Methodology Update Bulletin

ForgeSolar Radiometric Physics Engine v3.2.1 — July 2026
Document generated 14 Nov 2026

This bulletin summarizes recent updates to the ForgeSolar Radiometric Physics Engine, the radiometric modeling engine used by ForgeSolar for solar glare hazard analysis. These updates reflect advancements in optical physics research and improve the accuracy and safety compliance of glare assessments. Updates are grouped below by release, most recent first.

v3.2.1 (July 2026)

Single-Axis Tracker Footprint Orientation Refinement

For single-axis tracking systems using shade-avoidance or interval backtracking, the tracker's along-axis tilt is inferred from the orientation of the PV array's planar footprint. For footprints whose vertices spanned uneven terrain, the footprint orientation is now derived consistently from the planarized footprint. Fixed-mount arrays, and tracking systems on level footprints, are unaffected; reported footprint areas are unchanged for planar footprints and may increase slightly for footprints drawn across uneven terrain. As recommended, footprints spanning varying slopes or very uneven ground are often best modeled as separate planar arrays.

v3.2.0 (June 2026)

1. Route and Flight Path Downward View Restriction Correction

The downward view restriction filter for route and flight path receptors widened its threshold by half the beam spread, so that glare whose beam disk partially entered the observer's field of view was retained. At grazing sun angles (near sunrise and sunset) this allowed glare

originating below the path to slip past a 0° downward view restriction. Downward view restrictions of 1° or less are now treated as strict cutoffs, with no beam-spread allowance. Behavior for restrictions greater than 1° is unchanged.

2. Configurable Minimum Luminance Threshold and Sun Dominance Angle

The minimum luminance threshold and the sun dominance maximum angle are now user-configurable analysis inputs, set at the project level with an optional per-site override. Defaults are unchanged (5 000 cd/m^2 and 10°), so analyses run with default settings produce identical results to v3.1.3. The values used are recorded at analysis time and displayed on results pages and PDF reports.

3. Partial Obstruction Blocking for Route and Flight Path Receptors

Obstructions that partially block the line of sight between a PV array and a route or flight path now more accurately reduce the reported glare. This aligns route and flight path behavior with Observation Point receptors, which already modeled more accurate partial blocking. Hotspot plots for these receptors now show only the visible portion of the glare region. Results for sites without obstructions are unchanged.

v3.1.3 (May 4, 2026)

1. Vertical Surface Obstruction Pre-Filter Correction

The Vertical Surface (VS) analysis pipeline applies a coarse axis-aligned bounding box (AABB) pre-filter to skip obstructions that cannot affect the analysis before running the triangle-level line-of-sight check. In prior versions this pre-filter sometimes dropped obstructions between the VS and receptor(s) that were far from the VS.

2. Route and Flight Path Hotspot Plot Correction

The PV hotspot plot for route and flight path receptors sometimes failed to render the full remainder of each glare projection. The plot now displays the corrected glare projections, matching the inputs used for subtended-angle and retinal-irradiance computations. Annual glare minutes and hazard categories are unaffected.

v3.1.2 (March 2026)

1. Route Obstruction Mitigation

Enhanced obstruction mitigation for long route segments. Long route segments are now subdivided during the obstruction comparison so that each portion receives independent obstruction evaluation.

v3.1.1 (March 2026)

1. Sun Dominance Mitigation Correction

The sun dominance mitigation filter, which excludes glare timesteps where the reflected beam is within approximately 10 degrees of the direct sun from the observer's perspective, is now applied only to stationary observation point (OP) receptors. In prior versions, the filter was applied globally to all receptor types, including flight paths and routes. This was inconsistent with the German LAI policy, which defines sun dominance as a mitigation applicable only to fixed observation points. Flight path and route receptors now receive unfiltered glare results regardless of the sun dominance setting. Projects with sun dominance mitigation enabled should be re-analyzed to obtain updated results for path-based receptors.

v3.1.0 (March 2026)

1. Receptor Illuminance Calculations

The engine now computes receptor illuminance (lux) alongside source luminance (cd/m²) at each glare timestep. Luminance describes how bright the glare source appears, while illuminance describes how much light arrives at the receptor. Illuminance is derived from the existing per-timestep luminance and subtended angle data using the fundamental photometric relationship:

$$E_v = L \times \Omega_{source}$$

Where L is the source luminance and Ω_{source} is the solid angle of the glare source as seen from the receptor. This quantity requires no new physics inputs and is computed from data already produced at each timestep. Peak illuminance values are reported per receptor and per surface, providing an additional metric for assessing glare impact at observation points.

v3.0.0 (February 2026)

1. Improved Luminance Calculations

The engine now uses more physically accurate luminance calculations developed from independent laboratory measurements of commercial PV modules. Previous engine versions lacked direct luminance measurements and had to extrapolate values from slope-error data and simulated scaling, which in many cases yielded artificially low predictions.

1a. Product-Specific Profiles (BRDF-Based)

Product-specific profiles derive peak luminance directly from laboratory BRDF (Bidirectional Reflectance Distribution Function) characterization of commercial PV modules, performed by independent testing laboratories (e.g. Fraunhofer ISE) following established photometric standards (ASTM E2387). The measured luminance data provides piecewise maximum luminance (L_{max}) values as a function of incidence angle, and the engine evaluates these curves directly. This is the most physically accurate approach, as it uses empirically measured luminance from the actual module surface.

The generic "deeply textured" luminance curve is derived from the upper envelope (the maximum at each incidence angle) of three measured deeply-textured product profiles, with a ~15% safety margin applied. This ensures the generic deeply-textured profile is conservative relative to all known deeply-textured modules.

1b. Revised Generic Profiles (Radiometric Formula)

For revised generic profiles where product-specific BRDF data is not available, luminance is computed using the fundamental radiometric relationship for a reflecting surface:

$$L = E_v \times \rho / \Omega \times k_{peak}$$

Where:

- L is the source luminance (cd/m²)
- E_v is the illuminance on the panel surface (lux), derived from the direct normal irradiance (DNI)
- ρ is the surface reflectance at the given incidence angle

- Ω is the solid angle of the reflected beam cone (sr), computed from the beam divergence angle (β) as $\Omega = 2\pi(1 - \cos(\beta/2))$
- k_{peak} is a Gaussian beam peak correction factor (= 4.0) that converts from average cone luminance to the peak on-axis luminance an observer at beam center would experience, accounting for the non-uniform intensity distribution of the reflected beam

This formulation follows from first principles of radiometry and photometry. Key references include Palmer & Grant, 2010 ("The Art of Radiometry," SPIE Press); McCluney, 2014 ("Introduction to Radiometry and Photometry," 2nd ed., Artech House); and Boyd, 1983 ("Radiometry and the Detection of Optical Radiation," John Wiley & Sons). The BRDF measurement methodology follows Nicodemus et al., 1977 (NBS Monograph 160) and ASTM E2387.

In practice, the updated profiles may predict higher luminance values than the originals for the same site configuration. This reflects improved physical accuracy rather than a change in actual glare risk.

2. Beam Divergence Limit for Diffuse Surfaces

A 120° maximum beam divergence (β) is applied during the glare check calculation. This limit ensures physically meaningful results for highly diffuse PV surfaces, including newer product-specific modules with large slope error or surface roughness. Surfaces where the computed divergence exceeds this threshold are noted in the analysis results.

3. Unified PV and Vertical Surface Analysis Pipeline

The Vertical Surface (VS) and PV array glare analysis pipelines have been consolidated into a single shared methodology. VS analysis now uses the same parametric modeling approach as PV array analysis, providing deterministic glare prediction across both surface types. VS faces are mapped to a horizontal reference plane using coordinate rotation, enabling the full glare check used for PV arrays. This produces more accurate glare predictions and ensures consistent behavior for material profiles, beam divergence handling, and field-of-view filtering across both PV arrays and Vertical Surfaces.

4. Vertical Surface Obstruction Modeling

Vertical Surface analyses now fully model obstruction mitigation, matching the existing capability for PV array analyses. The obstruction mitigation cache is computed once per VS face and applied to all receptor types, using the same projection and intersection logic as PV arrays.

5. 3D Quad-Ray Intersection for Obstruction Mitigation

Obstruction mitigation has been upgraded to use a 3D quad-ray intersection approach. Each obstruction wall segment is decomposed into triangle pairs, and line-of-sight rays from PV surface sample points to receptor positions are tested against these triangles. This replaces the prior projection-based shadow approach, which relied on heuristic cone expansion and polygon subtraction. The new method directly answers the physical question of whether an obstruction blocks the line of sight between a PV surface and a receptor, producing more accurate and geometrically robust blocking predictions.

> ***Conclusion:*** *The results presented in current ForgeSolar reports represent a higher degree of accuracy and safety compliance than prior engine versions. The updates described above improve luminance modeling, extend analysis capabilities to Vertical Surfaces, and align the radiometric methodology with current optical safety research.*

© 2026 Sims Industries d/b/a ForgeSolar. All Rights Reserved.
For questions regarding this methodology update, contact support@forgesolar.com.