PVPMC WORKSHOP 2026

SESSION 1 — IRRADIANCE MODELING

Comparative Assessment of Decomposition × Transposition

Methods for POA Estimation under Tropical High-Cloudiness Conditions

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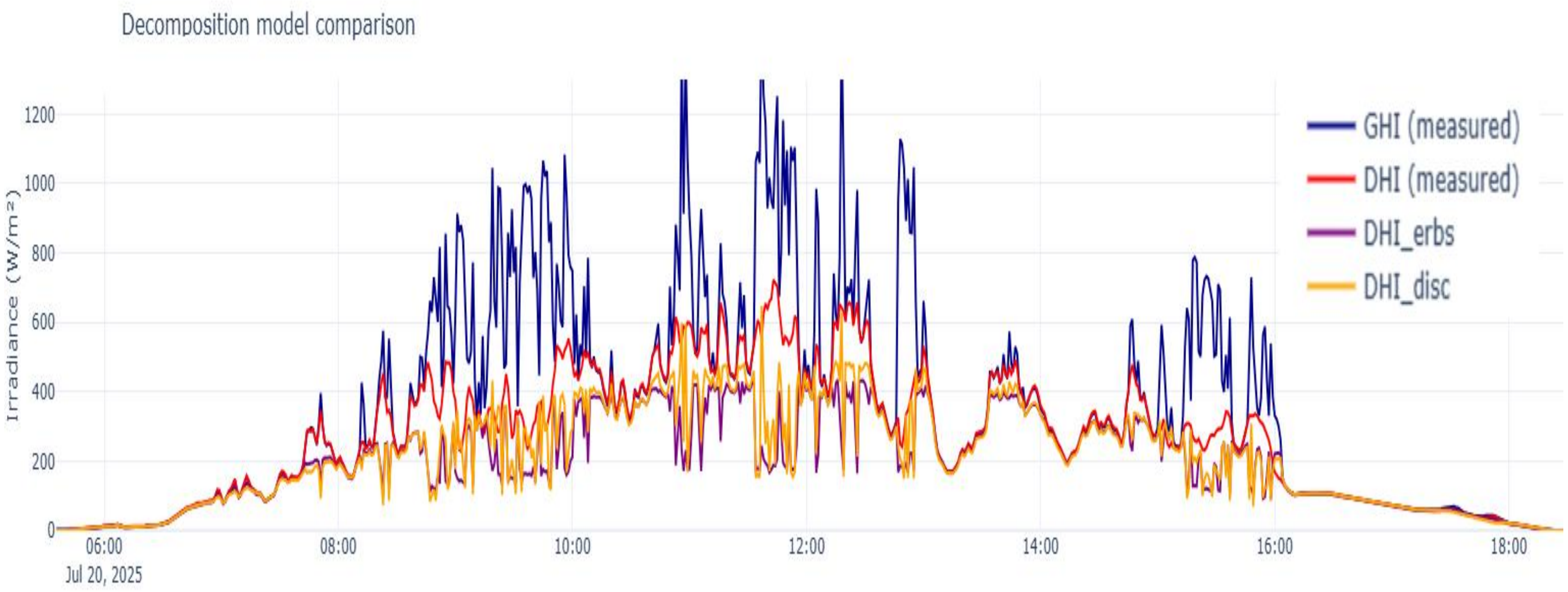
Models diverge where cloudiness is the rule



THE QUESTION

What impact does the choice of the decomposition × transposition method have on the POA estimation?

30 method pairs · 170 days · same site.

CONTEXT

86 % of days at this site are **not clear-sky.**

Mean Kt = 0.50 · no marked seasonality.

THE ANSWER

–4.64 % to +3.55 %

Global POA bias range across the 30 method pairs.

≈ 8 percentage points of spread on the same dataset.

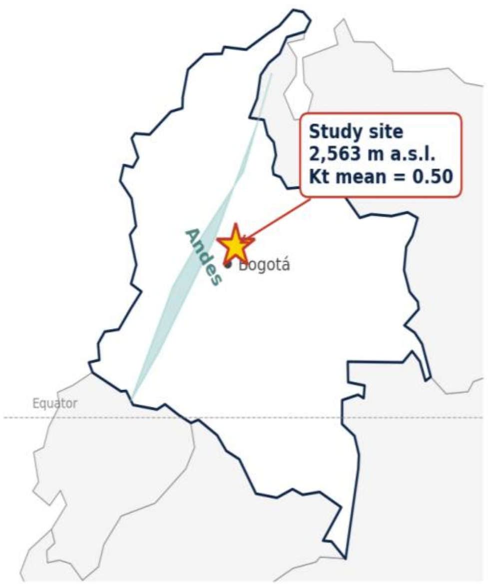
This spread propagates into **EYA · EPI · PR** — and into financing, contracts and instrumentation decisions.

It gets worse in the tropics — so we built a study case

Cucunubá, Cundinamarca · Colombian Andes · equatorial latitude · persistent cloudiness

Colombia · Tropical, equatorial

Tropical Andes · Cundinamarca



LATITUDE
5.24°N
near-equatorial — high zenith dynamics

ELEVATION
2,563 m
Andean plateau

DAILY MEAN Kt
0.50
predominantly partly cloudy

PEAK SUB-HOURLY DHI
> 600 W/m²
cloud-edge enhancement events

Class A station — IEC 61724-1 compliant, deployed July 2025

Geotagged in-field photograph — 15 Jun 2025 · Cucunubá, Cundinamarca

INSTRUMENTATION

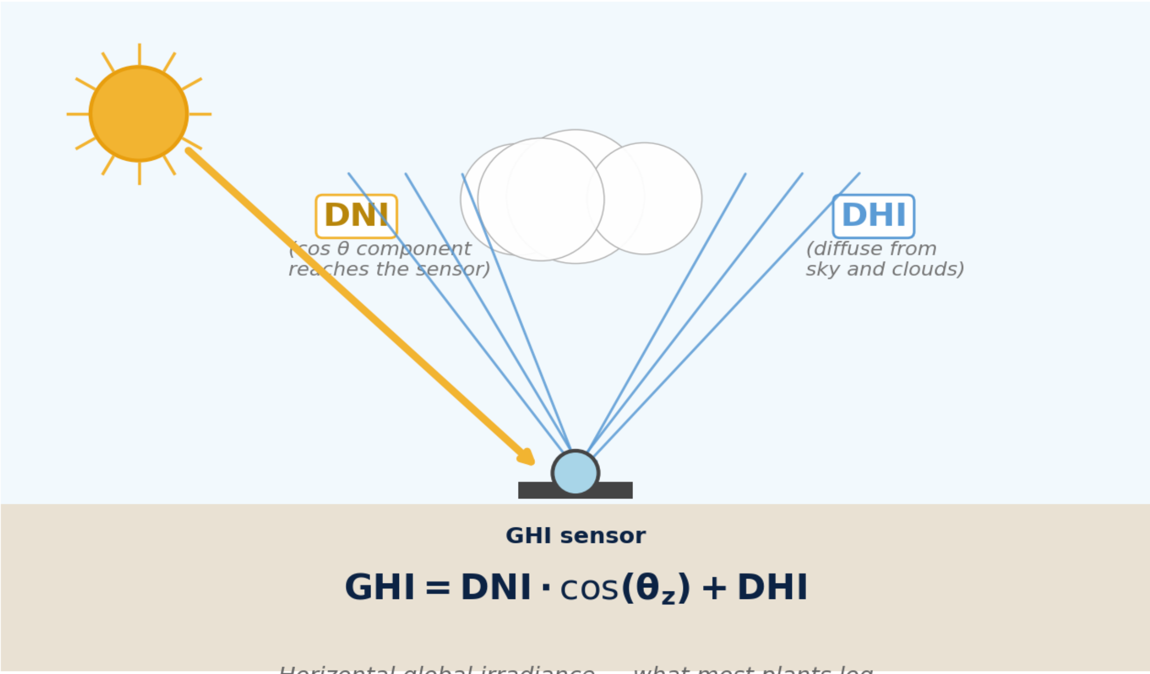
GHI	Class A pyranometer — secondary standard
DHI	shaded pyranometer on sun tracker — direct measurement (the differentiator)
DNI	pyrheliometer on tracker
POA	Class A pyranometer on tracker plane

DATA ACQUISITION

1-second sampling · 1-minute averages · cellular link · autonomous power
Operational since 15 July 2025 · 170 valid days analyzed (Table 4-5)

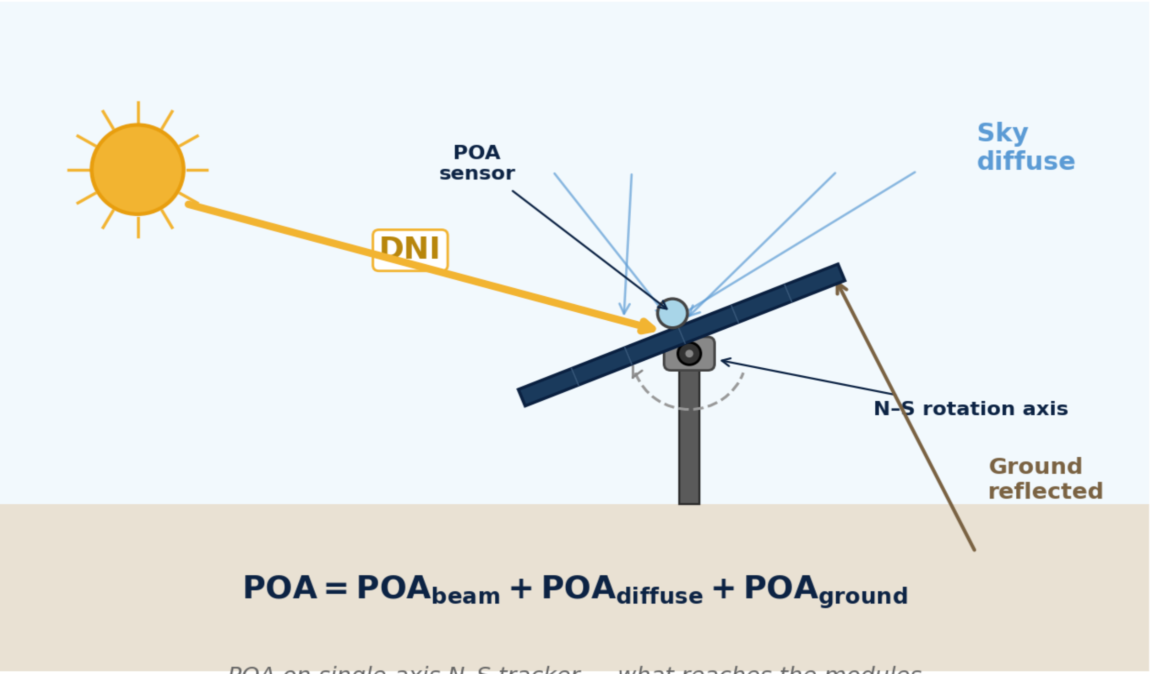
Solar variables — what we measure, what we model

Horizontal-plane variables — what we measure



Horizontal global irradiance — what most plants log

Plane-of-array (POA) — what we want to estimate



POA on single-axis N–S tracker — what reaches the modules

Closure equation: **$GHI = DNI \cdot \cos(\theta_z) + DHI$** Most utility-scale PV plants log GHI, but not DHI — a global pattern, not just Colombia.

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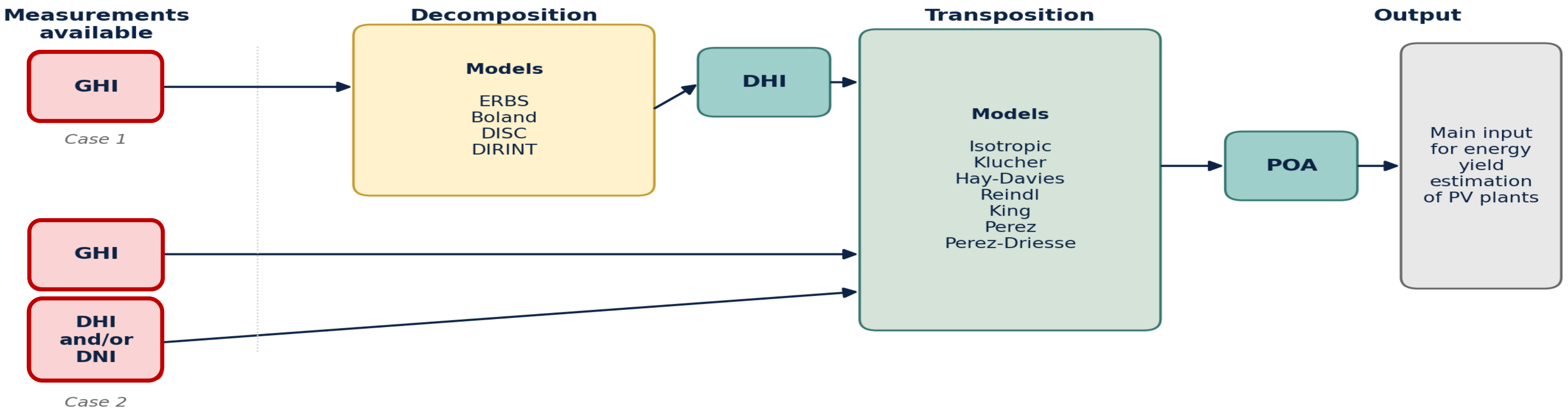
Two-axis comparison — 4 decomposition × 6 transposition models



01

Measurement station design

GHI · DHI · DNI · POA simultaneous (IEC 61724-1)

02

QC adapted to the tropics

BSRN-derived 18-flag protocol re-tuned for high-cloudiness

03

Decomposition × transposition

4 × 6 combinations — measured DHI vs modeled DHI — pvlib

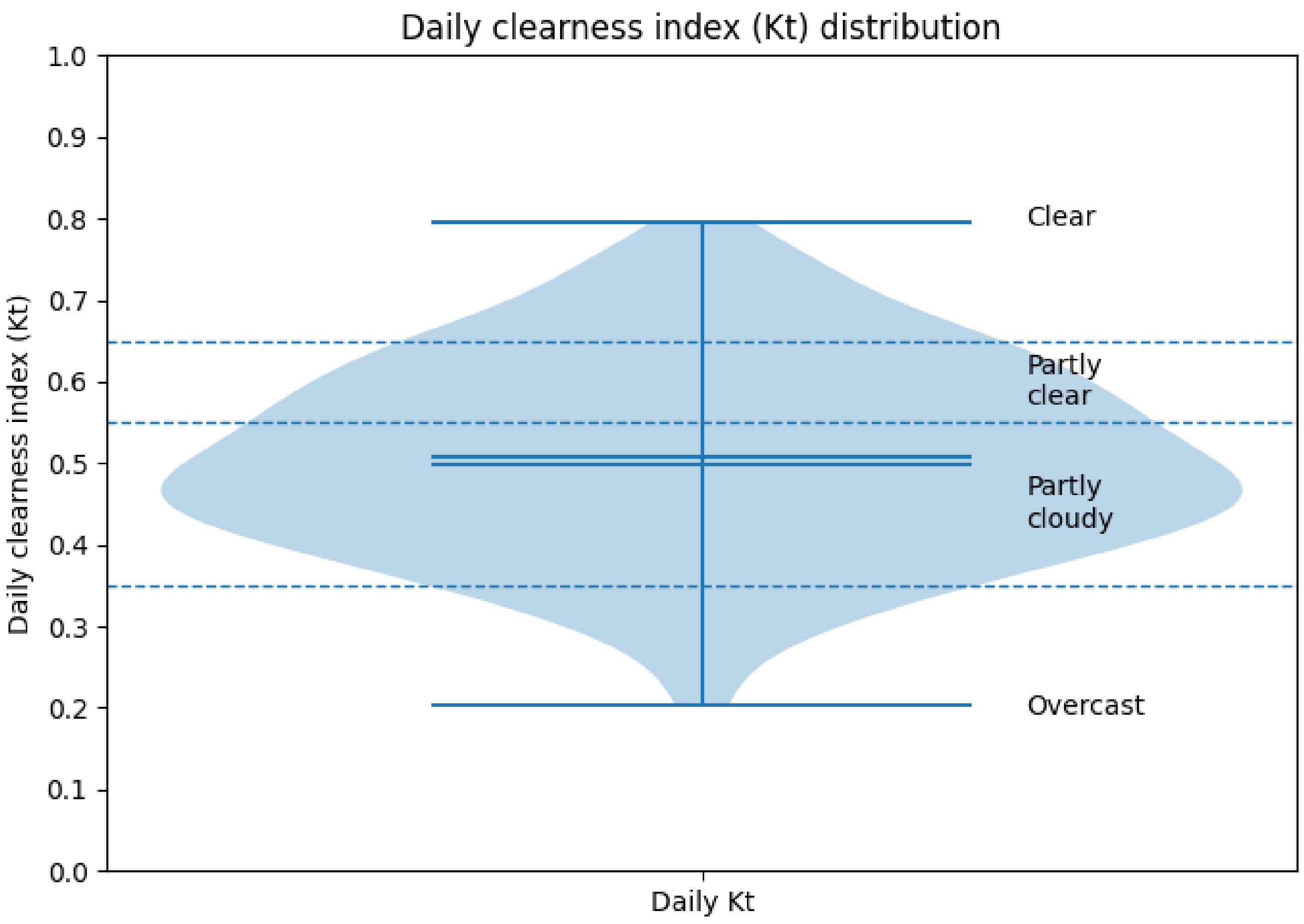
04

Energy translation

PVsyst at 5-min resolution — validated (corr 0.997)

Persistent cloudiness, no marked seasonality

170 days of 1-min GHI · DHI · DNI · POA — Jul to Dic 2025

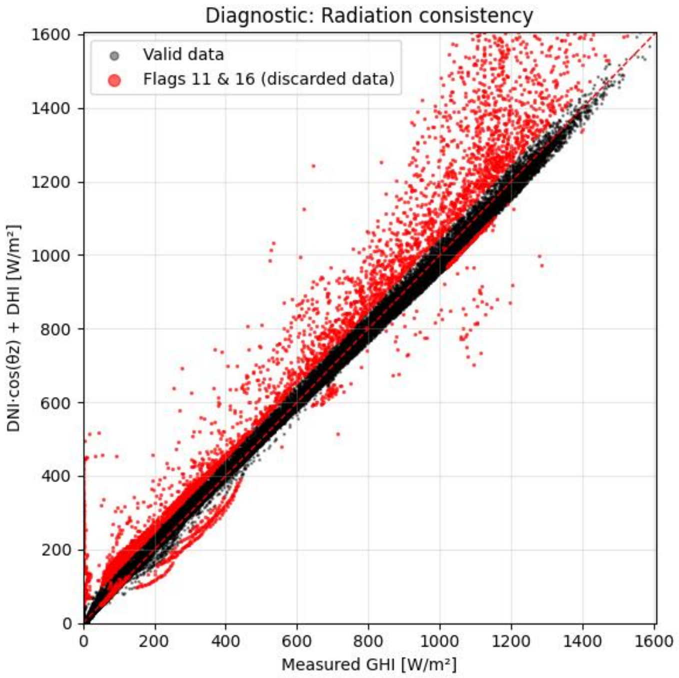


SKY REGIME DISTRIBUTION

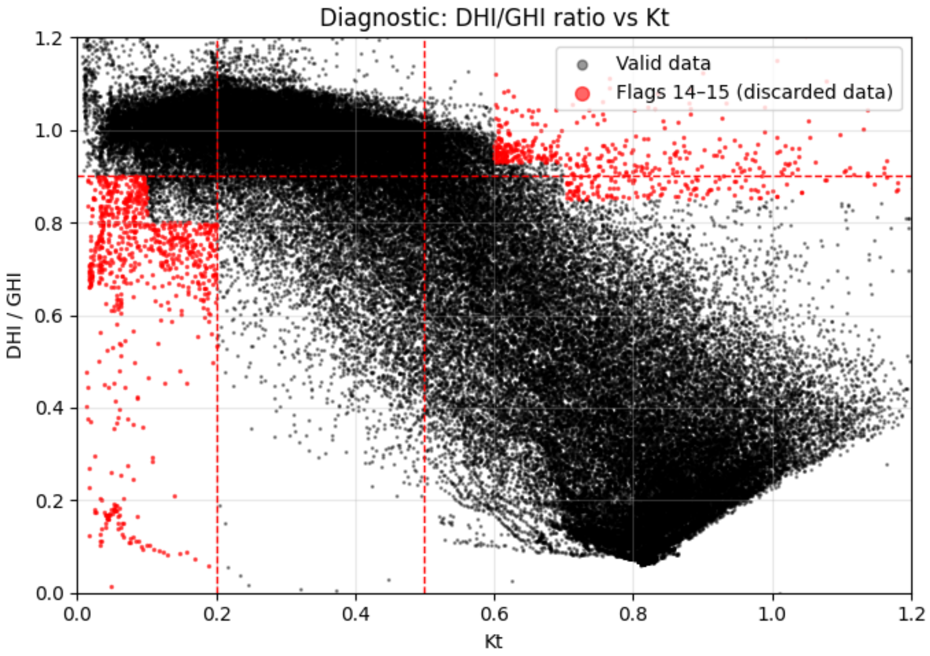
Sky regime	Kt range	Days	Share
Clear	Kt > 0.65	**24**	**14 %**
Partly clear	0.55 < Kt ≤ 0.65	**37**	**22 %**
Partly cloudy	0.35 < Kt ≤ 0.55	**95**	**56 %**
Overcast	Kt ≤ 0.35	**14**	**8 %**

78 % of days fall in partly-clear / partly-cloudy regimes.
Cloudiness is dominant and persistent year-round — Kt is the natural stratification variable.

Standard QC discards physically valid data — we re-tuned it



BSRN closure · GHI vs DNI·cos(ϑ) + DHI



Diffuse fraction vs Kt · flags 14–15 stratified by Kt

ADAPTATIONS APPLIED

Flag #9
redefined for tropical zenith range

Flags #14–15
stratified by Kt instead of fixed thresholds

Modified Kt index
removed — produced systematic false positives at high zenith

quality test

2.9% of the measurement data were discarded.

With the adaptation of quality filters 97.09 % of records preserved as legitimate.

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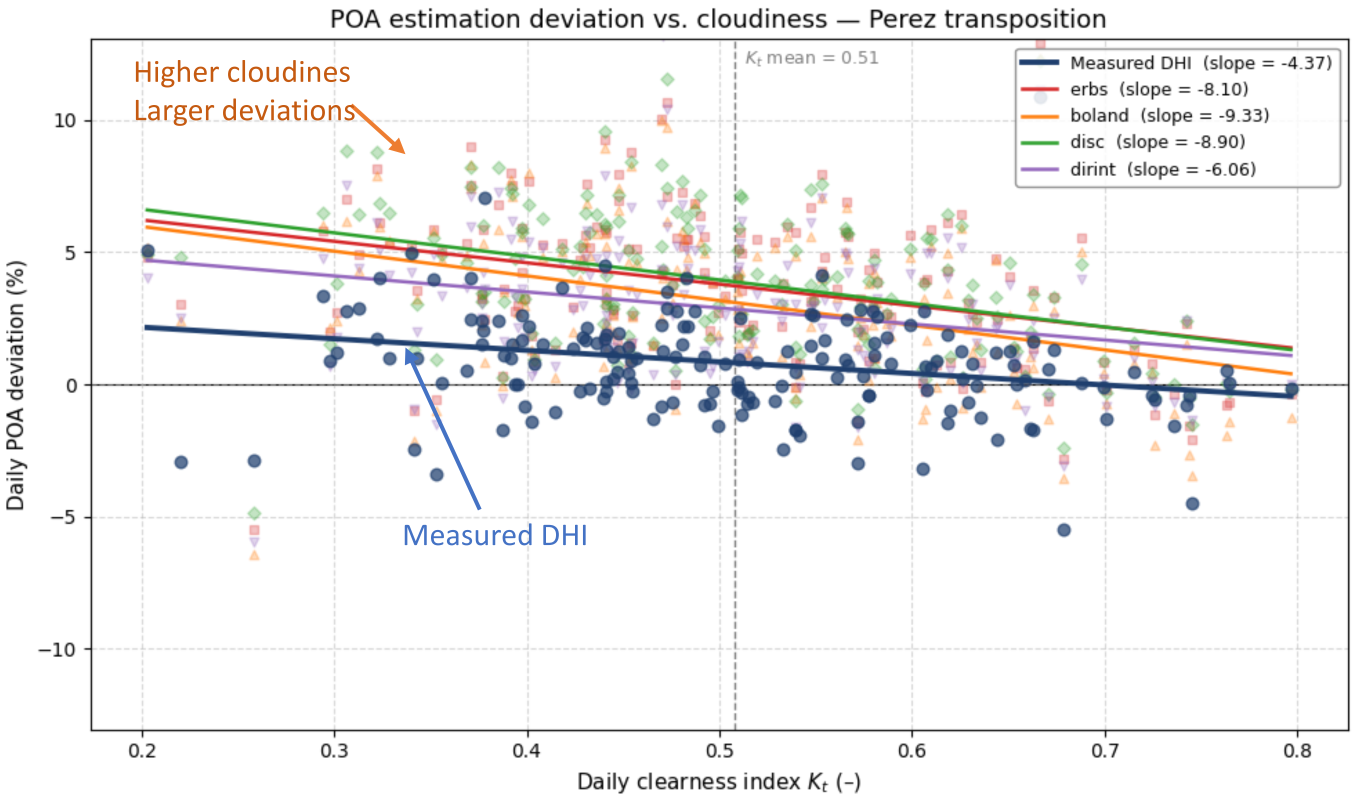
POA deviation grows as cloudiness increases — systematic bias



Slope of POA deviation vs K_t — by decomposition × transposition

	DHI source				
	Measured	ERBS	Boland	DISC	DIRINT
Perez	-4.37	-8.10	-9.33	-8.90	-6.06
Hay-Davies	-1.43	-5.89	-6.23	-5.80	-3.42
Isotropic	-5.64	-8.73	-9.25	-7.80	-5.35
Reindl	-1.64	-6.61	-6.97	-6.52	-4.06
King	-7.98	-11.06	-11.58	-10.13	-7.68
Perez-Driesse	-1.97	-7.90	-8.74	-8.02	-5.37
Median	**-3.17**	-8.00	-9.00	-7.91	-5.36

Slope of POA % deviation vs Kt — by decomp × transp (Table 6-1)

Median slope
decomposition
−7.74

Median slope
measured DHI
−3.17

Lower Kt → larger POA overestimation. Effect is this is a bias, not noise

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Measuring DHI cuts the bias significantly — Hay-Davies leads

Daily POA BIAS % — by decomposition × transposition (Table 6-3)

Global BIAS (%) of POA estimation — by decomposition × transposition

	DHI source				
	Measured	ERBS	Boland	DISC	DIRINT
Perez	+0.61	+3.41	+2.73	+3.53	+2.59
Hay-Davies	-1.13	+1.61	+0.93	+2.02	+1.08
Isotropic	-4.64	-1.57	-1.95	-1.37	-2.37
Reindl	-0.82	+1.95	+1.27	+2.36	+1.42
King	-0.72	+2.35	+1.98	+2.55	+1.56
Perez-Driesse	+0.36	+3.30	+2.71	+3.55	+2.60
Median	**-0.77**	+2.15	+1.62	+2.46	+1.49

HIGHLIGHTS

Best with measured DHI

Hay-Davies

−1.13 %

CNO reference combination

DISC + Perez

+3.53 %

Median measured DHI: **−0.77 %**
Median decomposition: **+1.93 %**

Direct DHI measurement neutralizes the systematic bias. **The combination matters as much as the model.**

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From a measurement decision to EYA, operations and PPA exposure

−7.74 → −3.17

Slope POA deviation vs Kt

measured DHI cuts the cloudiness-driven bias by 60 %

1 – 2 %

On daily injected energy

up to 3 % in extreme decomp × transp combinations

≈ 0.1 %

Class A station vs project CAPEX

marginal cost vs EYA accuracy gain (Sec 6.3 thesis)

1 Energy yield assessment

P50 and P90 built on a less-biased base · smaller margin needed to absorb model uncertainty.

2 Operational benchmarks (EPI / PR)

PR not conditioned on a model with persistent over-estimation · cleaner anomaly detection.

3 PPA / contractual exposure

Lower spot-market mismatch when bilateral commitments are tied to a less-biased forecast.

4 Where it pays off most

Sites with mean Kt ≤ 0.55 and high day-to-day Kt variability · the bias scales with cloudiness.

KEY TAKE-AWAYS

Three things to take with you

1 Sky regime drives model bias

For high-cloudiness sites, decomposition models systematically overestimate POA in many case · the bias scales with Kt — it is not random noise.

2 Measuring DHI is the simplest correction

Slope reduced by 60 % · bias intercept by an order of magnitude · global BIAS within ±1 %.

3 Cost-benefit is clearly favorable

Class A meteo station < 0.1 % of project CAPEX · the EYA-accuracy gain outweighs the instrument cost in any utility-scale project under similar regimes.

FULL THESIS

Cepeda, E. (2026). Evaluation of decomposition × transposition models for POA estimation under tropical conditions.
Universidad Nacional de Colombia · M.Sc. Electrical Engineering ·
https://repositorio.unal.edu.co/handle/unal/89827

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