Calibrating Ensemble Forecasts of Short-Wave Solar Radiation Using Quantile Regressions

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Background
“The sun could be the world’s largest source of electricity by 2050”


Total UK Solar PV installed capacity
April 2017
Source: BEIS
Ensemble Calibration: Quantile Regression
WP1: Refinements

WP2: Statistical Post-Processing

WP3: Solar Radiation Nowcast

WP4: Core NWP cloud/radiation schemes
Unified Model Ensemble Suite

MOGREPS-G
- Δ33km 70 Levels
- 7 day forecast 4 times/day
- 12 members

MOGREPS-UK
- Δ2.2km 70 Levels
- 36 hour forecast 4 times/day
- 12 members

www.metoffice.gov.uk
Analysis (now) 

Initial condition uncertainty 

Forecast uncertainty 

Analysis (now) 

Climatology (later) 

Best estimate
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Methodology

MOGREPS-UK:
• 12 members
• 4 cycles per day: 03Z, 09Z, 15Z, 21Z
• Forecasts up to 36h ahead
• Total surface SW radiation (direct + diffuse)

Ensemble calibration - Quantile Regressions:
• Training: 7-day moving window
• Predictors: ensemble mean + variance
• 11 quantiles: q = \{0.025, 0.1, 0.2, \ldots, 0.9, 0.975\}

Observations:
• Hourly obs of total solar radiation (in \text{W/m}^2)
• 42 UK sites, QC

Verification:
• January 2016 – December 2016
• Time of day, time of year
• Normalised by top-of-atmosphere radiation
• Bias, MAE, RMSE, quantile score and skill, rank histograms
Quantile Regression

Estimation of probability products:

• Fix a probability level

• Derive associated quantile

\[ F_Y(y) = P(Y \leq y) \]
\[ Q_Y(\tau) = F_Y^{-1}(\tau), \quad \tau \in [0,1] \]

(Koenker and Basset, 1978)

Optimisation problem:

• Minimise loss function

\[ Q_{Y|X}(\tau) = X\beta_{\tau} \]
\[ \hat{\beta}_{\tau} = \arg \min_{\beta \in \mathbb{R}^k} \sum_{i=1}^{n} (\rho_{\tau}(Y_i - X_i\beta)) \]

• Regression analysis
Results
Rank Histogram

- QR
- DMO

Frequency

Probability

0 2.5 10 20 30 40 50 60 70 80 90
Bias

MAE

Forecasts range offset by DT (hours)

QR – 03Z
DMO – 03Z
QR – 09Z
DMO – 09Z
QR – 15Z
DMO – 15Z
QR – 21Z
DMO – 21Z
Background

Quantile Regression

Results

Summary

MAE ($W/m^2$)

Bias

Time of year

Bias

Time of year

MAE ($W/m^2$)

Time of year
Summary and Further Work
Summary

Quantile Regression is an appropriate post-processing method to calibrate ensemble forecasts of solar radiation

- Overall error of ensemble mean is reduced: lower negative bias
- QR reduces spread of the distribution
- QR improve skill of forecasts, particularly for extreme quantiles
- Higher errors around midday and summer are proportional to higher magnitude of solar radiation

Further Work

- Apply QR corrections to MOGREPS-G
- Verify integrated irradiance
- Compare different training periods
- Operational implementation