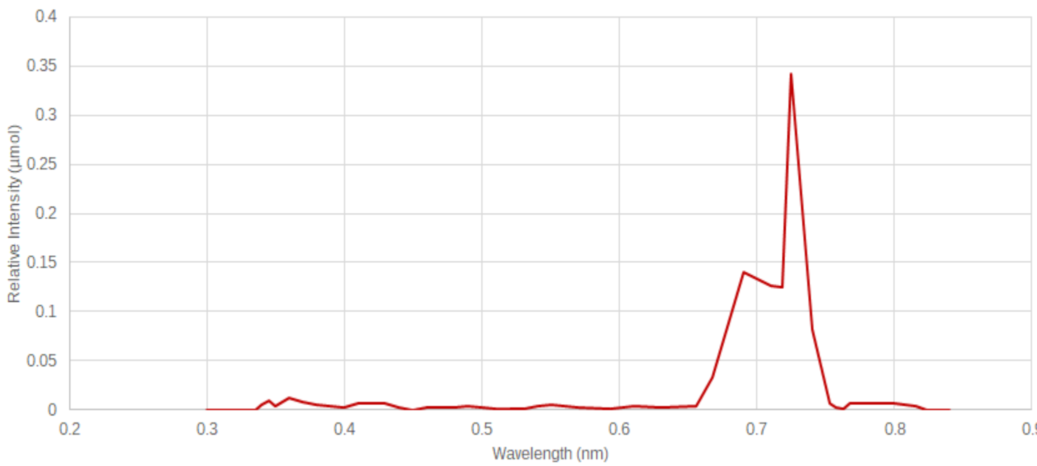


Figure 122 SciBrite Far Red