WHEN TRUST MATTERS

Simulating single-axis tracker systems in complex terrain

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Trackers in complex terrain – problem statement

https://www.pv-tech.org/tracker-terrain-loss-the-elephant-in-the-room-and-the-low-hanging-fruit/

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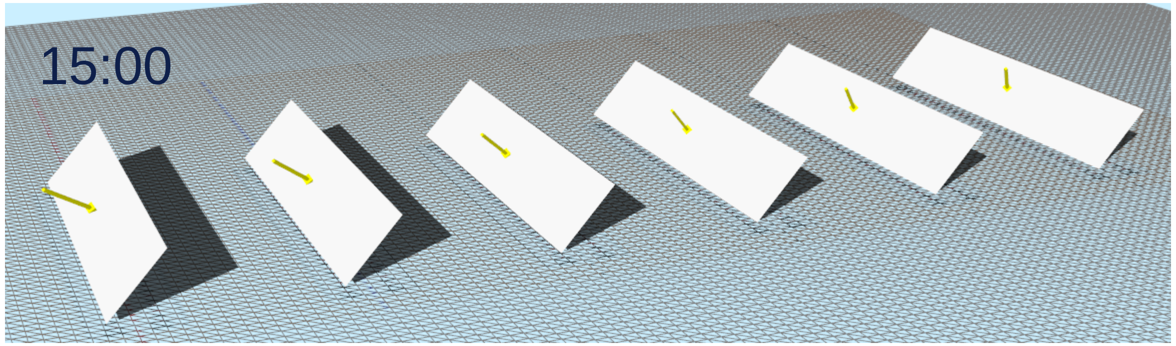
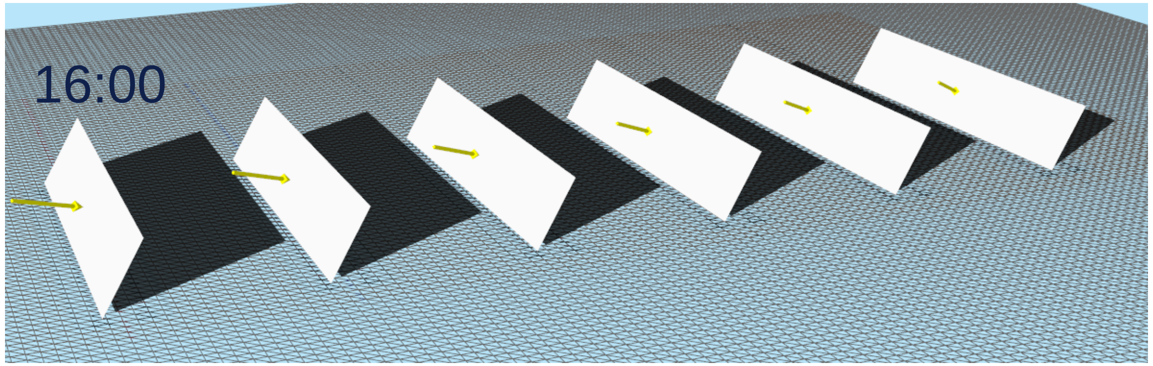
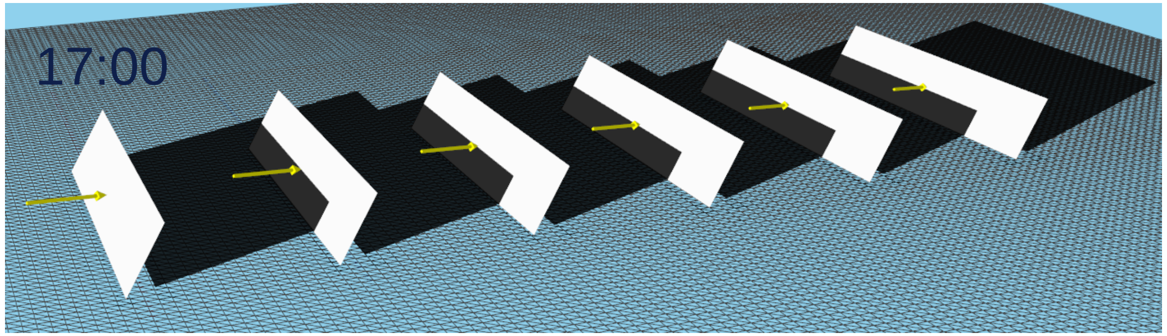
Tracking algorithms

Some basics about single-axis tracking

- Optimise sunlight incident on module surface



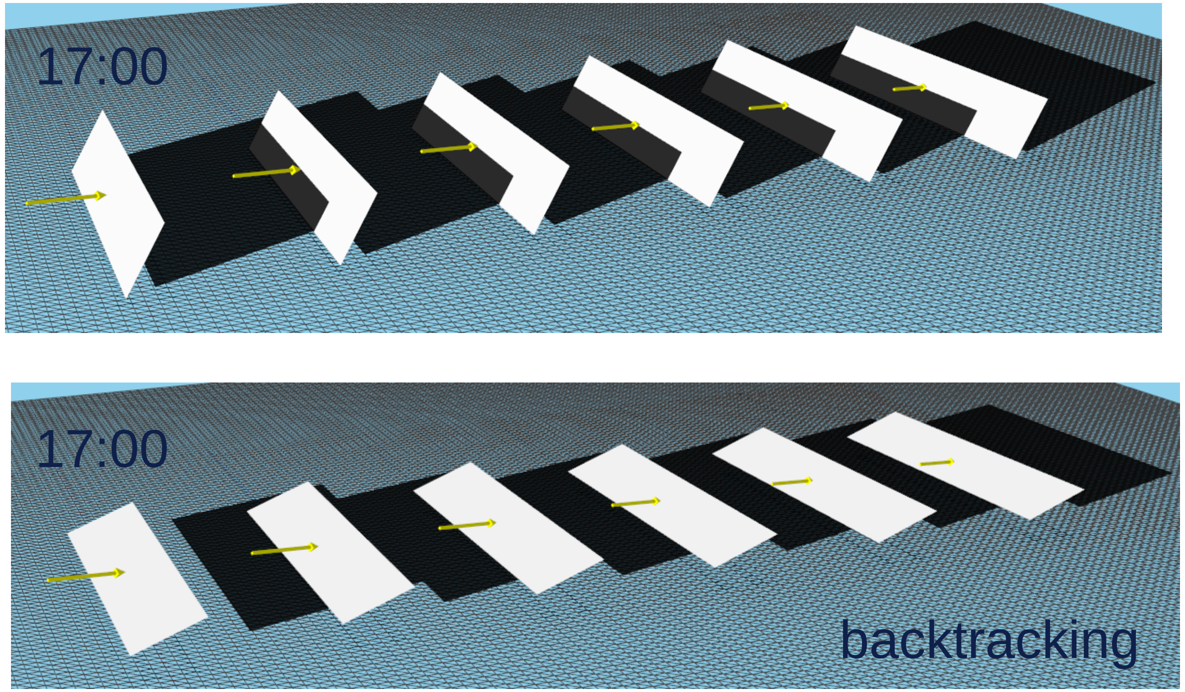


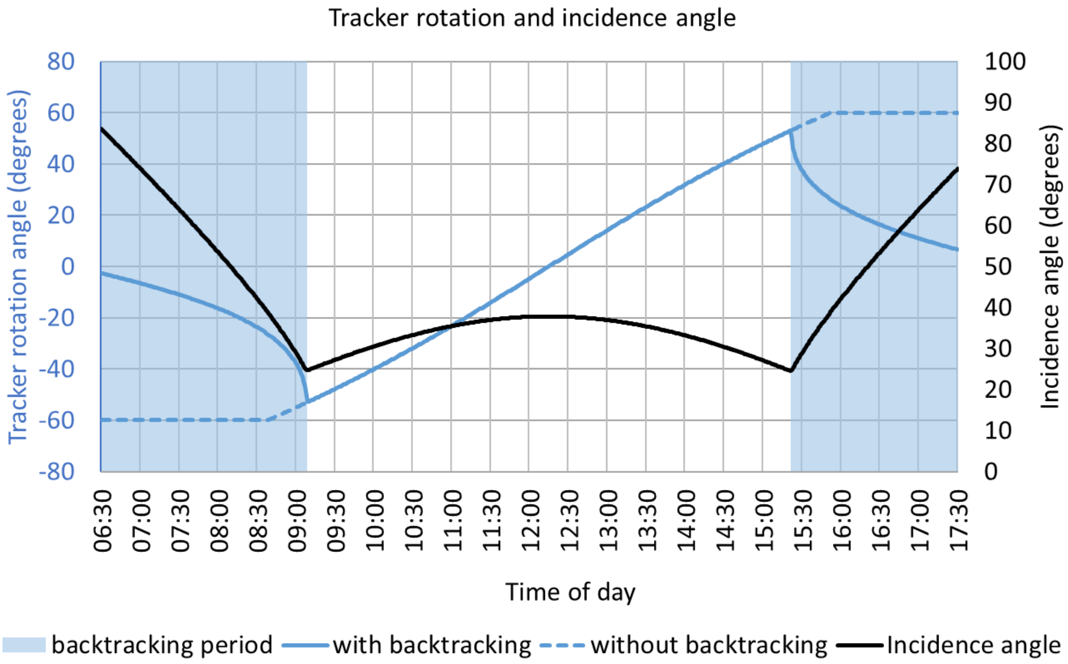


Minimising the incidence angle is not the end of the story…

Some basics about single-axis tracking

- Avoid row-to-row shading by backtracking, driven by GCR





Tracking on slopes

- Assume trackers installed on a slope with west→east 10 degrees downward tilt
  - **Morning** >>> backtracking can stop earlier as trackers are installed away from shade line

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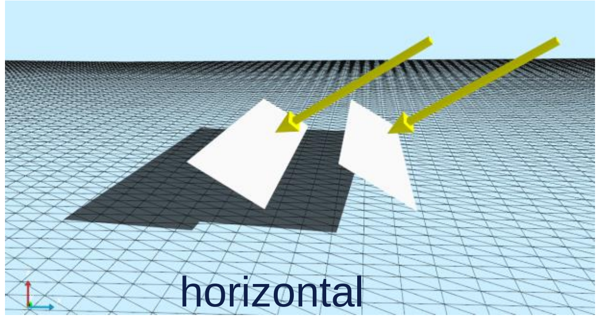

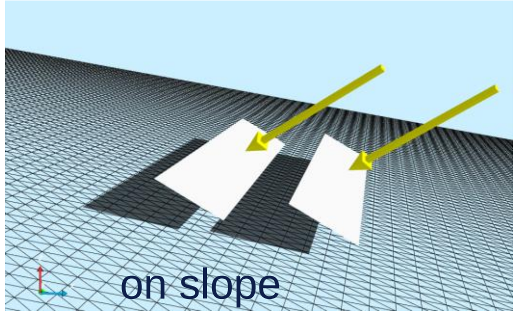

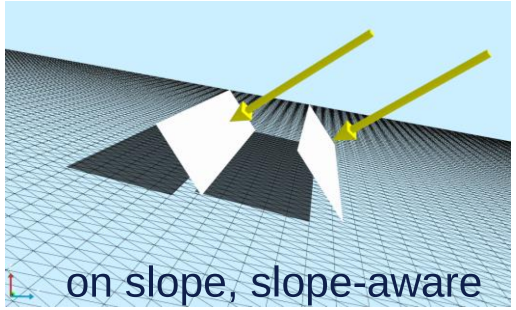

  - **Afternoon** >>> backtracking needs to start earlier as trackers are installed closer to shade line

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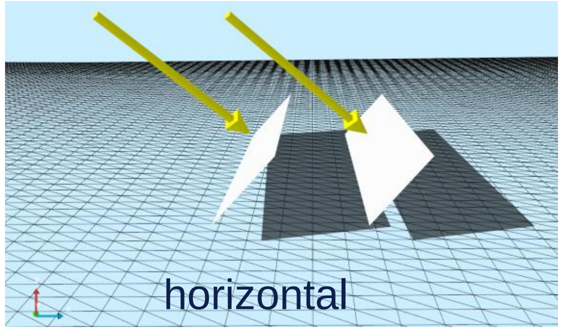
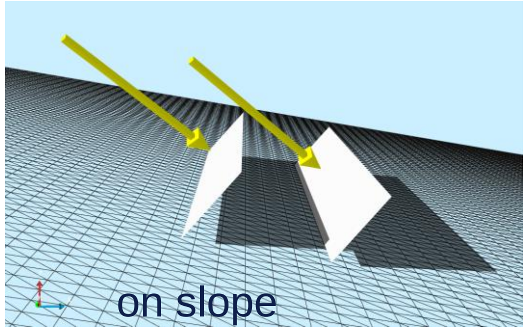
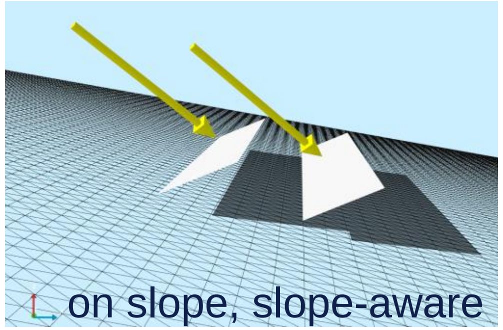
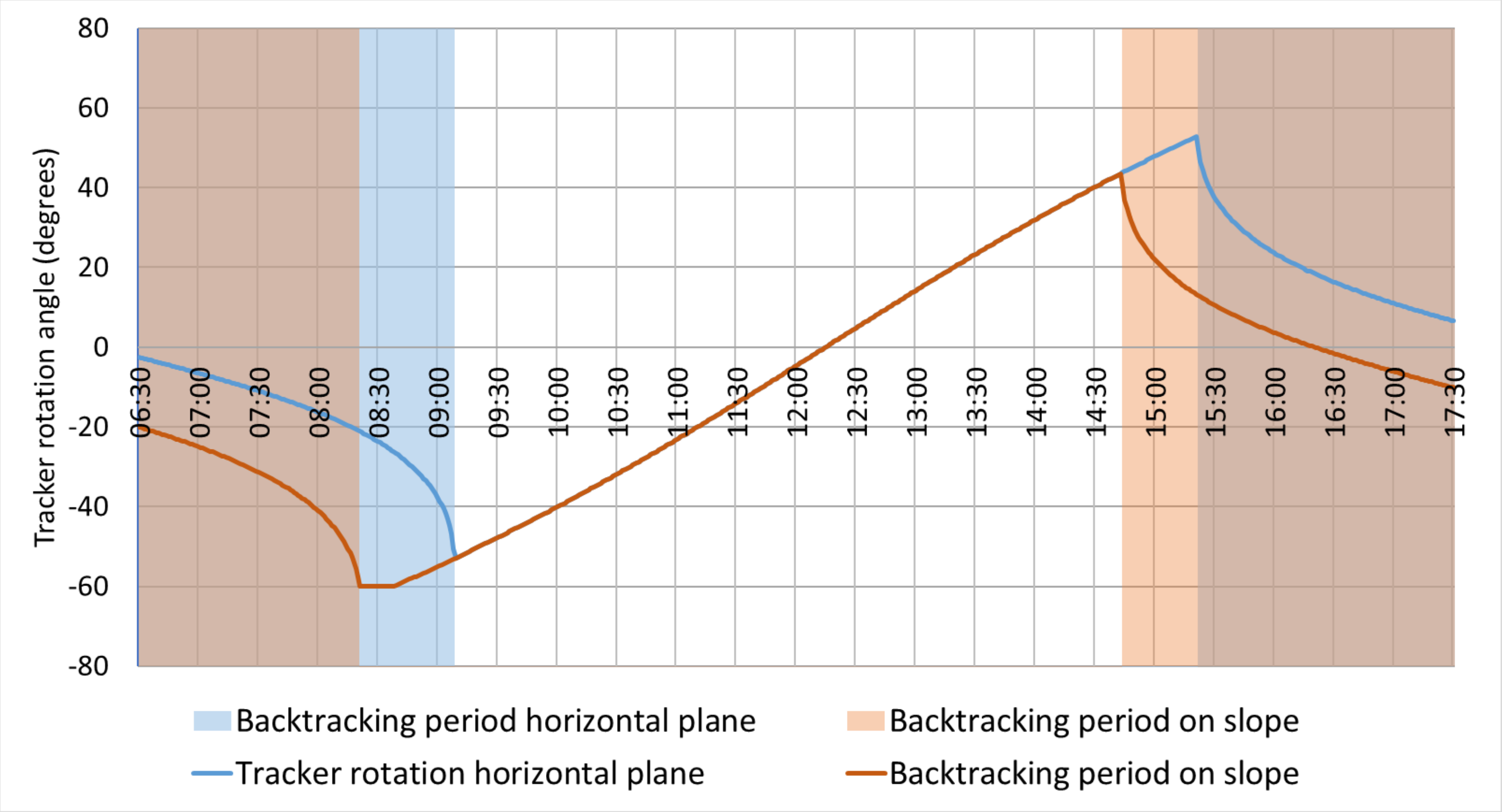






Tracking on slopes

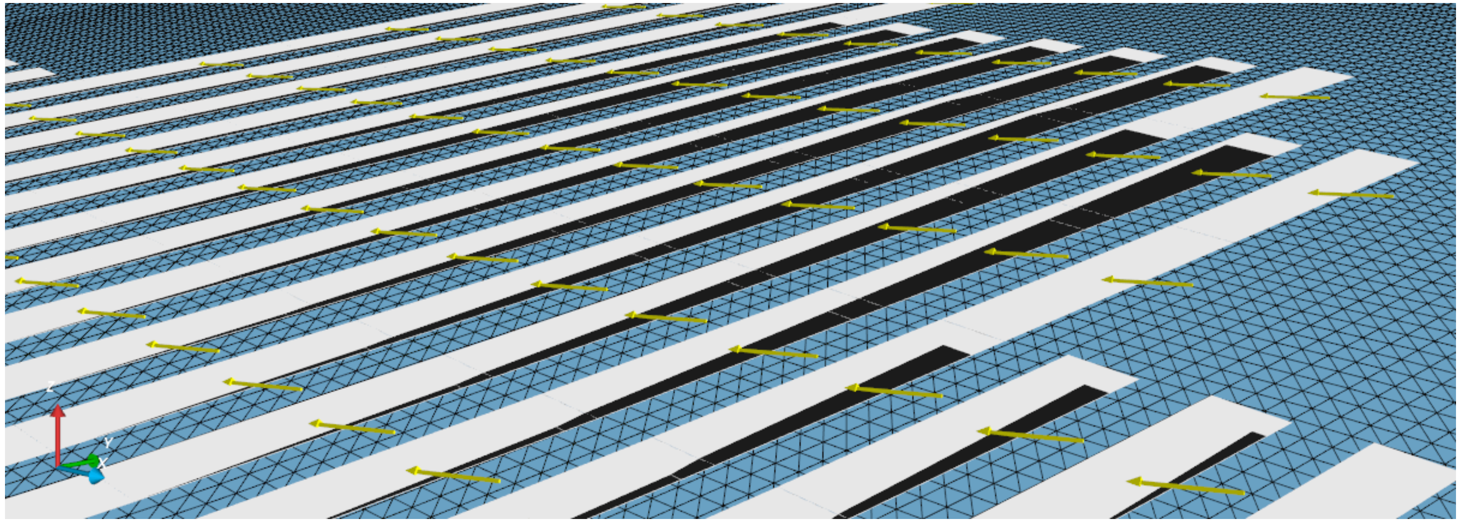
- Backtracking needs to be slope-aware
- Backtracking periods shift compared to flat terrain, depending on slope tilt and orientation



Tracker simulations with SolarFarmer

SolarFarmer shading model

- Tracker rotation determined by system plane (tilt+azimuth) with slope-aware backtracking (optional)
- Irradiance shading models
  - Direct irradiance – each tracker is a shading obstacle in a 3D geometric shading model
  - Sky diffuse irradiance – hemicube model to determine visibility of the sky on module level
  - Reflected irradiance – infinite sheds model to determine shading of the ground
- Electrical mismatch model
  - Irregular shading on submodule level considered for individual strings to determine electrical mismatch

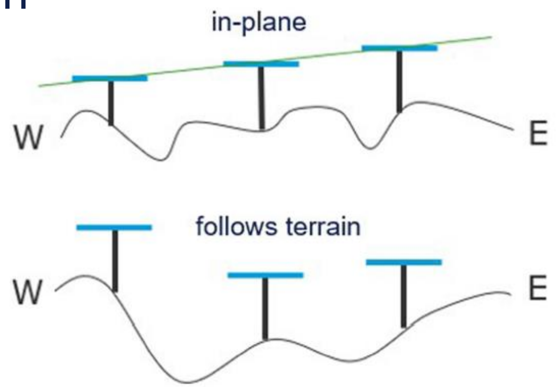


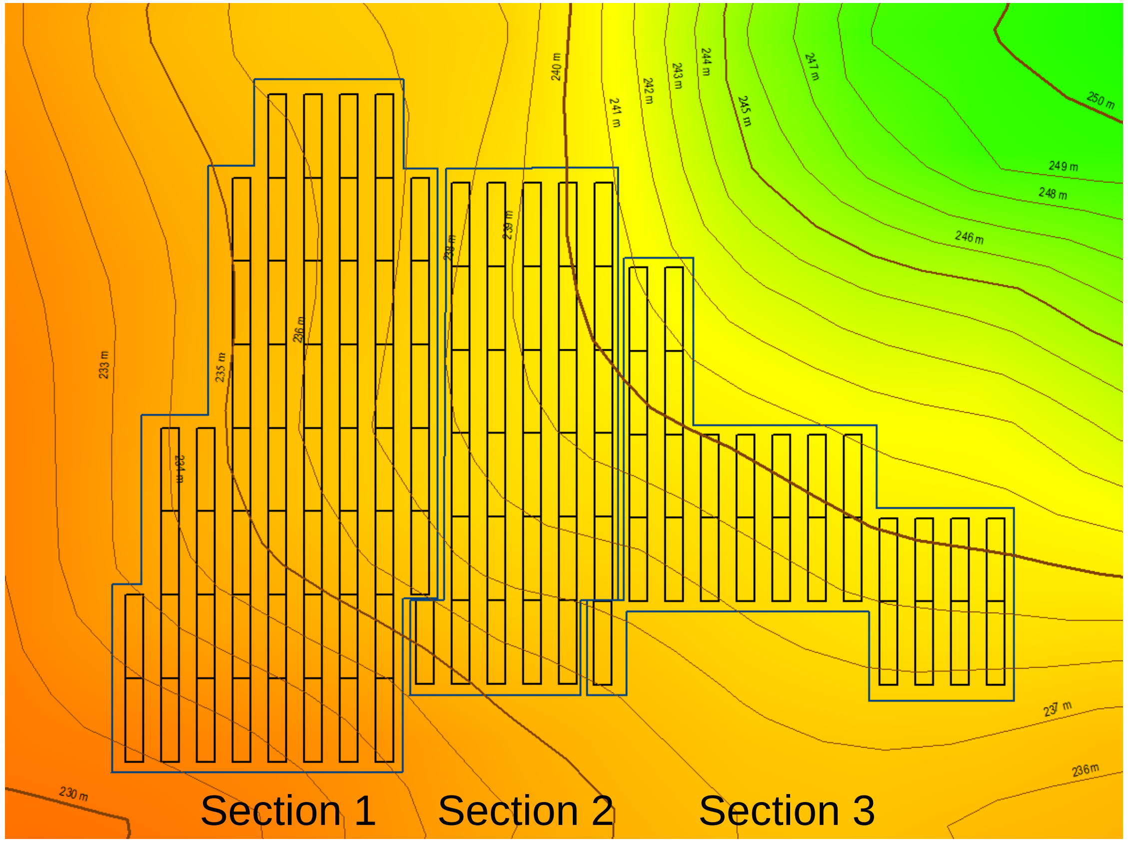
Tracker Terrain Loss

Estimating tracker terrain ~~loss~~ effect

- Tracker terrain effect = $\dfrac{Yield_{Terrain}}{Yield_{Horizontal}} - 1$

- Case study – Hopewell Friends, US
  - South-west slope with some variation across the site
  - GCR = 0.51
  - 1 year modelling period with 5-min time steps
  - Backtracking either standard or slope-aware
  - Modelled with 111 trackers placed
    - “in plane” (all tracker axes on a plane)
    - “follow terrain”





Tracker rotation is determined via section-wise system plane azimuth and tilt

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Estimating tracker terrain effect

Number of layout sections	Tracker placement mode	POA Irradiance gain (%)	Shading loss (%)	El. mismatch loss (%)	Yield (kWh/kWp)	Tracker terrain effect (%)
	Horizontal	25.5	1.7	0.0	1681.8	NA()
Standard backtracking						
1	In plane	26.9	2.6	3.4	1628.6	-3.2
	Follow terrain	26.9	2.7	3.4	1625.8	-3.3
3	In plane	27.1	2.6	3.1	1637.1	-2.7
	Follow terrain	27.1	2.6	3.1	1636.4	-2.8
Slope-aware backtracking						
1	In plane	27.0	1.9	0.0	1700.0	+1.1
	Follow terrain	27.0	2.1	2.1	1658.9	-1.4
3	In plane	27.1	1.9	0.0	1701.8	+1.1
	Follow terrain	27.1	2.0	1.5	1673.9	-0.5

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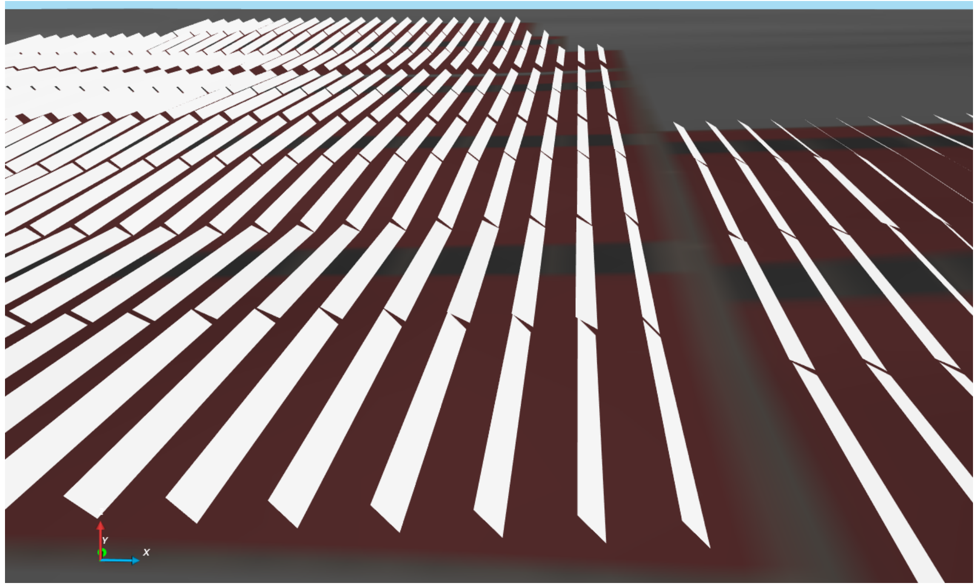
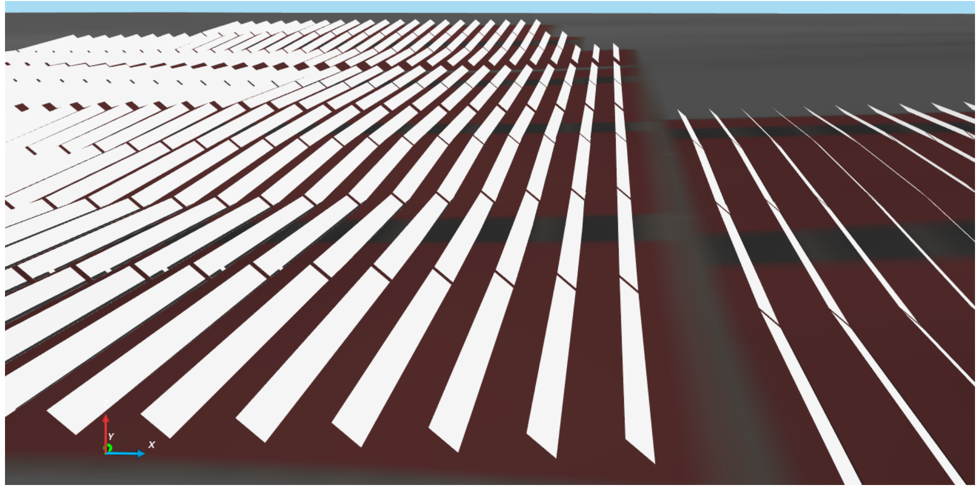
Independent tracking

Independent tracking

- To avoid shading losses for trackers following terrain
- At all simulation time steps, each tracker has its own rotation angle
- Rotation angles typically provided by tracker manufacturers
- Required model inputs
  - Exact 3D locations of individual trackers
  - Tracker rotation time series, typically sub-hourly

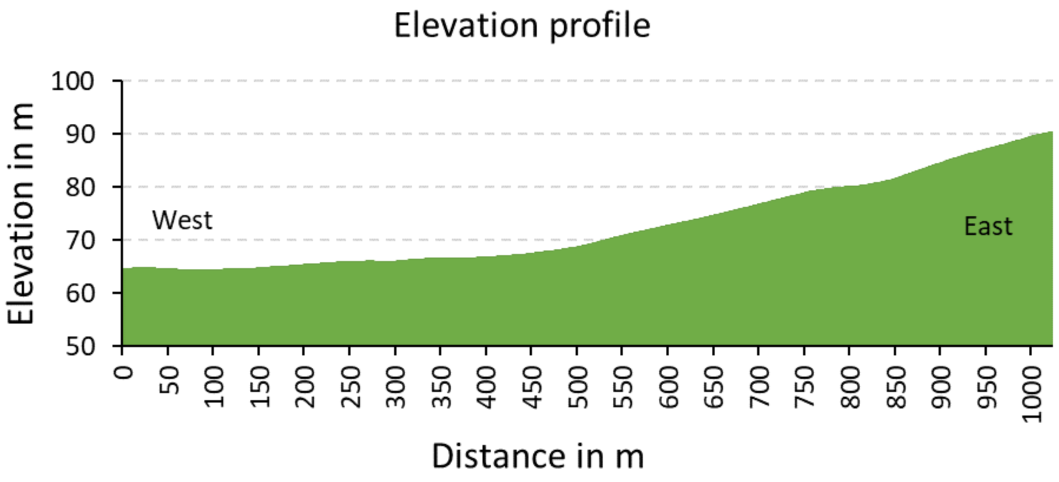




Tracker visualisation with independent tracking (top) and SolarFarmer's slope-aware tracking (bottom)

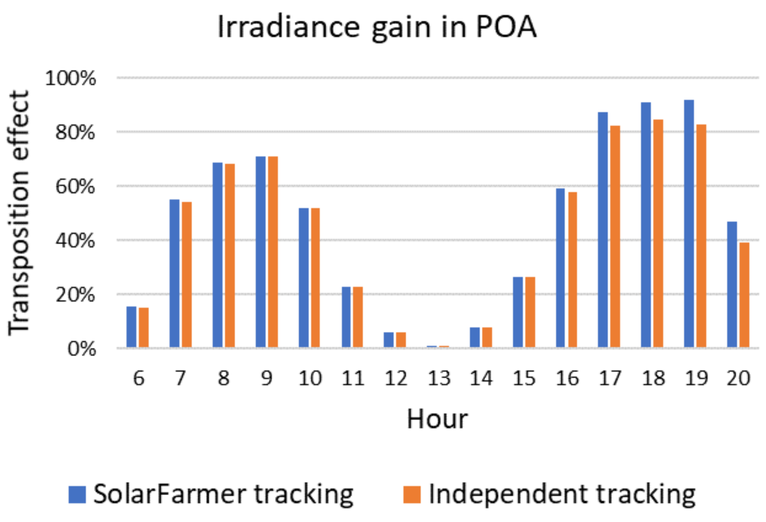
Independent tracking – case study

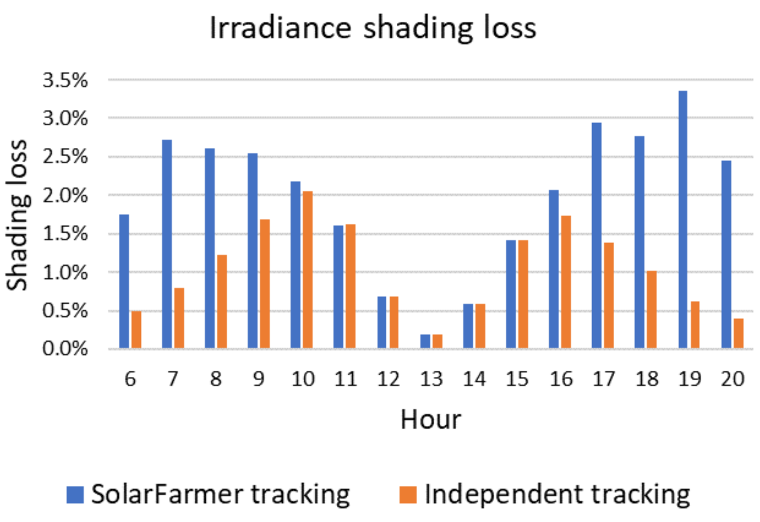
- Inputs provided by PV Hardware Solutions
- Site in Spain
  - 1400 individual trackers
  - GCR = 0.4
  - terrain sloping upwards from west to east and also some height variations from north to south
- Simulations for trackers “follow terrain” and
  - PV Hardware Solutions independent tracking angles
  - SolarFarmer slope-aware tracking with single layout section
- 5-min time steps for one year

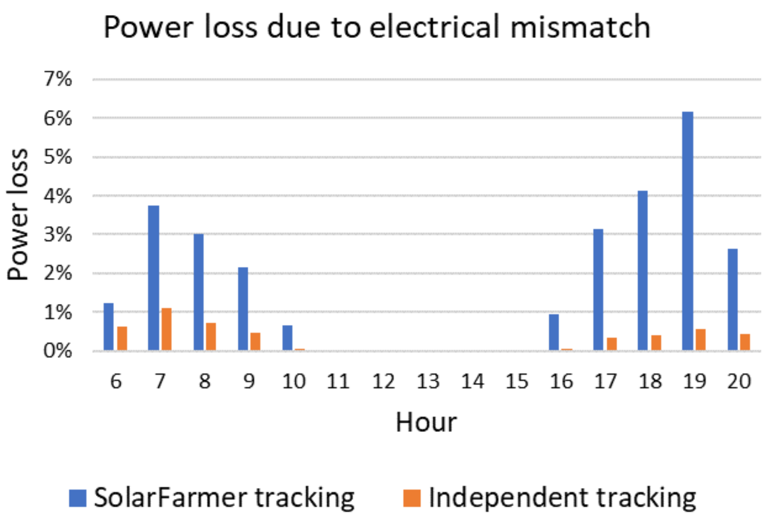


Independent tracking – case study

Results aggregated over entire modelling period and grouped by hour



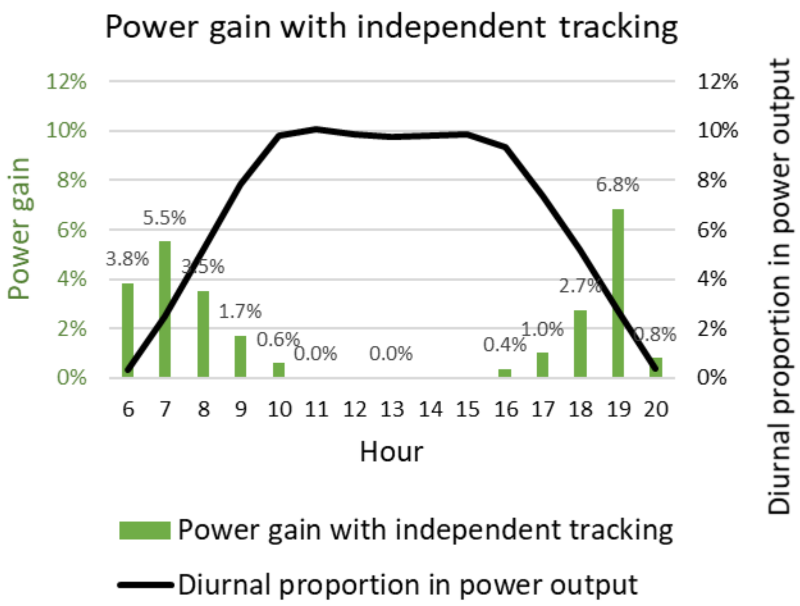




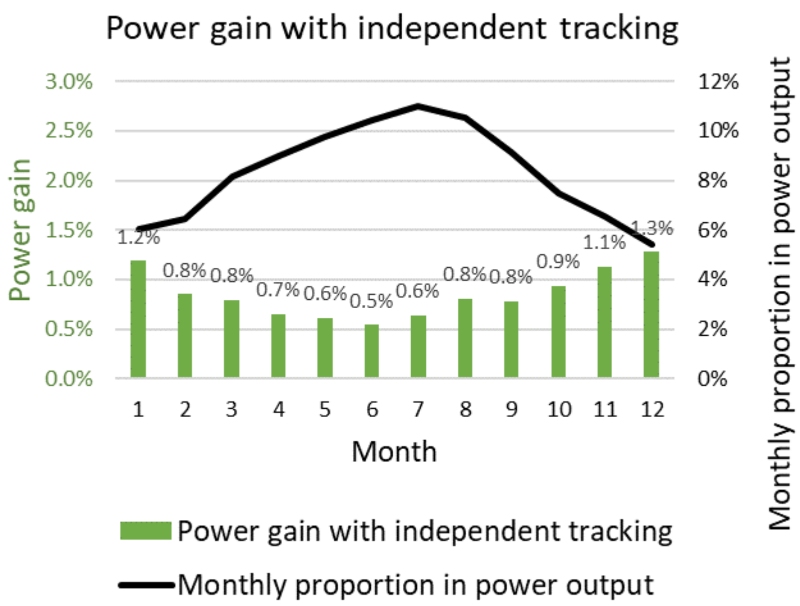
Independent tracking reduces shading and related loss in power output

Independent tracking – case study

- Compared to standard tracking, annual energy output is increased by 0.8 % for this case study

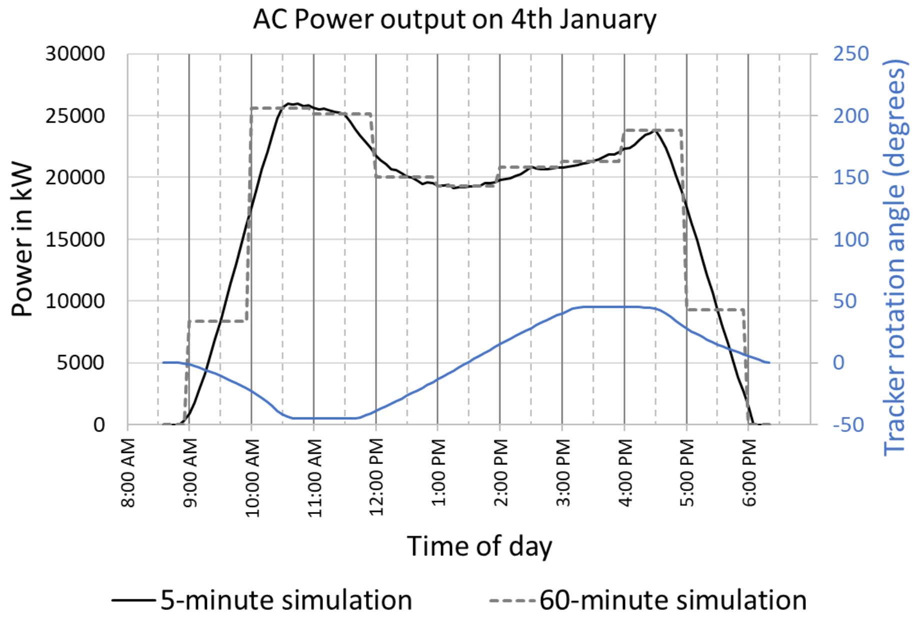


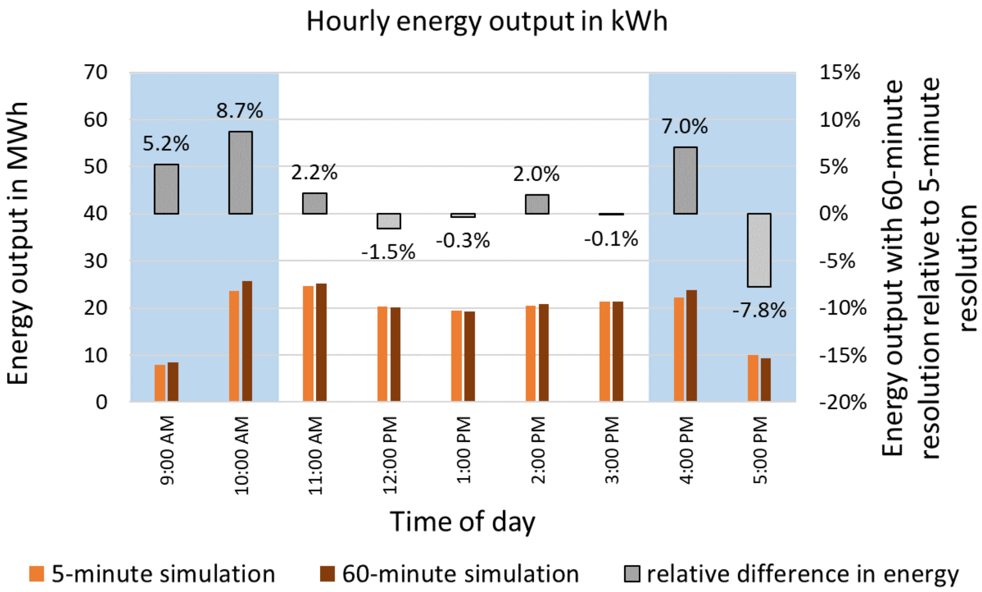
- Seasonal variation in energy gain, at least 0.5 %



Independent tracking – case study

- Simulation time resolution → sub-hourly modelling is important





Where do we go next with SolarFarmer?

Outlook

Tracking

- Diffuse capture
- High wind speed tracker stow strategy

SolarFarmer model

- (re)introduce shading from 3D obstacles
- 3D API calculations, including bifacial module support and independent tracking simulations

Validation

- Independent tracking

Please contact us of you want to collaborate with the SolarFarmer team on model validation!

References

- Slope-Aware Backtracking for Single-Axis Trackers: https://www.nrel.gov/docs/fy20osti/76626.pdf
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  - M. A. Mikofski and P. J. Rainey, “Tracker Terrain Losses,” in *2020 47th IEEE Photovoltaic Specialists Conference (PVSC)*, Jun. 2020, pp. 1859–1862, doi: 10.1109/PVSC45281.2020.9300381.
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Thank you!

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