
A sub-hourly spatio-temporal statistical model for solar irradiance in Ireland using open-source data

Maeve Upton^{*1}, Eamonn Organ¹, Amanda Lenzi², and James Sweeney¹

¹University of Limerick – Ireland

²School of Mathematics - University of Edinburgh – United Kingdom

Abstract

In today's changing climate, one of Ireland's greatest challenges is achieving the target of decarbonising the national energy grid by 2050. Expanding renewable energy capacity, particularly through harnessing solar power, is central to this transition. By December 2024, nearly 100,000 Irish homes had installed solar panels. However, renewable power generation is highly variable. To maximise renewable integration into the grid, accurate real-time predictions of solar power generation are essential.

A key component of this is the reliable estimation of solar irradiance, which underpins the modelling of solar photovoltaic (PV) power output. In Ireland's highly variable maritime climate, where ground-based measurement stations are sparsely distributed, identifying suitable solar irradiance datasets remains a major challenge.

Our research introduces a Bayesian spatio-temporal modelling framework to predict solar irradiance at both hourly and sub-hourly (10-minute) resolutions across Ireland. We validate our approach through cross-validation, including leave-one-site-out testing, demonstrating strong statistical robustness. In comparative studies, our model consistently outperforms alternative approaches such as reanalysis datasets and nearest-station interpolation. We then can extend solar irradiance estimates to solar power generation at hourly and sub-hourly resolutions. At the sub-hourly scale, 10-minute resolution estimates align closely with observed solar PV power outputs from residential and industrial installations in Ireland. Beyond improved accuracy, our framework provides full uncertainty quantification, scalability, and the potential for real-time implementation.

Keywords: Solar irradiance, Bayesian, Spatio, temporal, Solar Power, Uncertainty Quantification

^{*}Speaker