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Satellite Based and Ground Measured Solar Irradiance for PV Power Nowcasting: PV Live

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PVPMC modeling workshop
Weihai 04.02.2018

www.ise.fraunhofer.de

TRANSNET BW

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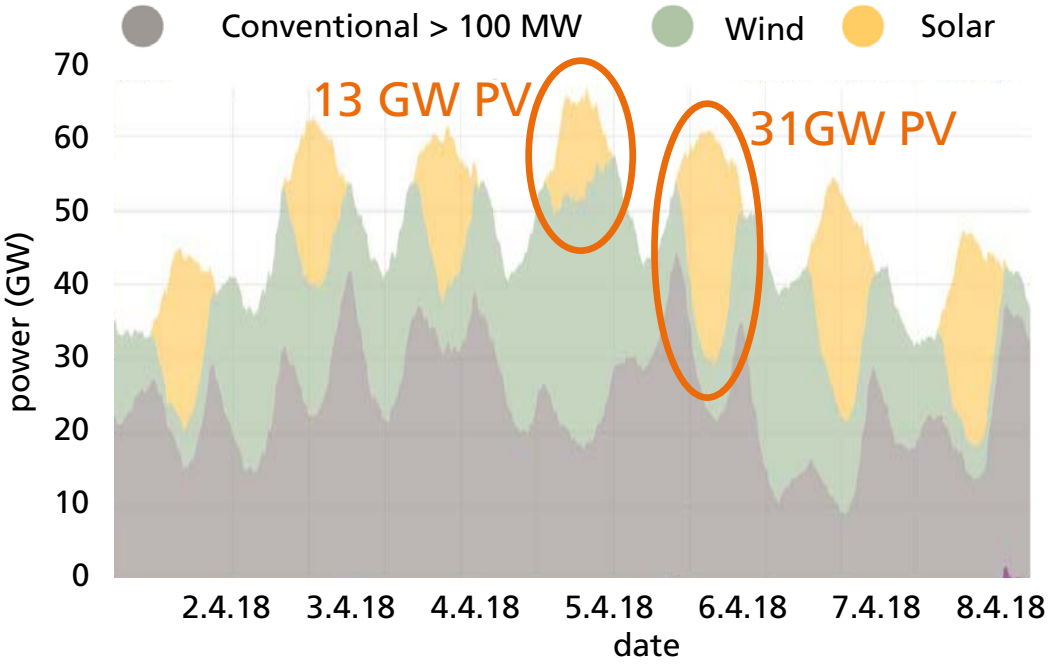
AGENDA

- Motivation
- PV Live project
- Evaluation

Motivation

Contribution of PV to electricity supply in Germany

- installed PV power (end 2017): 43 GW_{peak}
- up to 60% of electricity demand from PV
- strong variability of solar power



www.energy.charts, Sources: 50Hertz, Amprion, Tennet, TrannetBW, EEX

Motivation

Integration of PV by transmission system operators

- Trading of PV power at European power exchange EPEX
- Congestion management
- ➡ Requirements
  - PV forecast for the next hours and days
  - Assessment of current PV power feed-in

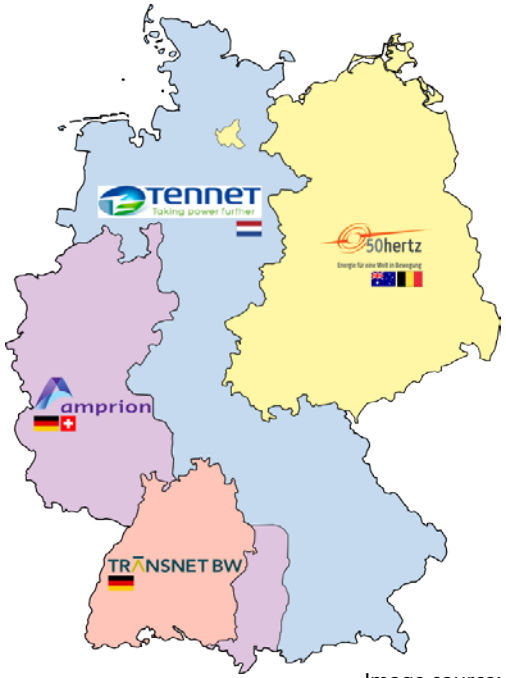


Image source: Francis Mc Loyd

Motivation

PV power feed-in for control area of TransnetBW

- Installed PV power 5.7 GW
- Approx. 317 000 PV power plants contribute to the PV power feed-in
- Not all PV power plants provide real-time measurements in 15min resolution
- Current overall PV feed-in must be estimated from available information

➡ **Upscaling method required**

PV Live

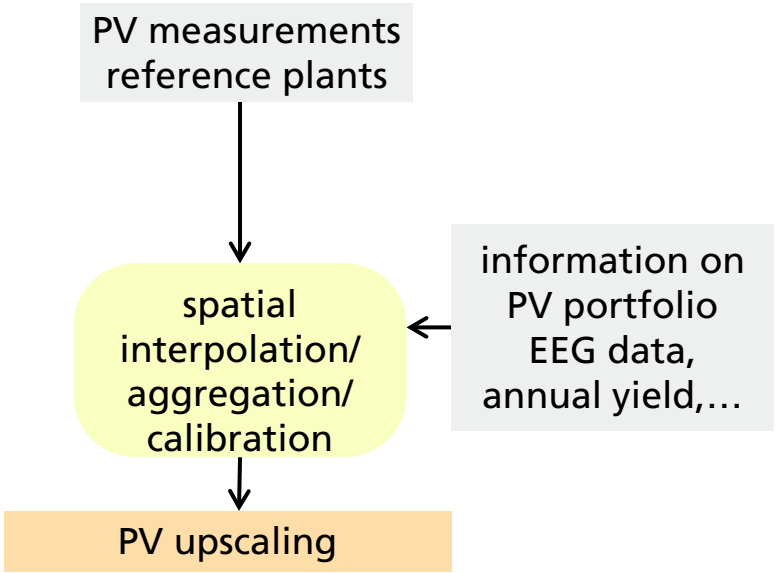
Standard upscaling method and PV Live

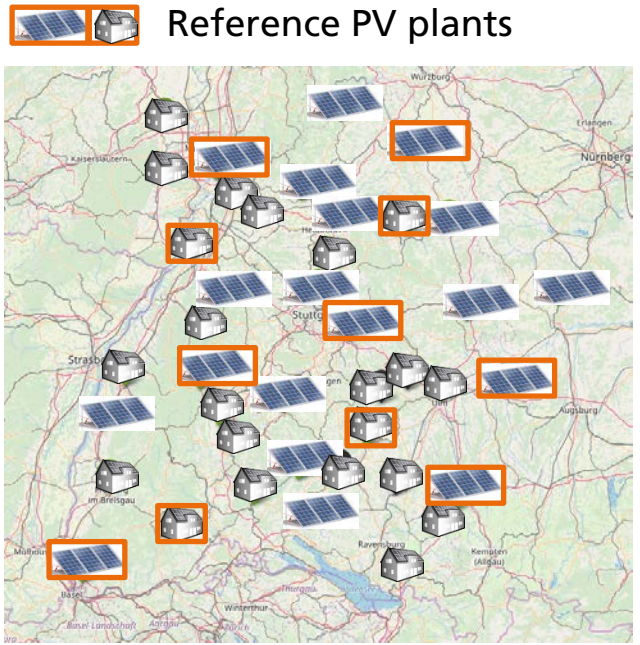
Standard Upscaling method
based on PV measurements

PV Live

Standard upscaling method and PV Live

Standard Upscaling method
based on PV measurements

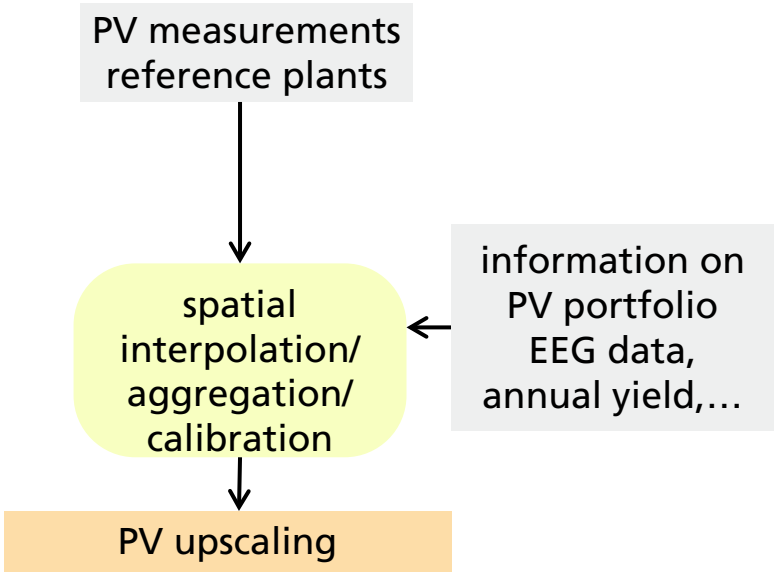




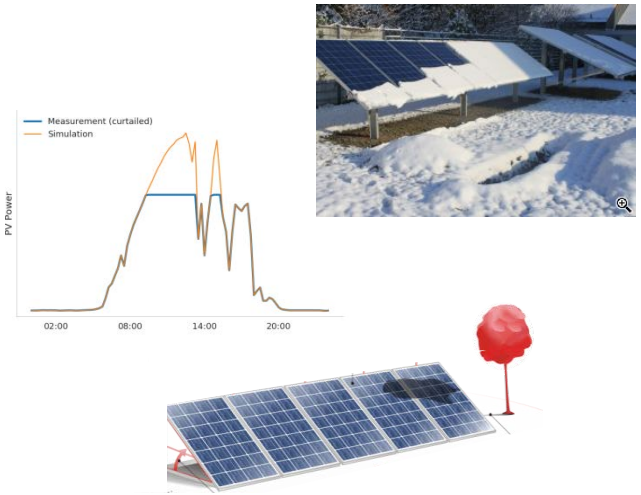
PV Live

Standard upscaling method and PV Live

Standard Upscaling method based on PV measurements



Influence of local, system-specifc factors **unclear**: shading, snow, curtailment, degradation, orientation, self consumption,..



PV Live

Standard upscaling method and PV Live

Standard Upscaling method
based on PV measurements

PV measurements
reference plants

Influence of
local, system-
specifc factors
unclear:
shading, snow,
degradation,
orientation, self
consumption,
curtailment,..

spatial
interpolation/
aggregation/
calibration

PV upscaling

PV Live upscaling method
based on solar irradiance data

solar irradiance/
temperature

PV simulation

PV power values

information on
PV portfolio
EEG data,
annual yield,…

spatial
aggregation/
calibration

PV upscaling

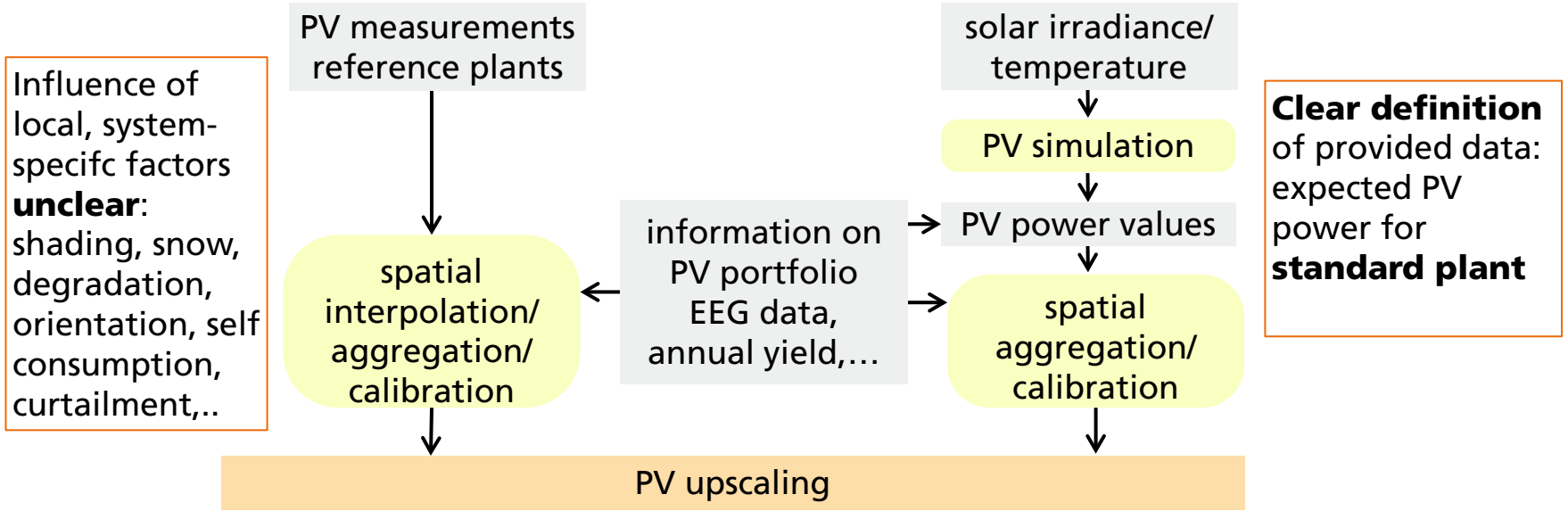
Clear definition
of provided data:
expected PV
power for
standard plant

PV Live

Standard upscaling method and PV Live

Standard Upscaling method
based on PV measurements

PV Live upscaling method
based on solar irradiance data



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PV Live

Ground-measurements and satellite-based irradiance data

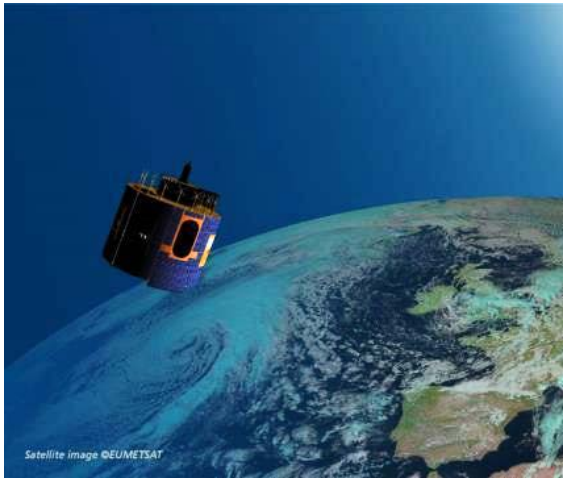
Ground-measurements

- 40 stations in Baden Württemberg
- 1min resolution

Satellite-based irradiance data

- High spatial resolution: ~1km x 2km
- Time resolution: 15min

Currently:
33 stations



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PV Live

The measurement station

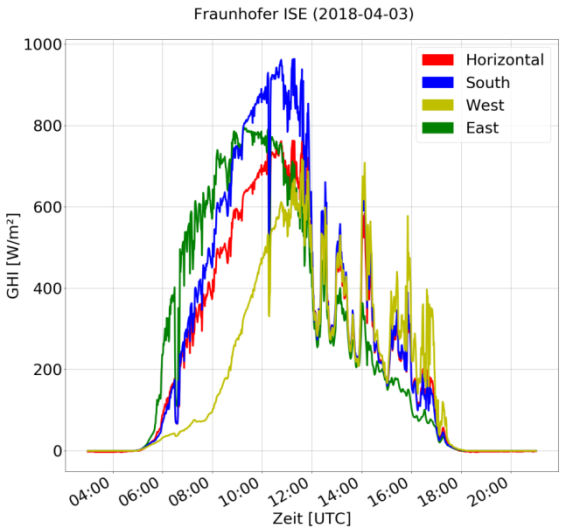
- 3 silicon sensors (tilted)
  - Tilt 25°
  - East/ South/ West

  -> simulated „standard PV plant“
- Pyranometer (horizontal)
  high accuracy/straight-forward combination with satellite-based irradiance values
- Real-time transmission every minute
  fast access to data

PV Live

Measurements and irradiance maps

Irradiance measurements in minute resolution: global horizontal and tilted irradiance



Satellite-based irradiance maps

Heliosat Method*

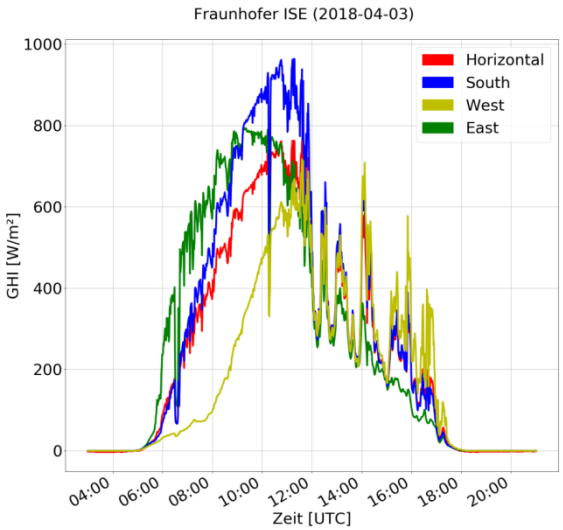
- Spatial resolution
  - ~4km x 4km
  - ca. 4000 grid points

*Hammer A., Lorenz E: 'Solar Energy Assessment Using Remote Sensing Technologies', *Remote Sensing of Environment 2003*

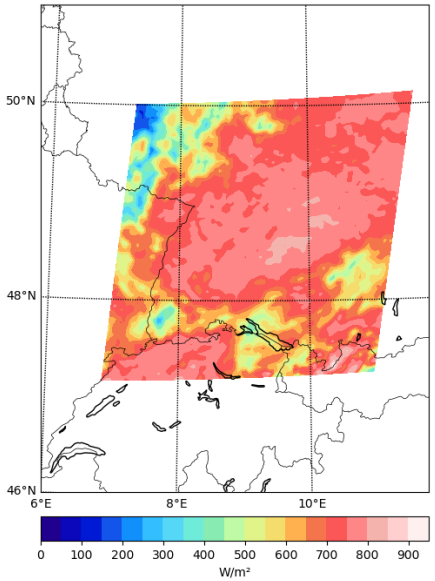
PV Live

Measurements and irradiance maps

Irradiance measurements in minute resolution: global horizontal and tilted irradiance



Satellite-based irradiance maps



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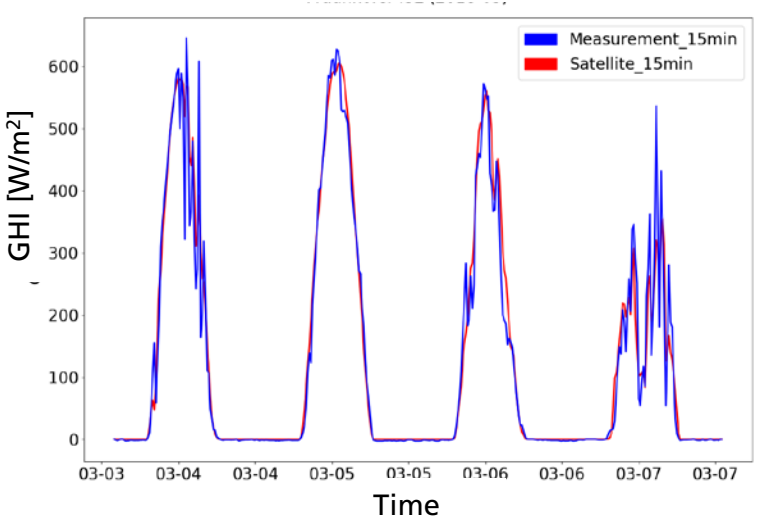
Evaluation

Satellite-based irradiance on different scales

- Dataset
  - 19 stations
  - August 17 – April 18
  - Global horizontal irradiance GHI

15min values
single stations



Evaluation

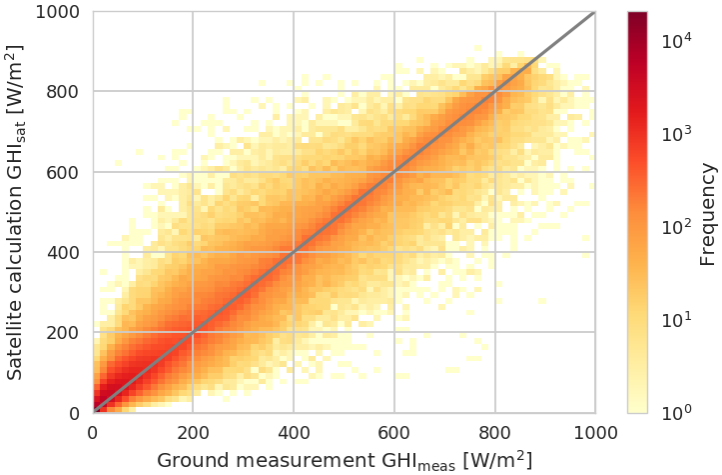
Satellite-based irradiance on different scales

- Quantitative evaluation
- Root mean square deviation

$$RMSD = \frac{1}{\sqrt{N}} \sqrt{\sum_{i=1}^{N} (GHI_{sat} - GHI_{mess})^2}$$

- Normalized with respect to average irradiance
- If normalized like PV wrt. STC (1000 W/m²) yields about 6%

15min values
single stations

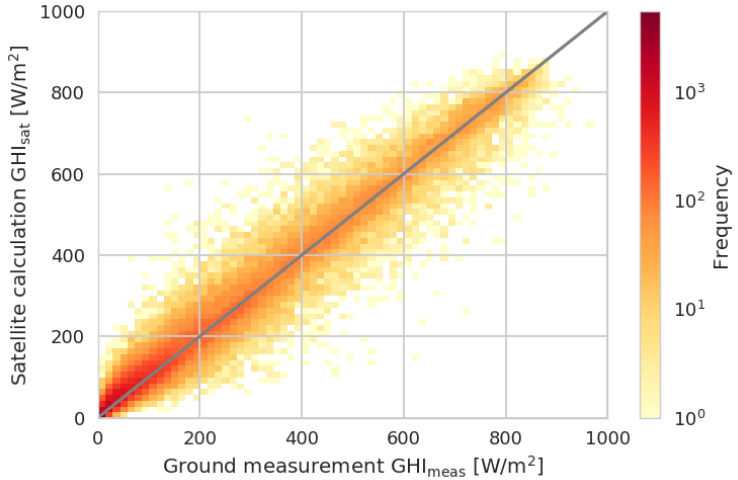


RMSD = 60 W/m² (29 %)

Evaluation

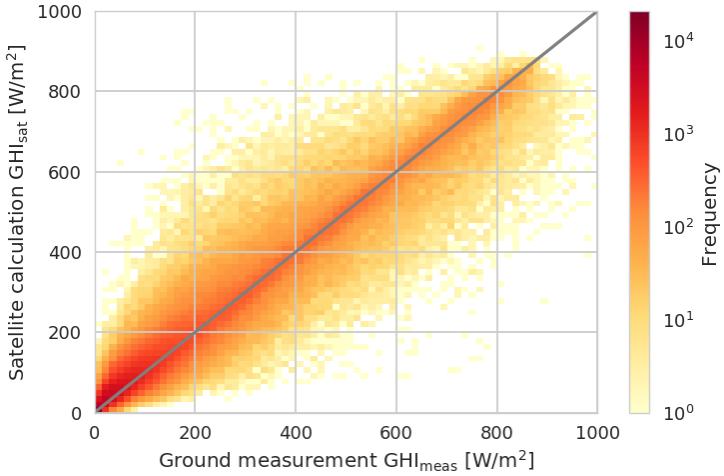
Satellite-based irradiance on different scales

Hourly values
single stations



RMSD = 45 W/m^2 (22 %)

15min values
single stations



RMSD = 60 W/m^2 (29 %)

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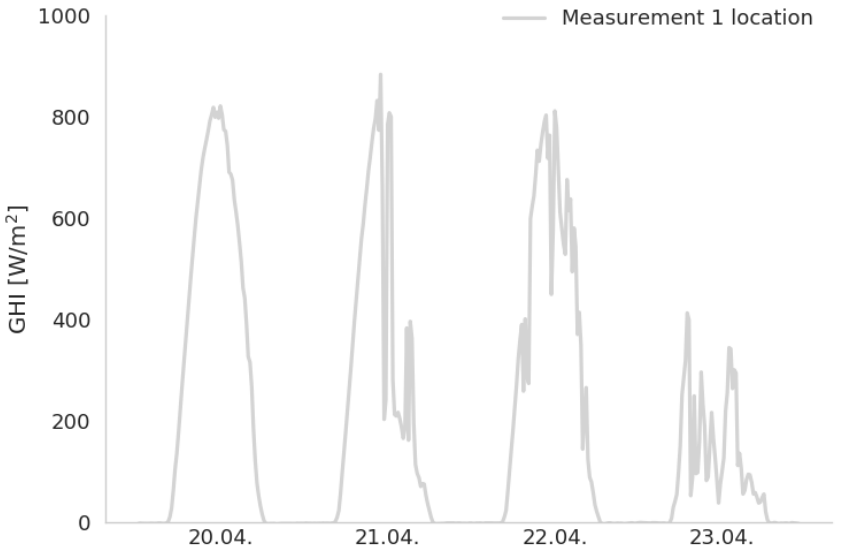
Evaluation

Satellite-based irradiance on different scales

From single station values to regional averages

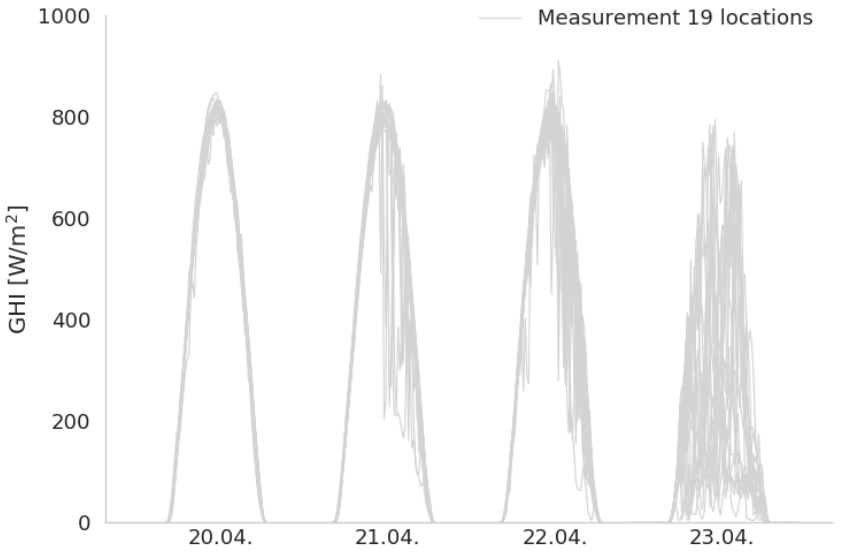


Evaluation

Satellite-based irradiance on different scales

From single station values to regional averages

- Here: mean of 19 sites

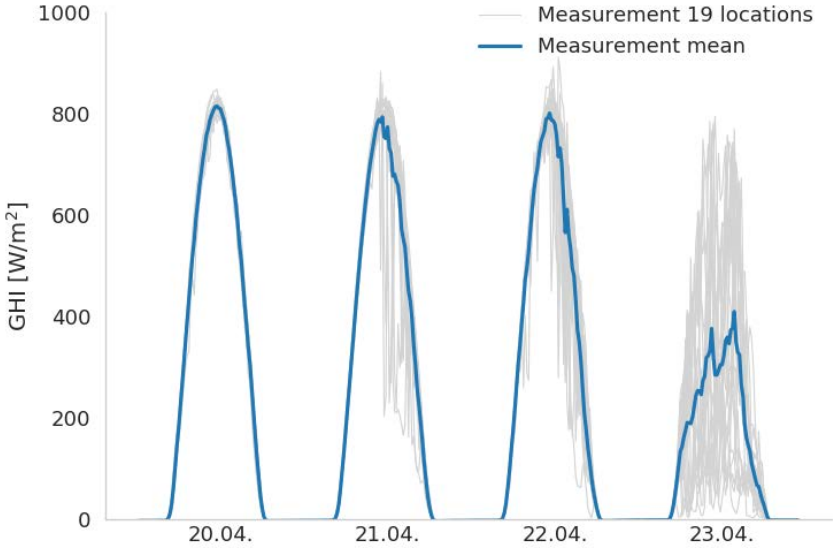


Evaluation

Satellite-based irradiance on different scales

From single station values to regional averages

- Here: mean of 19 sites
- Reduced fluctuations

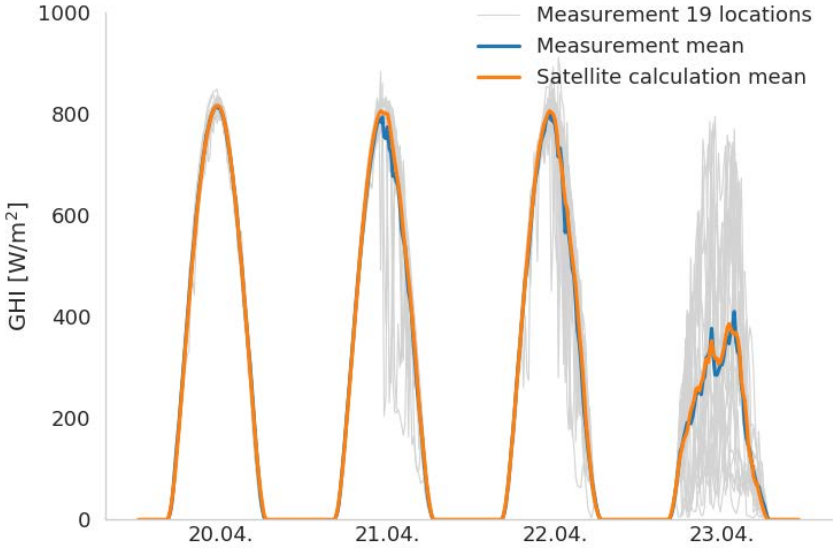


Evaluation

Satellite-based irradiance on different scales

From single station values to regional averages

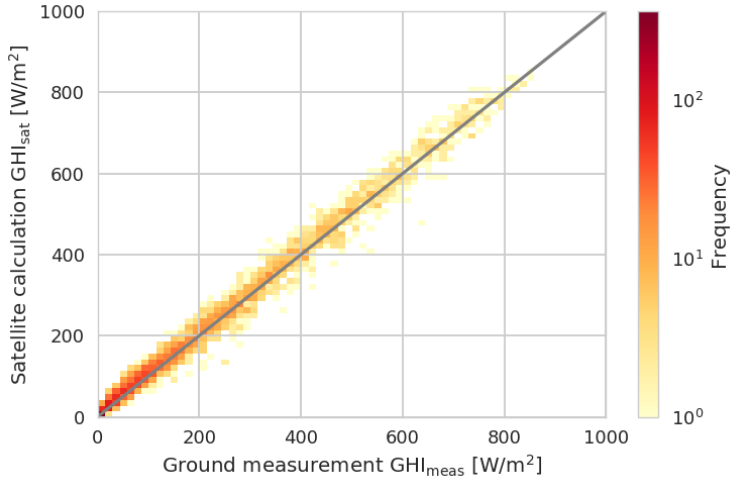
- Here: mean of 19 sites
- Reduced fluctuations
- Reduced deviation between measurements and satellite data



Evaluation

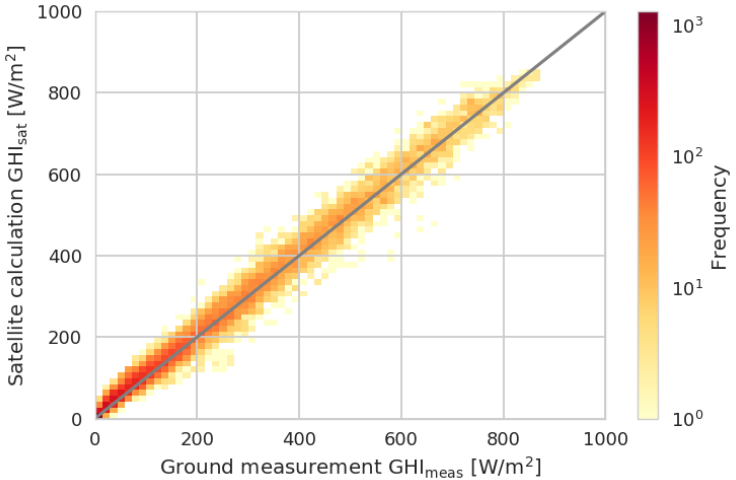
Satellite-based irradiance on different scales

Hourly values
average 19 stations



RMSD = 23 W/m^2 (11 %)

15min values,
average 19 stations

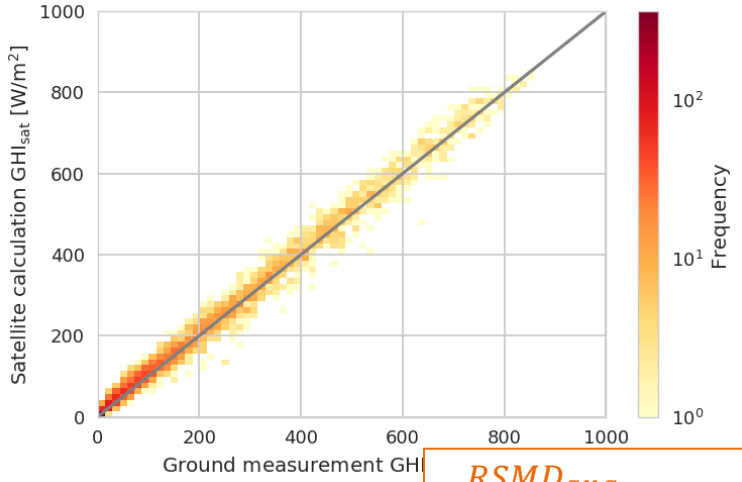


RMSD = 25 W/m^2 (12 %)

Evaluation

Satellite-based irradiance on different scales

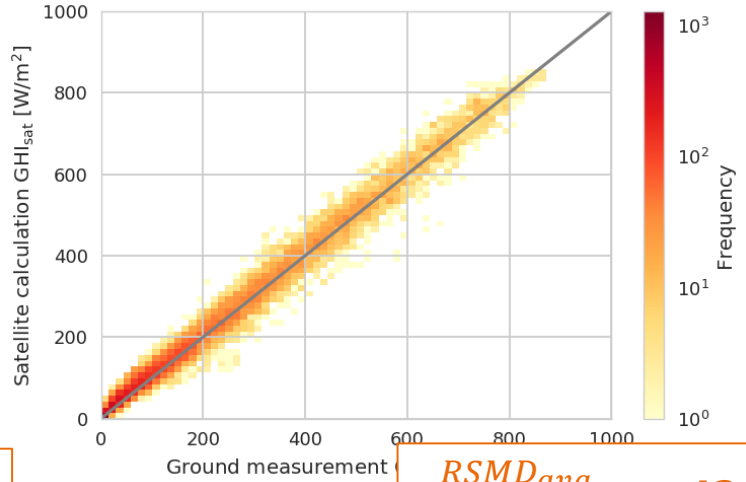
Hourly values
average 19 stations



RMSD = 23 W/m^2

$$\frac{RSMD_{avg}}{RMSD_{single}} = 51\ \%$$

15min values,
average 19 stations



RMSD = 25 W/m^2

$$\frac{RSMD_{avg}}{RMSD_{single}} = 42\ \%$$

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Evaluation

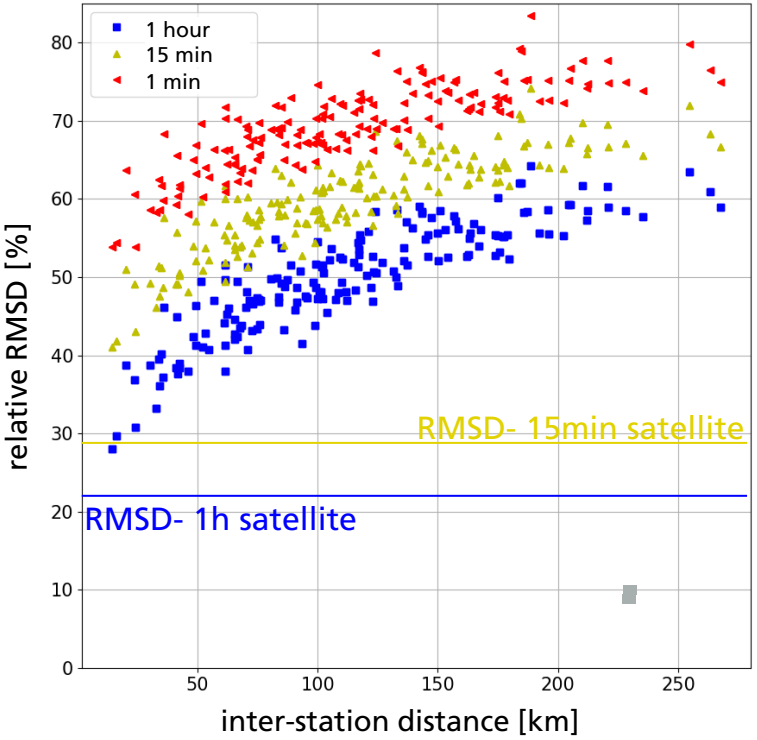
Satellite-based irradiance vs. interpolation of neighbouring ground measurement stations

- Estimation of irradiance at ground station with of neighbouring stations

  → Depends on inter-station distance

- Comparison with satellite-based irradiance (horizontal lines)

  → Satellite derived irradiance values with 15 min/1 h resolution better agreement for inter-station distances investigated here (> 10 km)



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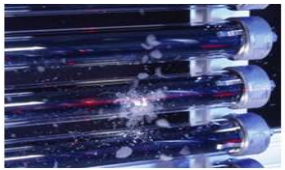
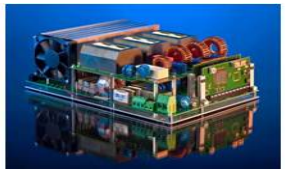
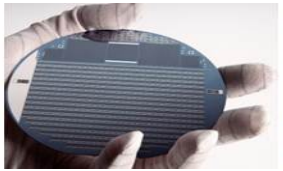
Summary

- Nowcasting of PV power important for grid integration of a large share of distributed PV plants
- New Approach PV Live: Irradiance data for PV power upscaling
  - High-resolution grid of measurement stations in Baden Württemberg
  - Combination with satellite-based irradiance
  - Aim: Improvement of PV power upscaling at TransnetBW
- Evaluation of satellite derived irradiance on multiple spatial and temporal scales shows good accuracy

Thank you for your attention!

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