SPECTRAL UNIQUENESS OF SOLAR SPECTRA AND SUITABILITY OF SMRS AS SPECTRAL INDEX

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OBJECTIVE

- How many parameters (spectral indices) are needed to uniquely identify a spectrum?
- Can spectral matching ratio (SMR) and effective irradiance uniquely identify a spectrum?

Study of the minimum number of parameters necessary to uniquely identify a spectrum

Spectrum ⟷ bijective identification ⟷ Set of spectral indices

Describe the dependence of solar radiation on wavelength
e.g., air mass (AM), aerosol optical depth (AOD) and precipitable water (PW)
Is the solar spectra described by three independent variables?

1. Data set & methodology

AERONET NETWORK
AM, AOD, PW
sampling every 15 minutes in average

↓

SMARTS
throughout a period of a year

↓

synthetic direct spectra

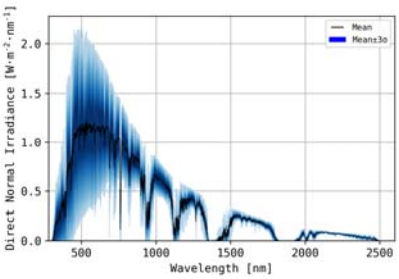


Fig. Synthetic spectra obtained with SMARTS and Madrid AERONET station (year 2014): the mean (in black) with a width of six standard deviations ±3s (in blue) of DNI.

2. Principal component analysis (PCA)

PCA translates a set of specimens to another set called principal components (PCs).

Decomposition of a given spectrum$_K$:

$$spectrum_k(\lambda) = \overline{spectra}(\lambda) + \sum_i \overbrace{PCvec_i(\lambda) \cdot PCval_i}^{\text{Principal component (PC)}}$$

mean spectrum of the studied set; eigenvectors; eigenvalues

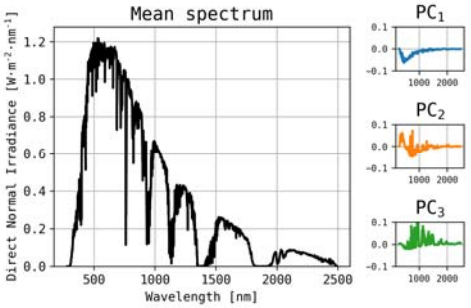


Fig. Mean spectrum of the set of synthetic spectra obtained with SMARTS and Madrid AERONET station (year 2014). On the right, the eigenvectors of the first three Principal Components (PCs).

3. Results

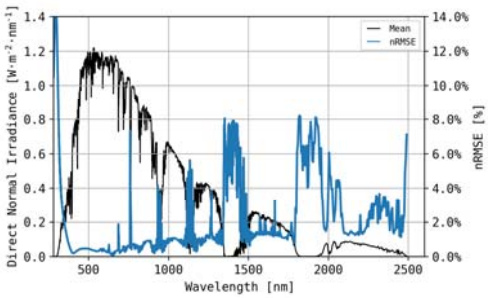


Fig. In black, the mean spectrum. In blue, the normalized root-mean-square-error (nRMSE) with values below 1%, except at bandwidths with low resolution mainly due to water absorption peaks.

RMSE of a set of n spectra:

reconstructed spectra by PCA; synthetic spectra

$$RMSE\ (\lambda) = \sqrt{\frac{\sum_{k=1}^{n}\left(spectrum_{PC_k}(\lambda) - spectrum_{ori_k}(\lambda)\right)^2}{n}}$$

Normalized RMSE:

$$n_{RMSE}(\lambda) = \frac{RMSE\ (\lambda)}{max_k\{spec_{PC_k}(\lambda)\} - min_k\{spec_{PC_k}(\lambda)\}}$$

Average normalized RMSE: $\overline{n}_{RMSE}$ = 1.37%

The first PC is responsible for 93.9% of the variability while the second and third PCs contribute for 4.4% and 1.5%, respectively. These three independent variables explain 99.8% of the variability.

Spectral matching ratio (SMR) and effective irradiance as parameters for uniquely identifying a spectrum

1. Definitions & methodology

Spectral matching ratio

$$SMR_{subcell_j}^{subcell_i} = \frac{B_{subcell_i}}{B_{subcell_j}}$$

Effective irradiance $B_{subcell}$

Subcell current under a given spectrum

$$B_{subcell_i} = \frac{I_{L,subcell_i}}{I_{L,subcell_{i_{ref}}}} B_{ref}$$

Subcell current under a reference spectrum; DNI of reference spectrum

By means of isotypes (more widespread used are LM-Ge). However, these devices are not off-the-self components. A linear model is proposed to calculate the effective irradiance for a "destination technology" upon "origin" technology.

B_{top}, B_{mid}, B_{bot} are independent variables that could potentially provide a unique definition of the solar spectra.

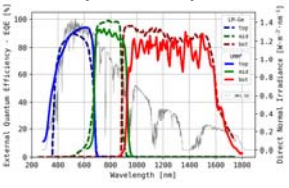
Could be used to estimate other spectral variables (*e.g.*,SMRs)?

2 cases under study: $UMM^A \approx LM(Ge) \neq UMM^B$ (Destination, Origin, Destination)

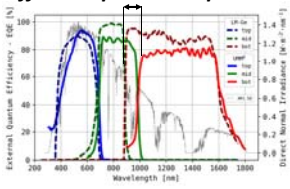
2 approaches: direct (UMM=LM-Ge) vs. indirect (UMM=f(LM-Ge))

2. Results

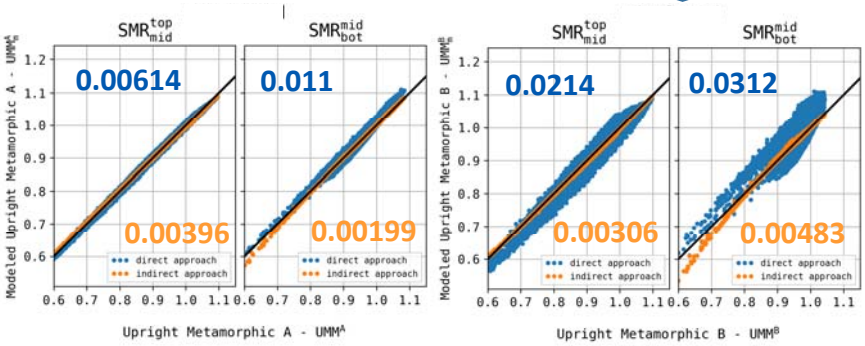
Similar spectral response



Different spectral response



Direct approach
UMM = LM-Ge
Indirect approach
UMM = f(LM-Ge)



CONCLUSIONS

- The PCA analysis shows that solar spectra can be uniquely described in CPV using just three, but not less, independent parameters.
- Three effective irradiance values (B_{top}, B_{mid}, B_{bot}) obtained by means of component cells and the resulting spectral matching ratios (SMRs) are proposed as a set of parameters to compose an unambiguous spectral measure.
- SMR values can provide enough information to identify spectra for other types of 3J technologies with significantly different spectral response.