Monthly Analysis on the microgen-database.org.uk Website

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Outline

- What is PR?
- Spec Efficiency
- Achieved Efficiency
    - Calculating system generation
    - Interpolating irradiance
    - Calculating irradiance received
- Computation
- What's Next?

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What is PR?

- Performance Ratio (PR) is a measure of PV performance that takes into account azimuth, elevation, weather and panel spec...

  ... but NOT shading, temperature or system losses

$$PR = \frac{\eta_{achieved}}{\eta_{spec}} \times 100\%$$

$$\eta_{achieved} \equiv Achieved\ Efficiency$$
$$\eta_{spec} \equiv Spec\ Efficiency$$

Spec Efficiency

- Efficiency of panels under Standard Test Conditions (STC):
  - Irradiance: 1000 W/m²
  - Air Mass Coefficient: AM 1.5 global
  - Temperature: 25°C
- Values sourced from external database:

Photon.info
The World of Information in the World of Solar Electricity

- Provides a means to normalise performance to panel specification, but fails to take into account panel response to different frequencies of light and temperatures

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Achieved Efficiency

$$\eta_{achieved} = \frac{G}{I_{received}}$$

- Calculated on a per-month basis
- Calculate G from MgDb readings
- Calculate $I_{received}$ from Met Office's MIDAS dataset

$$G \equiv Achieved\ Generation$$
$$I_{received} \equiv Irradiance\ Received\ (a.k.a\ H_T)$$

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Calculate System Generation

- Three possible scenarios:
  1) Readings available before sunrise on first day of month AND after sunset on last day of month – Little/no error
  2) Readings available within 10 days of start AND end of month AND MIDAS data available for months 1, 2 and 3 – More error
  3) Readings available within 10 days of start AND end of month BUT MIDAS data unavailable – Even more error
- Can cause results to vary month on month as extra readings are added or new MIDAS data becomes available

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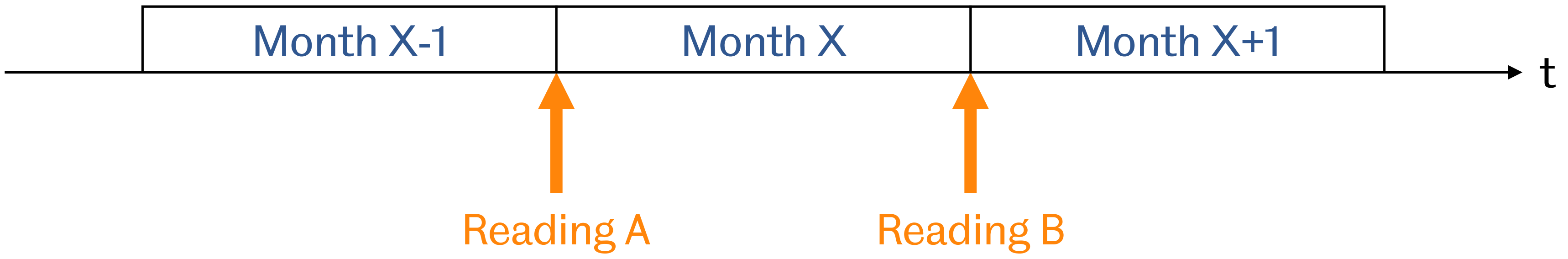
Calculate System Generation: Scenario 1

- Readings available before sunrise on first day of month AND after sunset on last day of month – Little/no error



$$G = B - A$$

- Fastest and most accurate

$G \equiv Achieved\ generation\ in\ month\ X$

$A \equiv Cumulative\ reading\ at\ start\ of\ month\ X$

$\mathrm{B} \equiv Cumulative\ reading\ at\ end\ of\ month\ X$

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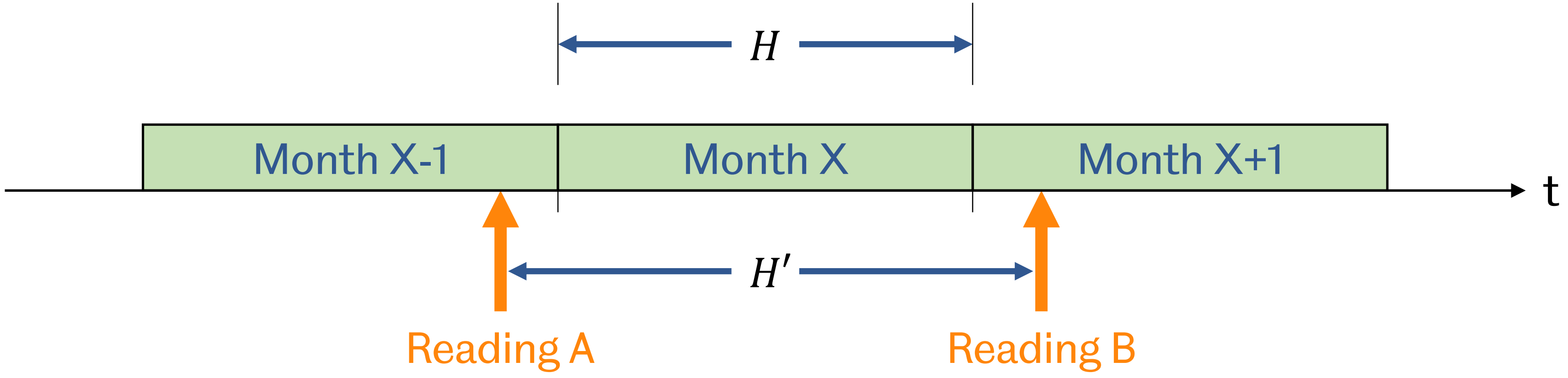
Calculate System Generation: Scenario 2

- Readings available within 10 days of start AND end of month AND MIDAS data available for months 1, 2 and 3 – More error



$$G = \frac{H}{H'} \times (B - A)$$

$$H \equiv Global\ Horiz\ Irradiance\ in\ month\ X$$
$$H' \equiv Global\ Horiz\ Irradiance\ between\ dates\ A\ \&\ B$$

Calculate System Generation: Scenario 3

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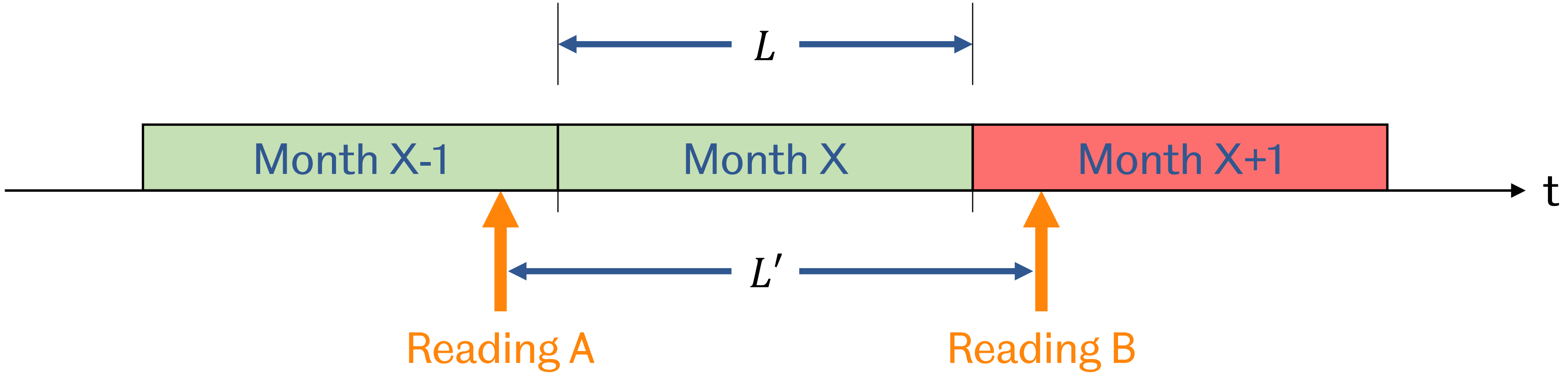
- Readings available within 10 days of start AND end of month BUT MIDAS data unavailable – Even more error



$$G = \frac{L}{L'} \times (B - A)$$

$L \equiv Daylight\ Hours\ in\ month\ X$

$L' \equiv Daylight\ Hours\ between\ dates\ A\ \&\ B$

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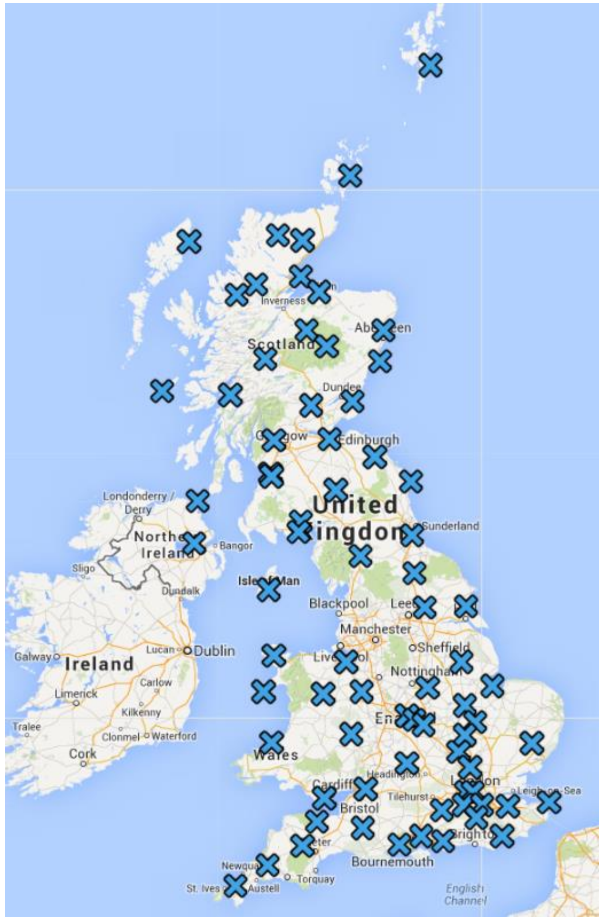
Interpolating Irradiance

- Currently restricted to using Met Office weather stations
- Roughly 75 stations reporting hourly irradiance each month
- Coverage is NOT uniform
- How to interpolate from these sites to your roof?



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Interpolating Irradiance: Shepard's Method

- Inverse distance weighting

$$\bar{H}(x) = \frac{\frac{\bar{H}_1}{d(x,x_1)^p} + \frac{\bar{H}_2}{d(x,x_2)^p} + \frac{\bar{H}_3}{d(x,x_3)^p} + \cdots}{\frac{1}{d(x,x_1)^p} + \frac{1}{d(x,x_2)^p} + \frac{1}{d(x,x_3)^p} + \cdots}$$

$$\bar{H}(x) = \frac{\sum_{i=1}^{N} \frac{\bar{H}_i}{d(x,x_i)^p}}{\sum_{i=1}^{N} \frac{1}{d(x,x_i)^p}} \quad (unless\ d(x,x_i) = 0)$$

- What value should we use for p?

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Interpolating Irradiance: Shepard's Method

- We "optimise" p…
  1) Try all integer values of p in the range 0 to 10…
     i. Calculate the relative error at each station for each value of p
     ii. Choose p' to minimise the mean relative error across all stations
  2) Try decimal values of p in the range $(p' - 0.5) \leq p \leq (p' + 0.5)$…
     Repeat steps i and ii
- Now we have p, we can interpolate the irradiance anywhere in the UK – but this only gives us the "Global Horizontal Irradiance"!

$$relative\ error = \frac{interpolated\ irradiance - actual\ irradiance}{actual\ irradiance}$$

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Calculating Irradiance Received

- Need to correct for array azimuth and elevation

  i.e. convert from “Global Horizontal” to “Global In-plane” irradiance

- Currently using equations from S. A. Klein, 1977†

$$\bar{H}_T = \bar{R}\bar{H}$$

$$\bar{R} = \left(1 - \frac{\bar{H}_d}{\bar{H}}\right)\bar{R}_b + \frac{\frac{\bar{H}_d}{\bar{H}}(1 + \cos s)}{2} + \frac{\rho(1 - \cos s)}{2}$$

we ignore this term

$s \equiv Array\ Elevation$

†Klein, S. A., 1977. Calculation of Monthly Average Insolation on Tilted Surfaces. Solar Energy, Volume 19, pp. 325-329.

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Calculating Irradiance Received

- Need to calculate the "diffuse fraction"

$$\frac{\bar{H}_d}{\bar{H}} = 1 - 1.13\bar{K}_T$$

- Use average monthly values of "clearness index"

$$\bar{R}_b = f(s, \delta, \phi, \gamma)$$

- Plug all the numbers into these equations and we come out with $\bar{H}_T$ - now we can calculate the PR!!!

$$PR = \frac{\eta_{achieved}}{\eta_{spec}} \times 100\% = \frac{G}{\eta_{spec} \times \bar{H}_T} \times 100\%$$

$\bar{H}_d \equiv Diffuse\ Irradiance$
$\bar{K}_T \equiv Clearness\ Index$
$\delta \equiv Solar\ Declination$
$\phi \equiv Latitude$
$\gamma \equiv Array\ Azimuth$

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Computation

- Currently programmed in Matlab with MySQL database storing data
- Takes roughly 1 minute to run 13 month report for one installation
- Regular reports run much faster thanks to parallel processing on the University's HPC Cluster a.k.a "Iceberg"
- Results are automatically uploaded to the website's database, but not the spreadsheet report ☹
- Potential for further optimisation and/or translation

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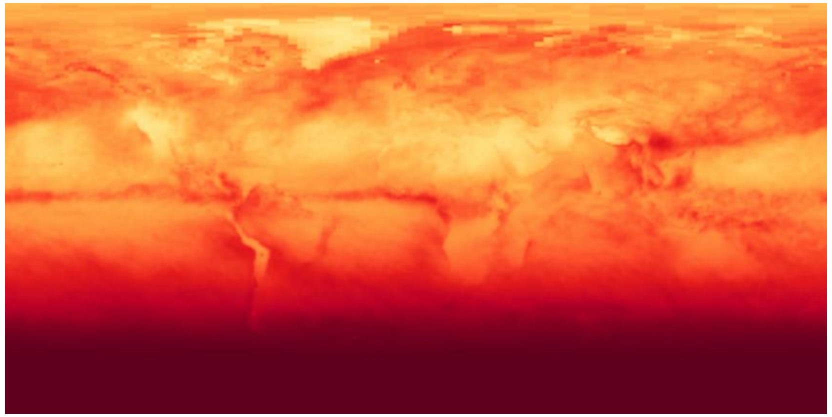
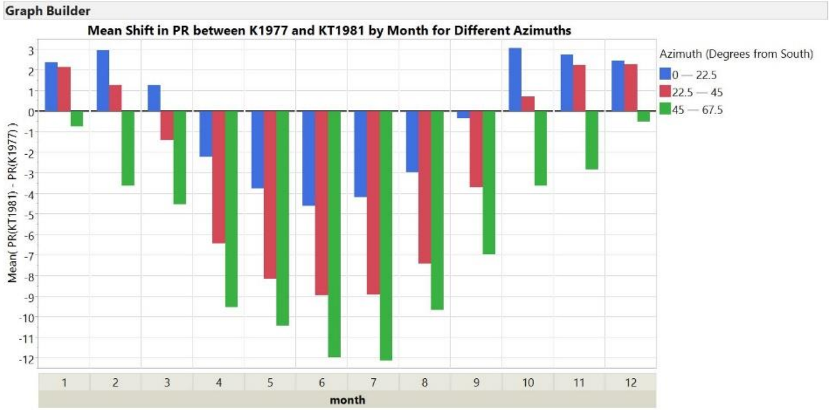
What Next?

- Currently working on improving analysis for East-West systems
- Source new irradiance datasets
- Analyse on higher resolution e.g. daily PR, nearest neighbours





Any Questions?