Two of the key factors in assessing the levels of thermally induced stress generated are the intensity of incident solar radiation and the ambient temperature variations.

INCIDENT SOLAR RADIATION

Incident solar radiation will directly influence the temperature of the glass, and the intensity of solar radiation varies throughout the day and the year, and is also dependent on several other factors, including;

- Location
- Orientation
- Slope
- Altitude
- Atmospheric Haze/Pollution and Cloud Cover
- Ground Reflectance

LOCATION

The intensity of solar radiation will vary depending on location For example; comparing locations at 40°, 50° and 60° North during August, at a vertical inclination and south facing, gives an increase in incident solar radiation at a greater distance North from the equator:

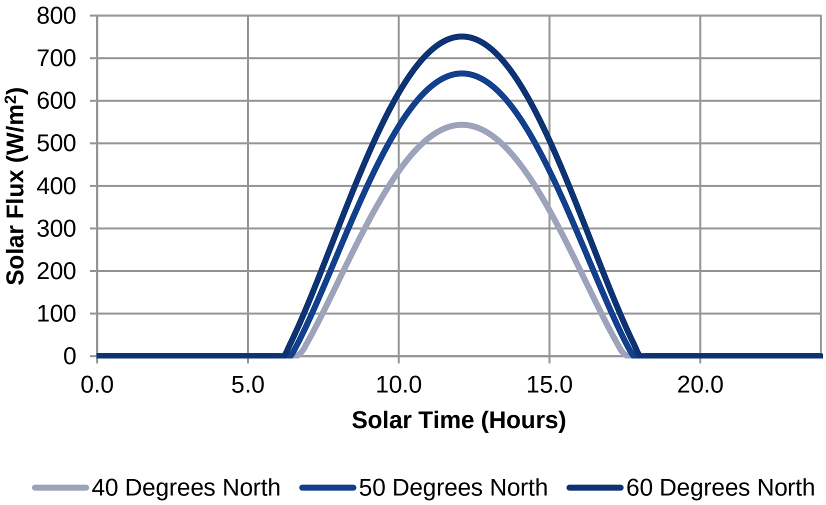


Figure 1 - Solar Flux by Latitude

ORIENTATION

Orientation has a significant impact on the levels of solar radiation, with South, South East and South West giving the highest levels in the northern hemisphere for vertical surfaces. North facing is subject to only low levels of solar radiation, predominantly from diffuse radiation scattered in the atmosphere and ground reflectance.

The below data shows the maximum intensity of annual solar radiation (W/m^2) incident on vertical glazing at a latitude of 55º North;

Table 1 - Solar Flux by Orientation

Orientation	Maximum Intensity of Incident Solar Radiation (W/m^2)
North	258
North East	615
East	790
South East	794
South	794
South West	794
West	790
North West	615

INCLINATION/SLOPE

As with orientation, slope also has a significant effect. In the UK, an angle in the region of 35º from horizontal is considered to be the optimum for obtaining maximum solar irradiance for solar panels. As such, glazing that is at a slope will also be subjected to greater levels of incident solar radiation than vertical units.

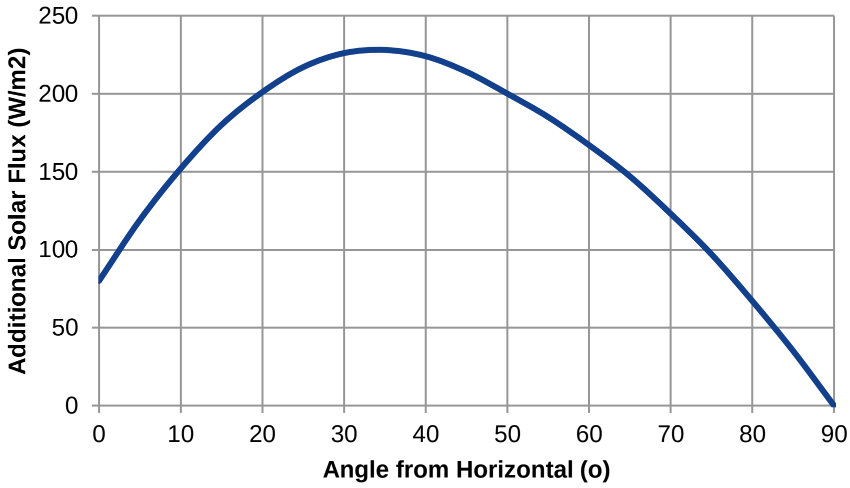


Figure 2 - Solar Flux by Slope

In additional, the external and internal heat transfer coefficients will also change, altering the rate of heat loss or gain within the units.

GROUND REFLECTANCE

Even areas of buildings under shading from direct sunlight will have some level of diffuse incident solar energy as a result of ground reflectance, or albedo. Incident solar energy is reflected by the ground to varying degrees, predominantly dependent upon the nature of the terrain and the angle of incident sunlight.

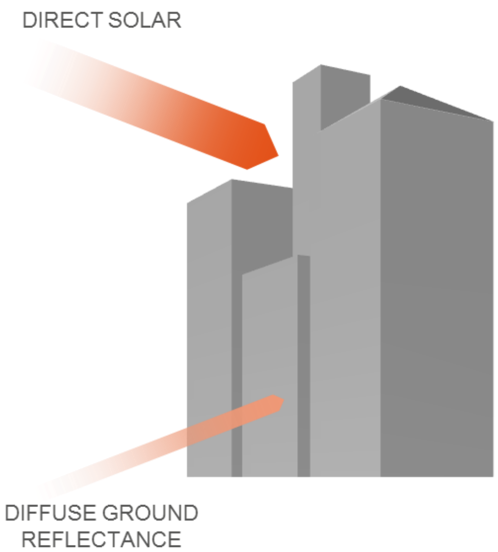


Figure 3 - Illustration of Incident Solar Flux

Built up areas would be expected to generate less ground reflectance, primarily due to the reduced level of direct solar energy reaching the ground due to shading from buildings. The reflectance of the ground surfaces may also influence the level of ground reflectance, with asphalt being a relatively poor reflector.

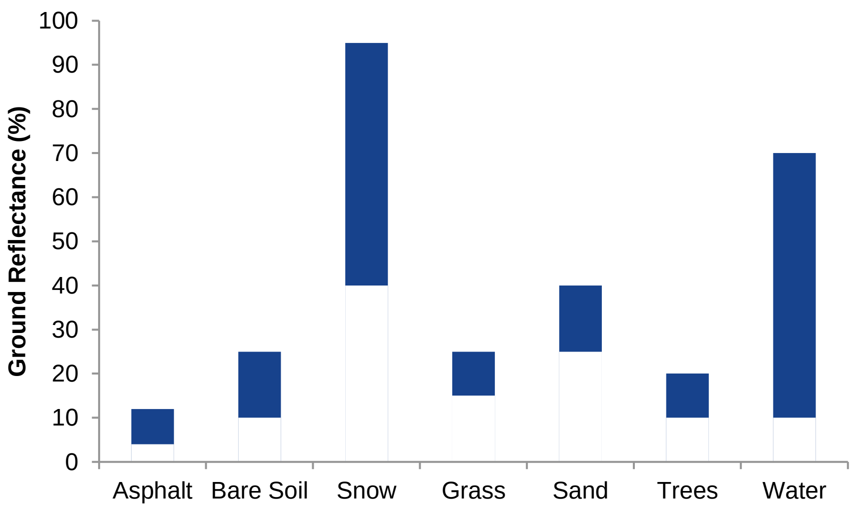


Figure 4 - Ground Reflectance by Surface

For calculation purposes, ground diffuse reflectance is often approximated based on the level of direct solar radiation.

CLOUD COVER & HAZE

Cloud cover will reduce the intensity of incident solar radiation. As such, on cloudy days, the level of heat build-up in glass will be lower. When assessing thermal safety, consideration is given to clear sky solar intensity, as this will provide the potential worst case condition.

Haze/pollution is a combination of smoke, dust and other airborne particulate matter, which can reduce the air quality and absorb some solar radiation, thus reducing the level of incident solar radiation to the ground or buildings. This will influence both direct solar radiation and ground reflected diffuse radiation as well. In essence, higher levels of pollution will be marginally beneficial for thermal safety, but to consider the worst case scenario, this factor is typically ignored.

ALTITUDE

Solar energy intensity is increased at higher altitudes, due to the reduced absolute air mass, which is a measure of the absorbing and scattering of incident solar radiation.

For this reason, when assessing thermal safety, areas of higher altitude will be subject to higher maximum levels of incident solar radiation. The below chart shows the increase in solar radiation intensity for vertical south facing glazing at latitude of 55º North;

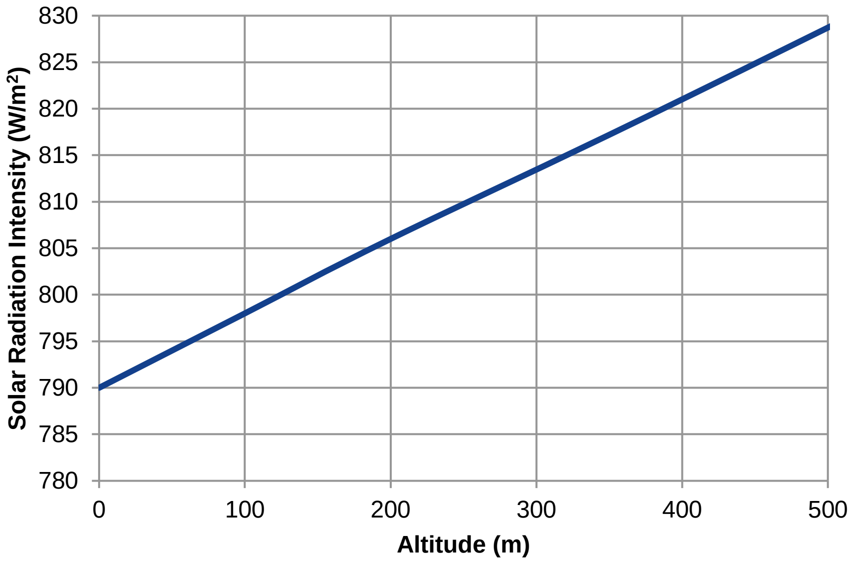


Figure 5 - Solar Flux by Altitude

ANNUAL SOLAR IRRADIANCE

Based on the above factors, the solar flux incident on glazing in a specific orientation can be plotted for the year, and from this the peak solar radiation intensity can be determined. The below example shows a plot for a full calendar year for a vertical pane at a latitude of 55º North, East facing;

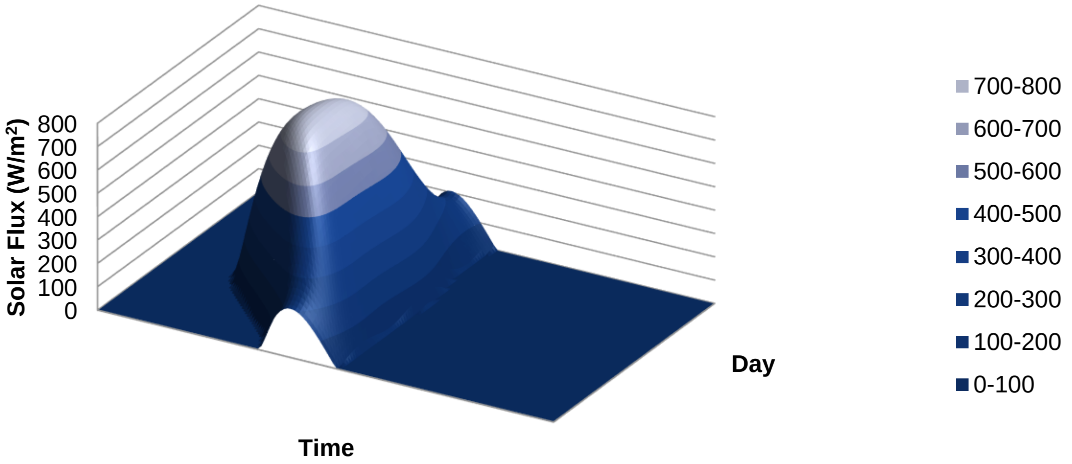


Figure 6 - Annual Solar Irradiance Profile

Incorporating diffuse solar radiation, and ground reflectance, this provides a peak flux of 768 W/m^2 on the 175th day of the year.

THE DIURNAL RANGE

The diurnal range, which is the temperature variation throughout the day, is an important consideration for thermal safety, as due to the thermal inertia (rate of conductance of heat) of framing systems, the temperature of the glass edge will typically lag that of the exposed glass, generating additional thermal stress across the glass.

Temperatures increase throughout the day as incident solar radiation warms up the Earth's atmosphere, and typically the maximum temperature will occur a couple of hours after solar radiation levels are at their peak, at around 14:00 hours. However, this will vary depending on cloud cover. A chart of temperatures throughout the day during January and July is shown below as an example.

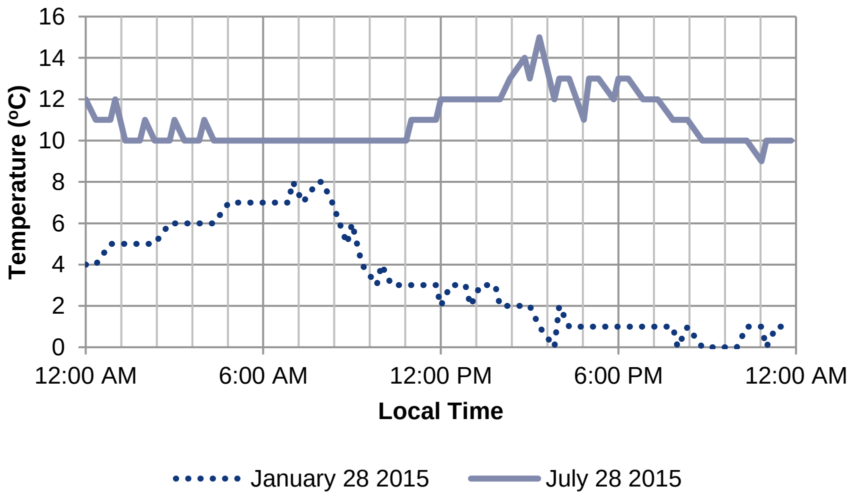


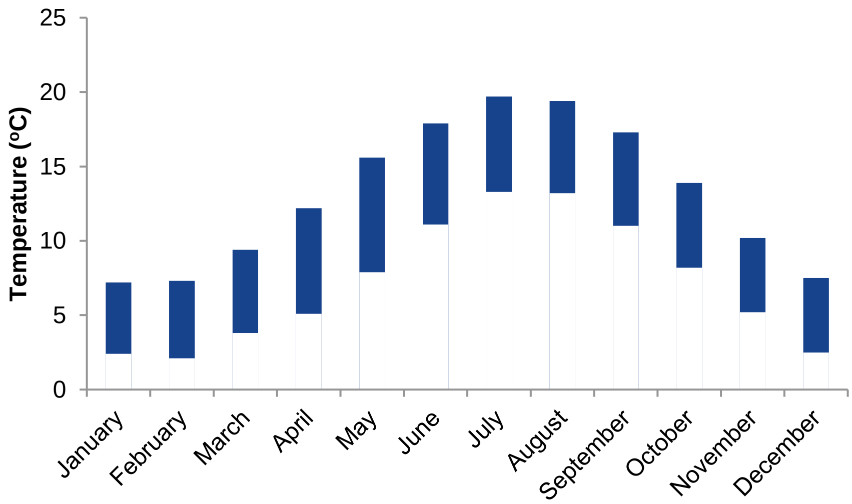
Figure 7 - Diurnal Temperature Profiles

Due to variations in the maximum and minimum temperatures between days within a month, with a low likelihood of the highest and lowest temperatures in a month occurring on the same day, the diurnal range is typically based on the average for each month, and the worst month taken as the value for the purposes of calculation.

The below table and chart show typical data obtained for a location in the North West of the UK.

Table 2 - North West UK, Average Temperatures

Month	Average Maximum (ºC)	Average Minimum (ºC)	Average Diurnal Range (ºC)
January	7.2	2.4	4.8
February	7.3	2.1	5.2
March	9.4	3.8	5.6
April	12.2	5.1	7.1
May	15.6	7.9	7.7
June	17.9	11.1	6.8
July	19.7	13.3	6.4
August	19.4	13.2	6.2
September	17.3	11	6.3
October	13.9	8.2	5.7
November	10.2	5.2	5
December	7.5	2.5	5



Diurnal temperature ranges will vary depending on the local climate, with coastal and higher altitude areas, typically showing a reduced diurnal temperature variation. For calculations, diurnal ranges throughout the UK can be considered. The below map, overlaid with peak average diurnal temperature ranges, shows the aforementioned trend;

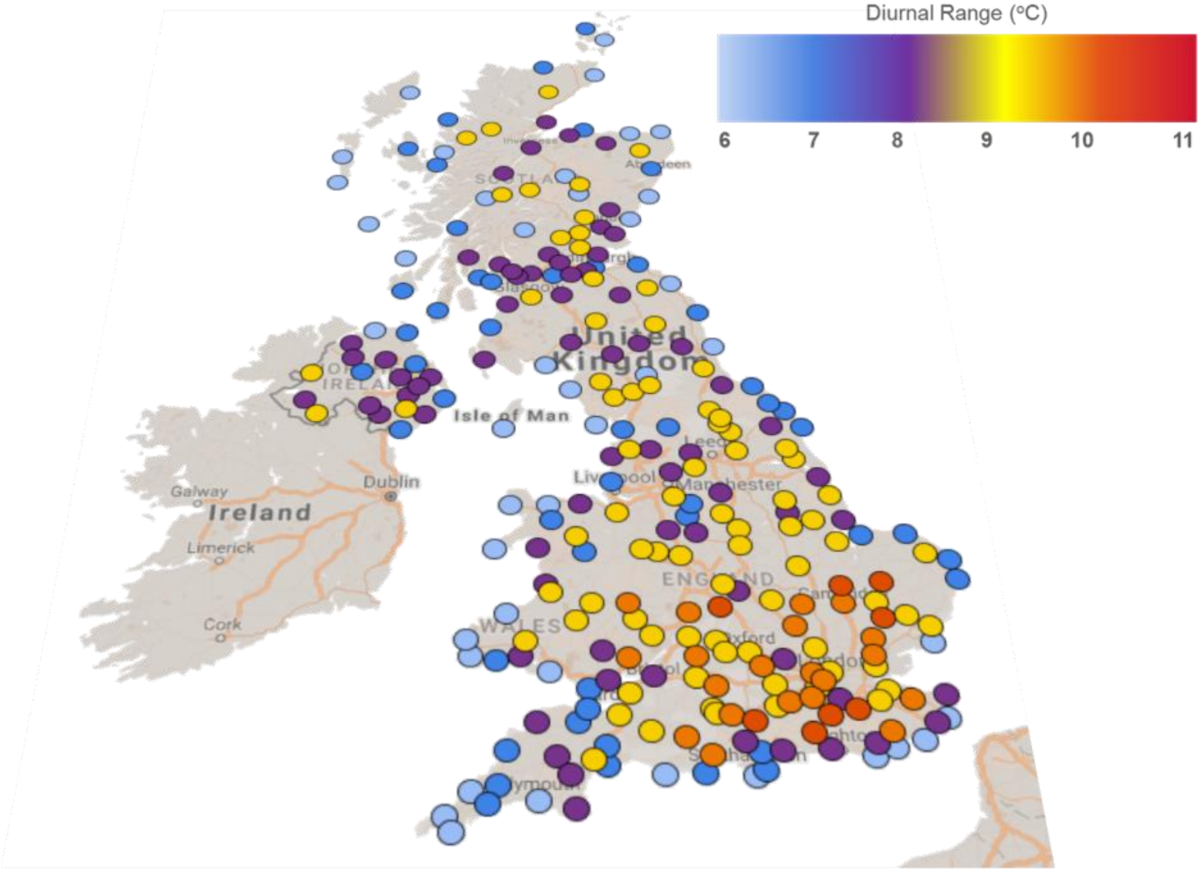


Figure 8 - UK Diurnal Temperatures