Solar irradiance modelling over Belgium using Regional Climate Models within the frame of a day-ahead photovoltaic production forecasting system

1. Introduction

Context:
- Growing interest and growing photovoltaic production in European countries
- Local hazards due to over-production for low voltages networks
- Needs of photovoltaic production assessment for the management of the electricity market

Scientific issues:
- Modelling of solar global irradiance using Regional Climate Models
- Model (shallow) convective clouds, low clouds clearance...
- Decompose global irradiance into diffuse and direct irradiances

2. Regional Climate Models

WRF-ARW v3.6
- Non-hydrostatic
- Inner 5 km horizontal resolution domain nested in 15km domain
- Outputs every 15 minutes
- Common set-up:
  - Ruddihia SW scheme, RRTMG LW scheme, Mellor-Yamada-Nakanishi-Niino PBL scheme

Modèle Atmosphérique Régional (MAR)
- Hydrostatic
- 10 km horizontal resolution
- Outputs every 15 minutes
- Set-up:
  - ECMWF radiation scheme, SISVAT surface model, Peter Bechtold cumulus scheme

3. Solar irradiance data

Sart-Tilman (ST):
- S0.586615° N; 5.564206° E; 210 m a.s.l
- Pyranometer: CM 121 Kipp & Zonen
- Diffuse radiation: CM 121 shadow ring Kipp & Zonen
- Records every 15° → 15° mean

Daussoux (DAU):
- S0.520194° N; 4:882925° E; 195 m a.s.l
- Pyranometer: 2 AP Kipp & Zonen
- Diffuse radiation: 2 AP tracker
- Records every 30° → 30° mean

4. Global irradiance modelling: results

Method: Normalized RMSE, normalized bias, and determination coefficient (R²) are computed at the 15° time scale for MAR and WRF-ARW forced by different reanalyses and by GPS data, compared to observations at Sart-Tilman and Daussoux stations. Observations performed when cloud cover of the sun azimuth angle is < 0.1 are discarded from the analysis in order to avoid less reliable measurements (different objects on the horizon).

5. Diffuse fraction estimation

Decomposition of global irradiance into direct and diffuse using a sigmoid model (Rius-Arias et al., 2010):
1) Determination of the atmospheric clearance index (kt):
   \[ kt = \frac{I_1}{I_0} = \frac{\cos Z}{\cos \theta} \]
2) Determination of diffuse fraction (K):
   \[ K = 0.39 - 1.044 \exp(-2.3-4.702\%I) \]

6. Conclusions

- The mean of the different WRF-ARW simulations shows better performances in general, mainly in summer, and is more stable + statistical + approach more suitable for solar irradiance forecasting/modeling
- Both models show in overall higher RMSE in winter. Bias is significantly negative in winter in WRF-ARW simulations (over-estimation of low clouds thickness)
- Positive bias in summer with both ROM (under-estimation of convective clouds occurrence)
- Encouraging results for first solar irradiance modelling over Belgium using MAR
- Diffuse fraction estimation is strongly dependent on global irradiance modeling → improvement required if modelling at 15 minutes targeted

7. References