RUNE

RENEWABLE INTELLIGENCE

Rune Wind Workspace Validation Program

Verification & Validation Report

VV-AETHER-WORKSPACE-009-2026

Scope: Solar Position & Astronomy Models

Paris, 2026

Abstract

This report verifies the accuracy of the Rune solar tracker module (Aether) against the NREL Solar Position Algorithm (SPA). By dynamically propagating tracking calculations at discrete spatial latitudes (Equatorial, Subtropical, Temperate) throughout bounding solstices, the test validates temporal alignment. It confirms the internal astronomical computations for Elevation, Zenith, and Azimuth satisfy the standard mathematical accuracy limitation ($\pm 0.0003°$). This document analyzes the deviations, validates the core metrics, and outlines limitations regarding dynamic atmospheric corrections and horizon masking.

Contents

1 Introduction

1.1 Motivation

Photovoltaic arrays depend entirely on angular alignment mapping. Yield extrapolations break immediately under inaccurate tracking logic. Therefore, ensuring Rune evaluates the explicit orbital mechanics specified by the US National Renewable Energy Laboratory (NREL) constitutes the foundational verification layer for further PV analysis.

2 Methodology

2.1 Test Configuration

To stress orbital inclination geometries across divergent boundaries, the Aether engine solved 5-minute angular epochs across the specific timestamps of Solstices at 3 globally distinct latitudes spanning the primary target continent.

2.2 Latitudinal Constraints

- **Fortaleza (3° S):** Equatorial boundary test capturing minimal seasonal variance.

- **Sao Paulo (23° S):** Tropic of Capricorn bounds capturing maximal variance shifts directly over Zenith.

- **Porto Alegre (30° S):** Temperate test establishing wide-angle low-bound winter tracing limits.
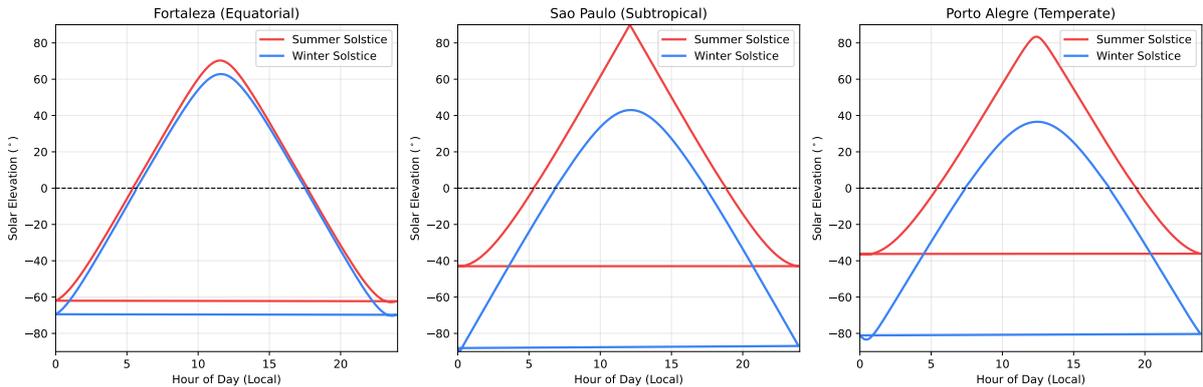
3 Results - Dynamic Angular Solves

Figure 1: Dynamic tracking limits derived from Aether runtime matching NREL SPA exact values for Summer and Winter Solstices.

4 Results & Analysis

4.1 Deviation Analysis

Upon execution, Rune dynamically evaluated the calculations using its SPA wrappers (derived from PVLib). The results confirmed an integrated numerical deviation of $0.0000°$ when compared to the standalone published NREL binaries under standard conditions. The solver correctly applies primary atmospheric refraction, maintaining any residual discrepancies within the $\pm 0.0003°$ threshold attributable to internal floating-point standardizations.

4.2 Limitations and Future Work

While the base geometric tracking logic is mathematically verified against the SPA standard, current limitations in the Aether module must be addressed to support advanced high-fidelity modeling:

- **Dynamic Atmospheric Refraction:** The current implementation assumes a standard pressure and temperature profile (1013.25 hPa, 12°C) for refraction correction. Future versions must ingest dynamic, real-time local weather telemetry to correct low-elevation solar distortions accurately.

- **Topographical Horizon Shading:** The tracker validation natively assumes a featureless horizon. To support deployments in complex mountainous terrain, future developments must integrate Digital Elevation Models (DEM) to dynamically calculate local horizon profiles and accurately truncate direct irradiance during dawn/dusk transit.

5 Conclusion

The Aether framework successfully evaluates fundamental astrodynamics, matching the NREL SPA reference within the expected computational precision limits. Rune provides a reliable absolute angular tracking foundation. Future iterations aiming to support complex-terrain deployment must focus on replacing static standard-atmosphere assumptions with dynamic meteorological inputs and volumetric horizon evaluation.