Seasonal and weather dependency of the spectral influence on PV performance

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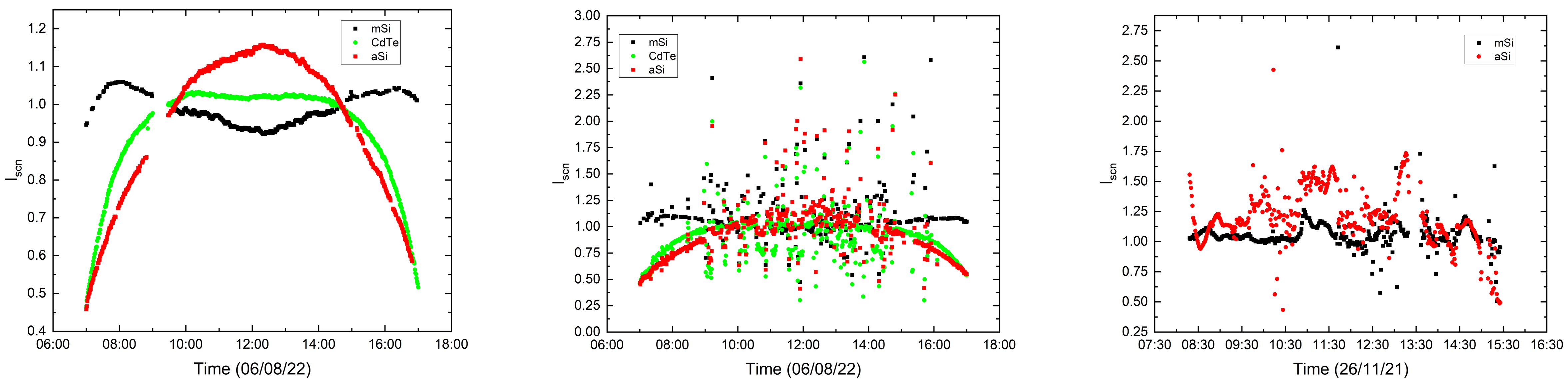
Introduction

- Spectral variation → up to 14% sensitivity even for crystalline silicon [1]
- Climate variation → > 5% absolute change in annual MMF [2]
- Existing work → lacking on specific weather conditions and implications for PVPM
- This study → clear and dynamic sky analysis, seasonal trends, optimised MMF modelling

Fig. 1: Nottingham test rig

Results 1: Spectral influence on PV



(a) Clear sky summer **(b)** Dynamic sky summer **(c)** Dynamic sky winter

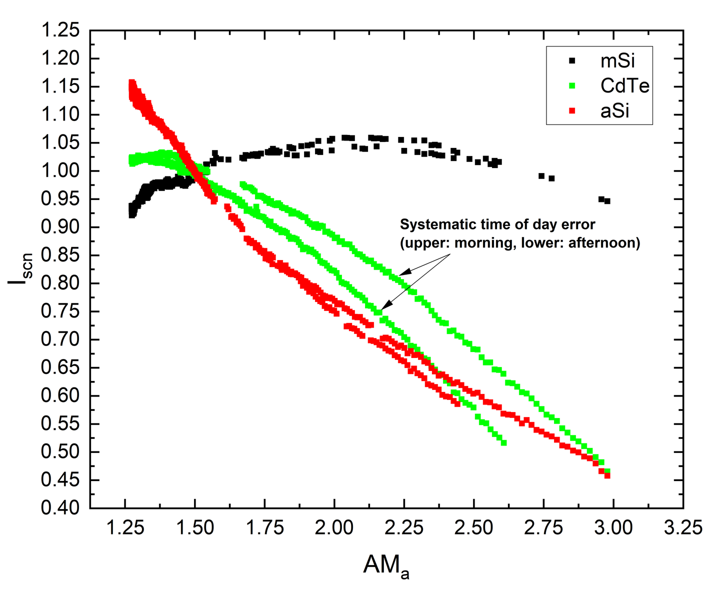
Fig. 2: Spectral influence on PV performance

- **Clear S→W:** I_{scn} stable for aSi, ↑ for mSi
- **Summer C→D:** I_{scn} ↓ for aSi, ↑ for mSi
- **Dynamic S→W:** I_{scn} ↑ for aSi, stable for mSi
- **Winter C→D:** I_{scn} ↑ for aSi, ↑ for mSi

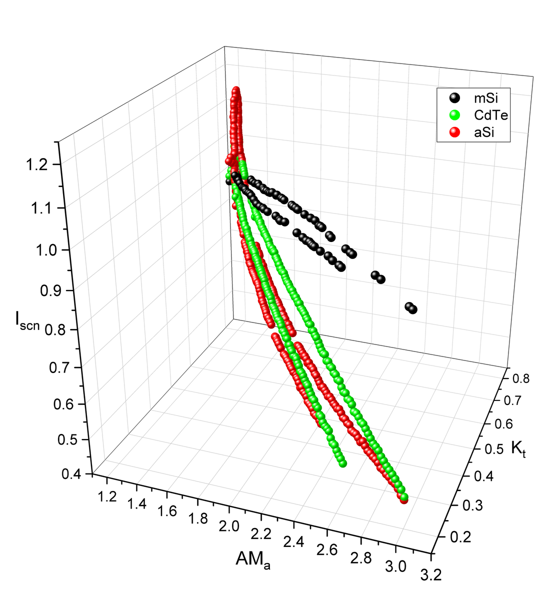
	Clear		Dynamic	
	S	W	S	W
mSi	0.973	1.001	1.054	1.041
aSi	1.043	1.050	0.926	1.173
CdTe	1.007	-	0.911	-

Table 1: Median I_{scn} values in summer (S) and winter (W), under different sky conditions

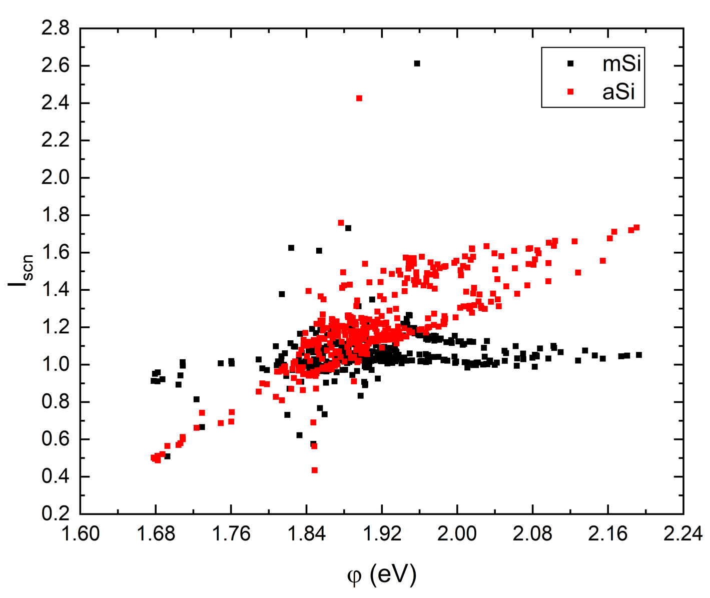
Results 2: Optimised MMF modelling



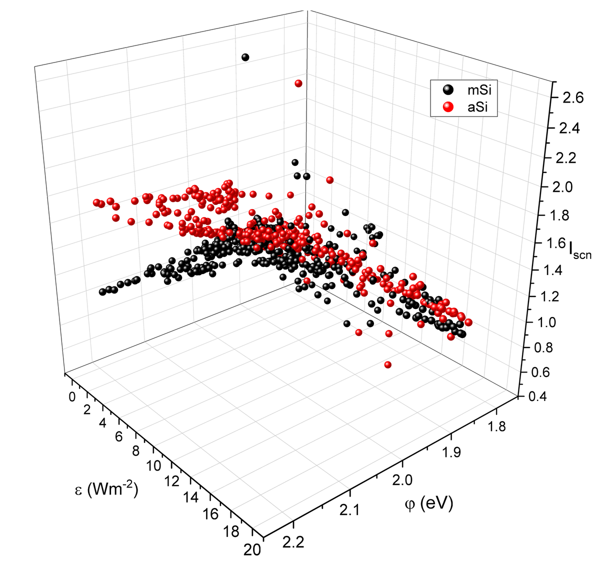
(a) $f(AM_a)$ (clear S)



(b) $f(AM_a, K_t)$ (clear S)



(c) $f(\varphi)$ (dynamic W)



(d) $f(\varphi, \varepsilon)$ (dynamic W)

Fig. 3: Example SCF fitting results

- Time-of-day error in the 1-variable characterisations
- Second variable decreases fitting uncertainty
- Higher responsivity of direct parameters is better for dynamic conditions
- Sub-optimal SCF choice can lead to 90% loss ($\Delta R^2 \approx 0.9$) in fitting accuracy for the same PV panel in different seasons/conditions
- *Note: AM_a=Absolute air mass, K_t=Clearness index, φ=Average photon energy, ε=650–670nm band depth*

Methods

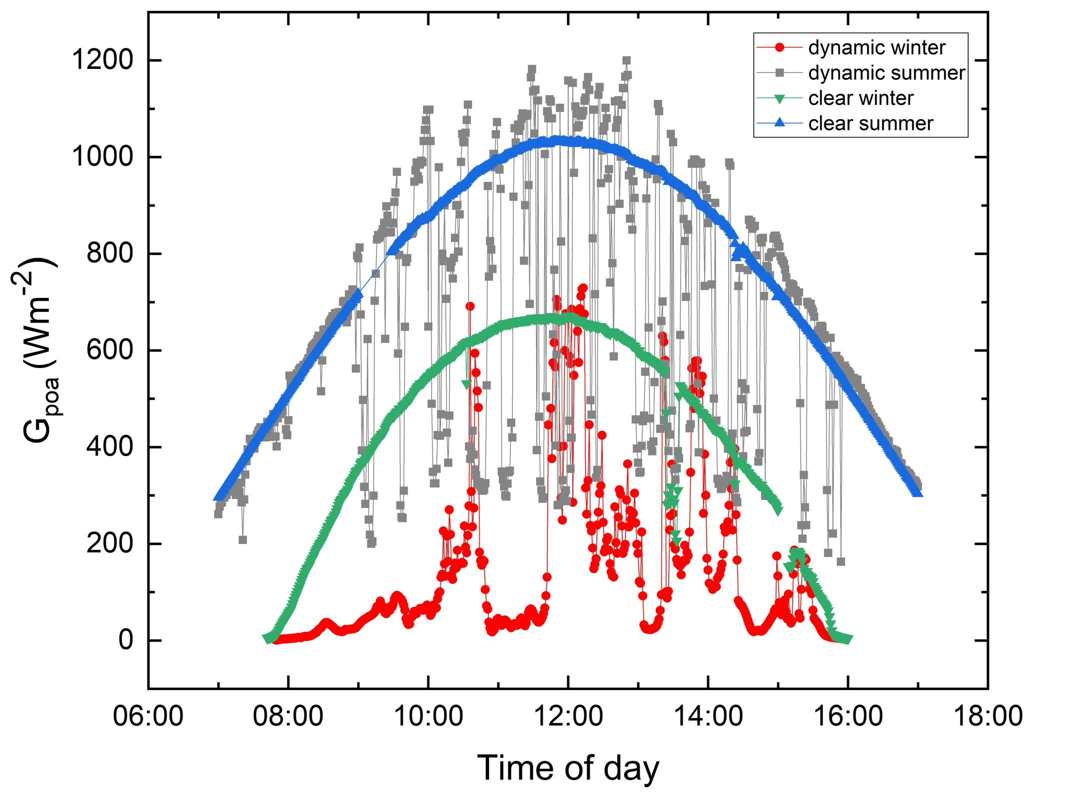


Fig. 4: Daily variation in G_{poa}.

Ref	Dep. variable	Type
[3]	AM_a	Proxy
[4]	AM_a, K_t	Proxy
[5]	φ	Direct
[6]	φ, ε	Direct

Table 2: SCFs analysed

- G_{poa}, φ, etc. used to define sky conditions
- 1-min I_{sc}; 5-sec G_{poa}, T_{amb}, T_{mod}; 30-sec E_λ
- AOI, T_{cell}, G_{poa} correction for I_{scn}
- $1 \leq AM_a \leq 15$, G_{poa}>10W m^{-2}

SCF recommendations

	Clear		Dynamic	
	S	W	S	W
aSi	AM_a	φ	AM_a	φ
CdTe	φ,ε	-	φ,ε	-
mSi	AM_a	φ	φ,ε	φ

Table 3: Optimal SCF choices according to R^2

- Proxy AM_a adequate for summer/clear
- Outlier summer/dynamic aSi; overfitting?
- CdTe needs a direct spectral parameter
- Winter → Direct; Summer → Proxy/direct
- Dynamic skies require a more responsive spectral parameter

Conclusion

- Median efficiency varies by up to 9% between seasons and sky conditions
- Time-of-day error in 1-variable SCFs
- Proxy variable for summer clear skies (mSi and aSi), direct variable for CdTe
- φ recommended in winter
- Extension to predictive model analysis required in future work

Acknowledgements

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References

[1] Kinsey, et al., Ren. Ener. 196 (2022) 995–1016.

[2] Schweiger, et al., IET R.P.G. 11 (2017) 558–565.

[3] King, et al., in: PVSC, 1997, pp. 1113–1116.

[4] Pelland, et al., in: PVSC, 2020, pp. 1258–1264.

[5] Daxini, et al., Ren. Ener. 201 (2022) 1176–1188.

[6] Daxini, et al., Preprint SSRN 4378056 (2023).