Potential of a low stratus risk product for the mitigation of irradiation and PV power production forecast error

Yves-Marie Saint-Drenan (IWES)
Carmen Köhler (DWD, i-EM), Andrea Steiner (DWD), Bodo Ritter (DWD)
1) Analysis of the day-ahead PV power forecast error
2) Example of a day marked by low stratus
3) Approach to a calibration considering low stratus
4) Results
5) Next steps
The analysis is based on the estimates and day-ahead forecast of the PV power generation provided by the German TSOs.

The daily MAE values for Germany have been evaluated over two years (2013-2014).

The 100 days with the highest errors were identified and the prevailing weather situation manually evaluated by the DWD.
Analysis of the DA PV forecast errors

![Graph showing daily MAE for 2013 and 2014](image-url)
Analysis of the DA PV forecast errors

Distribution of the 100 days according to cloud type and weather situation

→ A large share of the days with large error are marked by the presence of low stratus
Outline

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Example of a day with low stratus

Example: TSOs reported a large PV forecast errors on 12/02/2015
Example of a day with low stratus
Example of a day with low stratus

Satellite irradiation

Cosmo-DE

Cosmo-EU

IFS

* 11/02/2015 03:00 +33h

** 11/02/2015 00:00 +36h

Solar irradiation in W/m²
Example of a day with low stratus irradiation

Satellite

Cosmo-EU
IFS
Cosmo-DE

* 11/02/2015 03:00 +36h
** 11/02/2015 00:00 +39h
Example of a day with low stratus
Example of a day with low stratus
Example of a day with low stratus

Low saturation deficit
Example of a day with low stratus

- Low saturation deficit
- Strong temperature inversion
Example of a day with low stratus

Low saturation deficit

Strong temperature inversion
Example of a day with low stratus

Adaptation of the SK-scheme (*)(**) for the detection of LS:

- Strong temperature inversions below 800 hPa
- Low saturation deficit below the temperature inversion


Outline

1) Analysis of the day-ahead PV power forecast error
2) Example of a day marked by low stratus
3) Approach to a calibration considering the LSR
4) Results
5) Next steps
Calibration approach

Choice of the fit function

\[ G_{corr} = \left[ \left( a_{11} \tilde{TI} + a_{12} \tilde{SD} + a_{13} \tilde{TI} \cdot \tilde{SD} \right) + \left( a_{21} \tilde{TI} + a_{22} \tilde{SD} + a_{23} \tilde{TI} \cdot \tilde{SD} \right) \left( \frac{G}{G_{TOA}} \right) \right] G_{TOA} \]

with \( \tilde{SD} = \max[0, (SD_0 - SD)] \) \( \tilde{TI} = \max[0, (TI - TI_0)] \)

- \( G \): irradiance forecast [W/m\(^2\)]
- \( G_{corr} \): corrected irradiance forecast [W/m\(^2\)]
- \( G_{poa} \): extraterrestrial irradiance [W/m\(^2\)]
- \( TI \): max temperature inversion below 800 hPa [°C]
- \( TI_0 \): TI above which the correction scheme is activated [°C]
- \( SD \): saturation deficit below the temperature inversion [kg/kg]
- \( SD_0 \): SD below which the correction scheme is activated [kg/kg]
- \( a_{ij} \): calibration coefficients
Calibration approach

Choice of the fit function

\[
G_{\text{corr}} = \left[ (a_{11}\tilde{T}\!\!I + a_{12}\tilde{SD} + a_{13}\tilde{T}\!\!I \cdot \tilde{SD}) + (a_{21}\tilde{T}\!\!I + a_{22}\tilde{SD} + a_{23}\tilde{T}\!\!I \cdot \tilde{SD}) \left( \frac{G}{G_{\text{TOA}}} \right) \right] G_{\text{TOA}}
\]

with

\[
\tilde{SD} = \max[0, (SD_0 - SD)]
\]

\[
\tilde{T}\!\!I = \max[0, (TI - TI_0)]
\]

Activation of the correction scheme for \( TI > TI_0 \) & \( SD < SD_0 \)

- \( G \): irradiance forecast [W/m²]
- \( G_{\text{corr}} \): corrected irradiance forecast [W/m²]
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- \( TI \): max temperature inversion below 800 hPa [°C]
- \( TI_0 \): TI above which the correction scheme is activated [°C]
- \( SD \): saturation deficit below the temperature inversion [kg/kg]
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- \( a_{ij} \): calibration coefficients
Calibration approach

Choice of the fit function

\[
G_{\text{corr}} = \left( a_{11} \tilde{T}I + a_{12} \tilde{SD} + a_{13} \tilde{T}I \cdot \tilde{SD} \right) + \left( a_{21} \tilde{T}I + a_{22} \tilde{SD} + a_{23} \tilde{T}I \cdot \tilde{SD} \right) \frac{G}{G_{\text{TOA}}} \]

with

\[
\tilde{SD} = \max[0, (SD_0 - SD)] \quad \tilde{T}I = \max[0, (TI - TI_0)]
\]

**G** irradiance forecast [W/m²]

**G\text{corr}** corrected irradiance forecast [W/m²]

**G\text{poa}** extraterrestrial irradiance [W/m²]

**TI** max temperature inversion below 800 hPa [°C]

**TI_0** TI above which the correction scheme is activated [°C]

**SD** saturation deficit below the temperature inversion [kg/kg]

**SD_0** SD below which the correction scheme is activated [kg/kg]

**a_{ij}** calibration coefficients
Calibration approach

Choice of the fit function

\[ G_{corr} = \left( a_{11} \tilde{T}I + a_{12} \tilde{S}D + a_{13} \tilde{T}I \cdot \tilde{S}D \right) + \left( a_{21} \tilde{T}I + a_{22} \tilde{S}D + a_{23} \tilde{T}I \cdot \tilde{S}D \right) \left( \frac{G}{G_{TOA}} \right) G_{TOA} \]

with \[ \tilde{S}D = \max(0, (SD_0 - SD)) \]
\[ \tilde{T}I = \max(0, (TI - TI_0)) \]

Simple additive model with a cross term

-  \( G \) : irradiance forecast \([\text{W/m}^2]\)
-  \( G_{corr} \) : corrected irradiance forecast \([\text{W/m}^2]\)
-  \( G_{poa} \) : extraterrestrial irradiance \([\text{W/m}^2]\)
-  \( TI \) : max temperature inversion below 800 hPa \([\text{°C}]\)
-  \( TI_0 \) : TI above which the correction scheme is activated \([\text{°C}]\)
-  \( SD \) : saturation deficit below the temperature inversion \([\text{kg/kg}]\)
-  \( SD_0 \) : SD below which the correction scheme is activated \([\text{kg/kg}]\)
-  \( a_{ij} \) : calibration coefficients
Calibration approach

Choice of the fit function

\[
G_{corr} = \left[ \left( a_{11} \tilde{T}I + a_{12} \tilde{S}D + a_{13} \tilde{T}I \cdot \tilde{S}D \right) + \left( a_{21} \tilde{T}I + a_{22} \tilde{S}D + a_{23} \tilde{T}I \cdot \tilde{S}D \right) \frac{G}{G_{TOA}} \right] G_{TOA}
\]

with \( \tilde{S}D = \max[0, (SD_0 - SD)] \quad \tilde{T}I = \max[0, (TI - TI_0)] \)

- \( G \): irradiance forecast [W/m²]
- \( G_{corr} \): corrected irradiance forecast [W/m²]
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- \( TI \): max temperature inversion below 800 hPa [°C]
- \( TI_0 \): TI above which the correction scheme is activated [°C]
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- \( SD_0 \): SD below which the correction scheme is activated [kg/kg]
- \( a_{ij} \): calibration coefficients

Coefficients are assumed constant in time and space
Calibration approach

- The calibration is evaluated for the south of Germany
- Satellite-derived irradiance (HC3v4) and IFS forecast are used
- The coefficients $a_{ij}$ are evaluated by a multiple linear regression
- The correction is evaluated for the time period 01/2015 – 06/2015
- The effect of the calibration is assessed for the time period 07/2015-12/2012
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Results

- Correction scheme activated for 172 from 2046 time steps
- When the correction scheme is activated, RMSE: 56.2 -> 38.4 W/m²
- For the complete test data set, RMSE: 58.3 -> 57.0 W/m²
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Next steps

• Train & test of the approach for a whole year
• Parameter varying in space and time
• Test of the approach with ICON-EU & Cosmo-DE
• Application of the approach to PV power forecast
• Assessment of the improvement for the TSO forecasts
• Integration of further explanatory variables
Thank you for your attention!

Questions?