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Advancing CEOS Analysis Ready Data

Radiometric calibration, validation, and performance metrics

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WorldView-2 image of Vantor's calibration site at Colorado Air and Space Port (CASP) in Watkins, CO, USA. Vantor's five calibration tarps are visible east of the airport and air traffic control tower.

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How Do We Fit into the CEOS ARD Framework?

From SI-traceable calibration to application-ready data

TRACEABILITY

- SI-traceable calibration chain
- Aligned with national & international standards

TRANSPARENCY

- Clear algorithms & product understanding
- Accessible metadata & documentation

QUANTIFICATION

- Validation vs RadCalNet (independent SI-traceable reference)
- Quantified uncertainty
- Metrics that tell the complete story

At-Sensor Radiance

Measured radiance at the top of atmosphere

TSIS Solar Irradiance

SI-traceable solar irradiance measurement (TSIS)

Atmosphere

Atmospheric characterization & modeling (AERONET, MODTRAN)

Environmental Inputs

Weather & ancillary data (temperature, pressure, ozone, water vapor, etc.)

Surface Reflectance

NIST-traceable surface reflectance measurements for validation

**ARD requires more than calibration—
it requires traceable, transparent, and quantified performance.**

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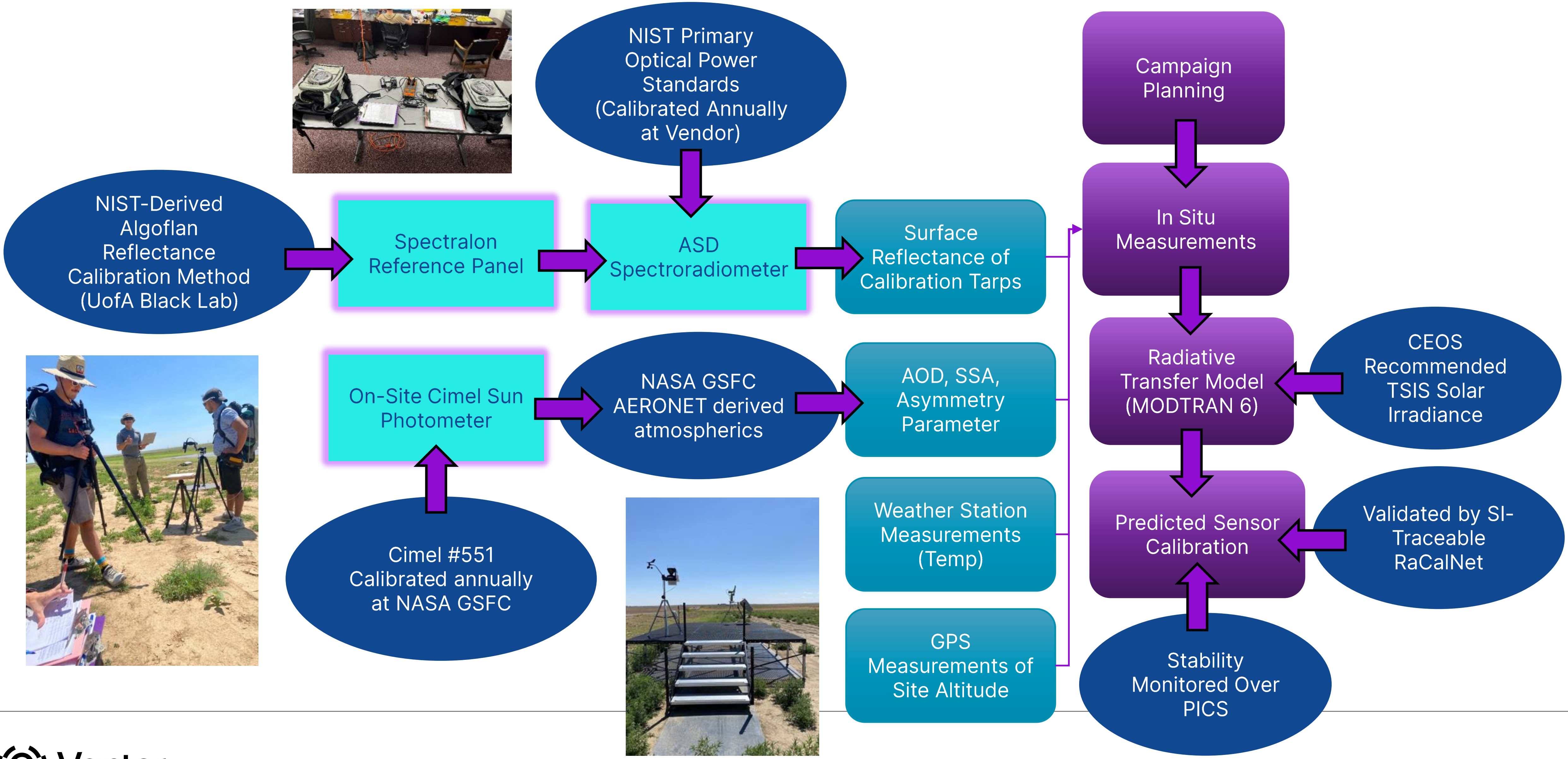
A Documented Calibration Chain for Vantor’s Primary Calibration at CASP



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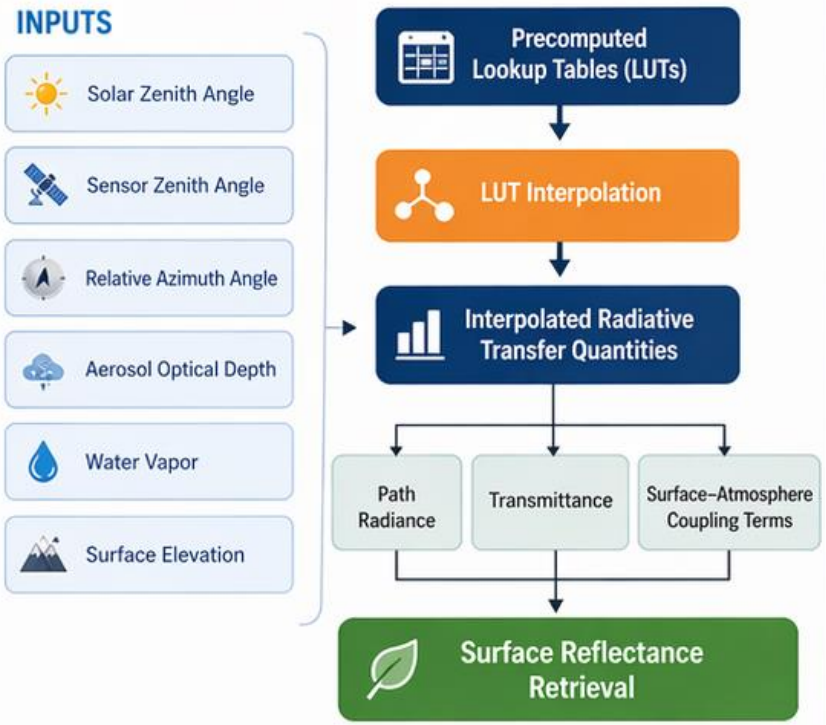
VANTOR'S ACOMP SURFACE REFLECTANCE PRODUCT CONTINUES THE CHAIN

From inputs to insights: rigorous processing and uncertainty characterization deliver trusted surface reflectance.

FROM INPUTS TO SURFACE REFLECTANCE



EXAMPLE OF BAND-DEPENDENT SURFACE REFLECTANCE UNCERTAINTY FOR ACOMP

RADIOMETRIC CALIBRATION AND ATMOSPHERICS DOMINATE

WHAT DRIVES THE UNCERTAINTY?

RADIOMETRIC CALIBRATION
Sets the measurement foundation across all bands

ATMOSPHERIC MODEL / PROFILE
Atmosphere is the biggest source of band-dependent uncertainty

All other factors combined contribute less uncertainty than these two.

UNCERTAINTY (% REFLECTANCE)

	BLUE (470 nm)	GREEN (560 nm)	RED (660 nm)	NIR (865 nm)
RADIOMETRIC CALIBRATION	3.0%	3.0%	3.0%	3.0%
ATMOSPHERIC MODEL / PROFILE	2.0%	2.0%	2.0%	1.5%
AEROSOL RETRIEVAL (AOD)	3.5%	2.5%	1.8%	1.0%
SURFACE ANISOTROPY (BRDF)	1.0%	1.0%	1.2%	1.5%
GAS ABSORPTION	0.8%	0.5%	0.7%	1.5%
LUT DISCRETIZATION / INTERPOLATION	1.0%	1.0%	1.0%	1.0%
ELEVATION / PRESSURE	0.8%	0.6%	0.5%	0.3%
ADJACENCY EFFECTS	2.5%	1.5%	1.0%	0.5%
SOLAR IRRADIANCE	0.5%	0.5%	0.5%	0.5%
COMBINED UNCERTAINTY (RSS)	**5.9%**	**4.9%**	**4.4%**	**4.2%**

KEY TAKEAWAY: Radiometric Calibration and Atmospherics are the top drivers of uncertainty in ACOMP surface reflectance—across all bands.

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WHAT IS THE BEST WAY TO SHOW RADIOMETRIC PERFORMANCE?

Traditional metrics can hide the truth. Residuals vs. reflectance **reveal it.**

DATA

- 408 coincident pairs
- Railroad Valley (RadCalNet)
- 8/31/2014 – 3/24/2026

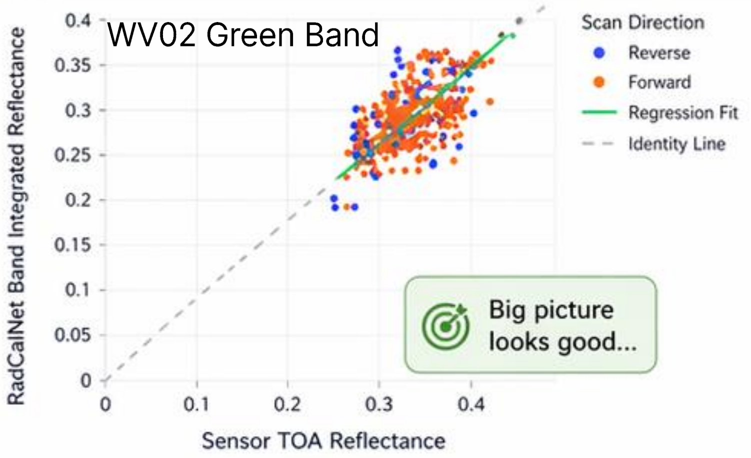
TRADITIONAL METRICS

- Mean % difference: 3.8%
- Gain: 0.964
- R: 0.67

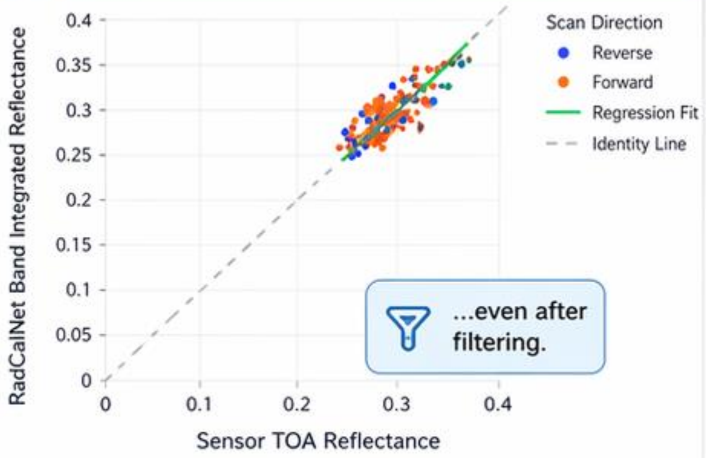
WHAT WE ACTUALLY SEE

- Overestimation at low reflectance
- Underestimation at high reflectance
- Zero-crossing ~0.32
- Behavior persists after filtering

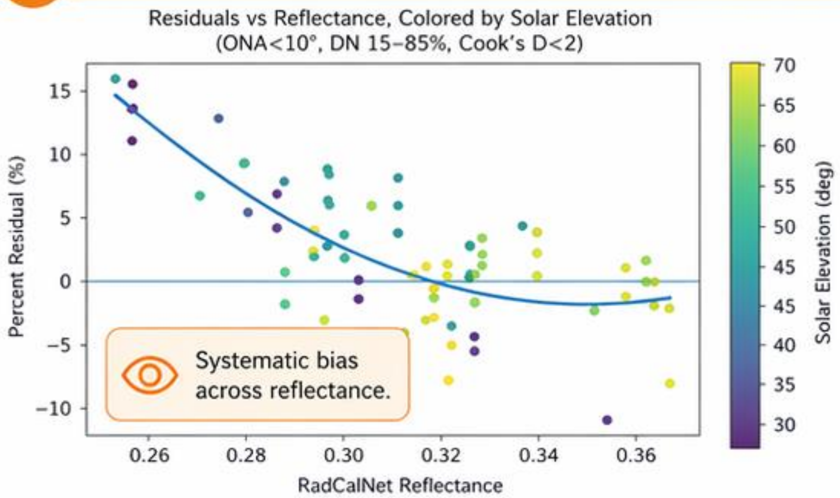
1. ALL DATA



2. FILTERED DATA



3. RESIDUALS vs. REFLECTANCE



KEY TAKEAWAY: Residuals vs. reflectance are essential to uncover systematic bias. Don't just look at the average—**look at the behavior.**

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Are Current Metrics Sufficient?

Mean bias depends on how the data are sampled

WHAT WE DO TODAY

Single metrics
(gain, mean bias, mean % diff)

Assume uniform behavior
Collapse variability into one number

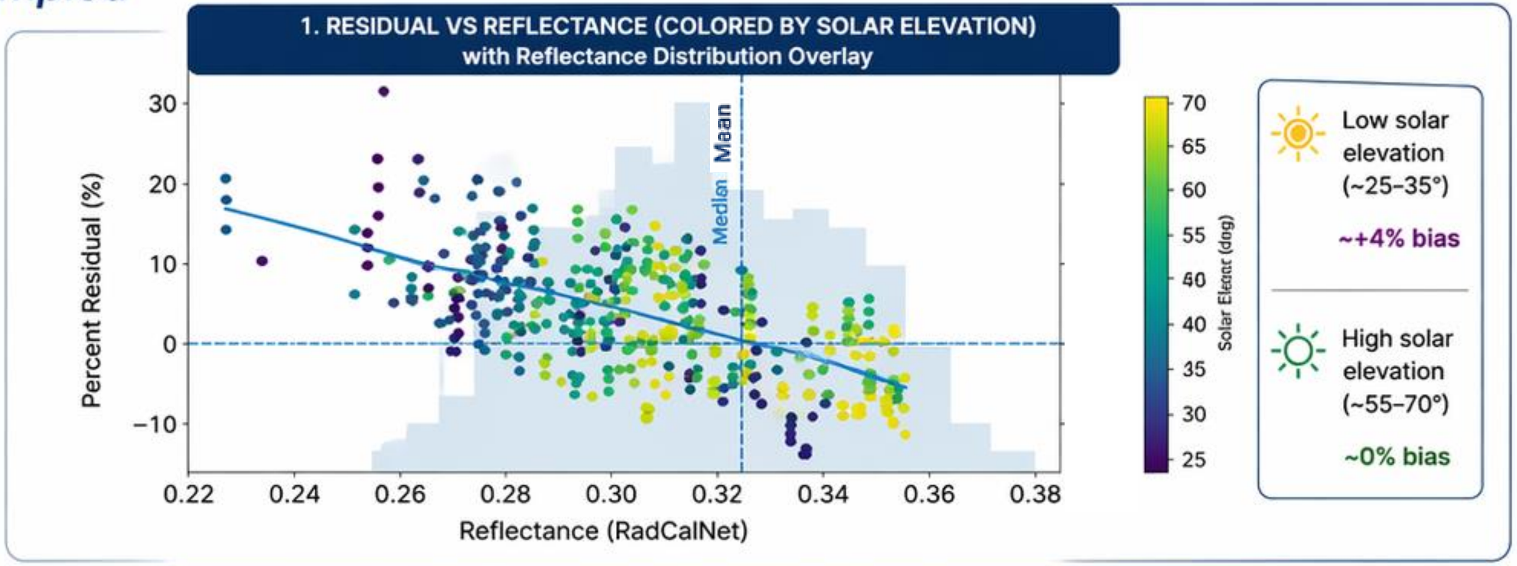
WHAT THE DATA ACTUALLY SHOW

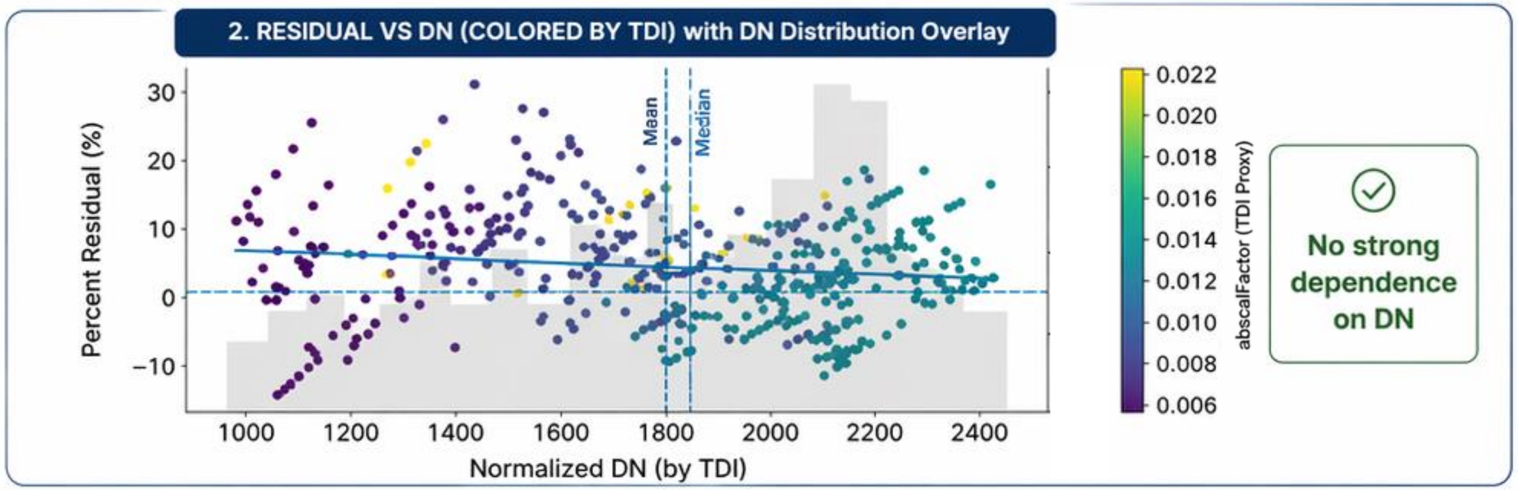
Bias depends on conditions
+4% at low solar elevation
~0% at high solar elevation

Sampling drives the reported bias
Reflectance distribution centered near residual zero-crossing
Mean bias depends on reflectance distribution

Not a detector issue
No strong dependence on DN
(within nominal linear range)

Implication
We need diagnostics that capture structure—not just a single average.





SINGLE METRICS MASK REAL RADIOMETRIC BEHAVIOR

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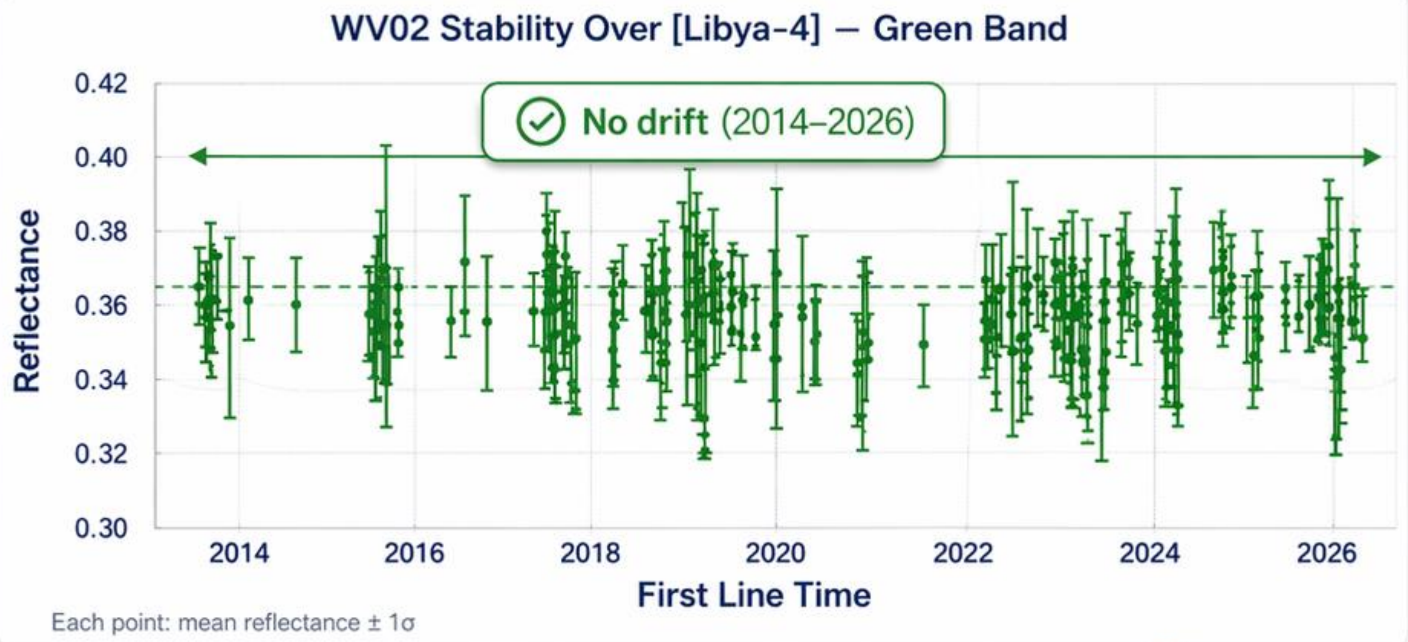
WV02 Green: Stable Over a Decade

Stability assessed independently of RadCalNet



STABILITY (INDEPENDENT OF RadCalNet)

CV ≈ 2.7%
Variability relative to the signal

No temporal drift
Over more than a decade (2014–2026)

Forward / Reverse agreement
<0.3%

BUT...
Bias depends on conditions

- View angle
- Solar angle
- Relative reflectance

HOW DO WE DEFINE PERFORMANCE?

- Is stability enough?
- Is a single bias number good enough?
- Is agreement to SI enough?
- Do we need more numbers?
- Or do we need something more application-driven?

Two truths: The sensor is **stable.** | The sensor shows **systematic bias** that depends on conditions.

Stability is necessary—but not sufficient.

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“How good is good enough?”

RE90 links calibration uncertainty to real-world product error

What is RE90?

RE90 = 90th percentile of application error

90% of errors are below this value

How RE90 is computed

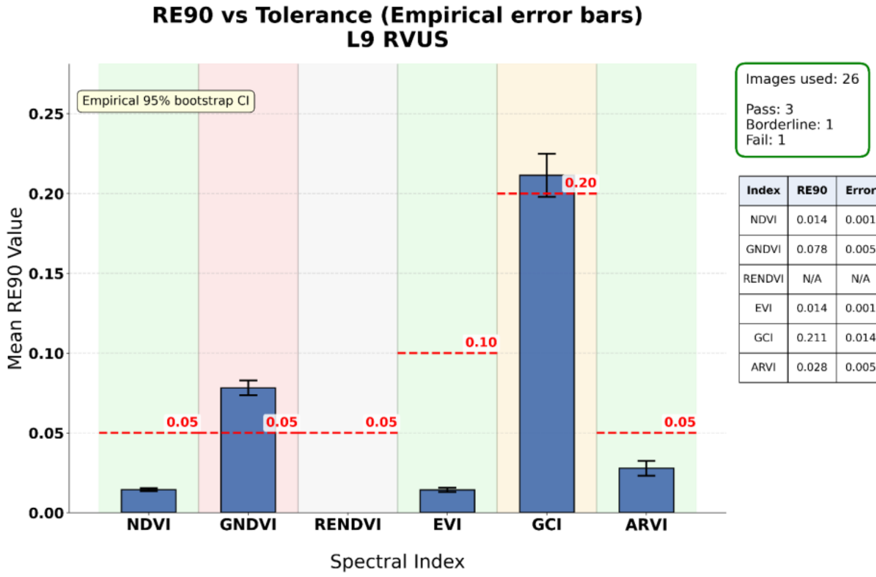
Perturb Calibration → **Propagate Through Atmospheric Correction** → **Evaluate Error in Real Application Products**

Why RE90?

- ✓ Application-driven (what users care about)
- ✓ Data-driven and transparent
- ✓ Robust (uses 90th percentile)
- ✓ Comparable across sensors (like CE90)
- ✓ Enables pass / borderline / fail decisions

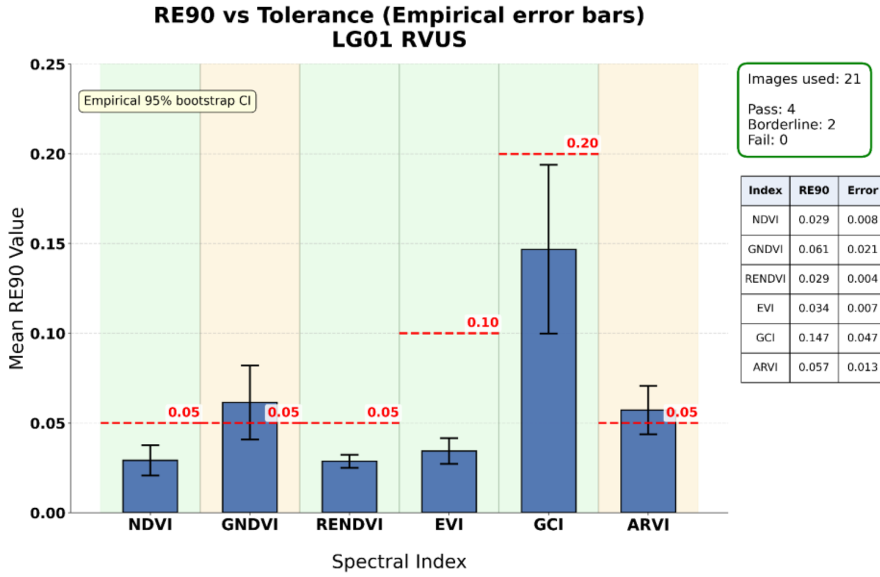
Does calibration meet application requirements?

Benchmark: Landsat 9 (Community Baseline)



Index	RE90	Error	Tol	Status
NDVI	0.014	0.001	0.05	PASS
GNDVI	0.078	0.005	0.05	FAIL
RENDVI	N/A	N/A	0.05	N/A
EVI	0.014	0.001	0.10	PASS
GCI	0.211	0.014	0.20	BORDER
ARVI	0.028	0.005	0.05	PASS

Example: WorldView Legion Performance



Index	RE90	Error	Tol	Status
NDVI	0.029	0.008	0.05	PASS
GNDVI	0.061	0.021	0.05	BORDER
RENDVI	0.029	0.004	0.05	PASS
EVI	0.034	0.007	0.10	PASS
GCI	0.147	0.047	0.20	PASS
ARVI	0.057	0.013	0.05	BORDER

RE90 answers: “Does calibration meet application needs?”

From calibration perturbation to real-world impact—measured against user requirements.

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Ochoa, Tina. Absolute Radiometric Calibration Sensitivity Analysis of Vantor’s Surface Reflectance Product, JACIE 2026, Reston, VA

What Does ARD Compliance Require for Radiometric Quality?

A complete framework—from traceable calibration to application-driven performance

Radiometric Quality for ARD Requires:

TRACEABILITY
SI-linked, unbroken chain to physical standards

UNCERTAINTY
Quantified at each step and propagated to products

VALIDATION
Independent, SI-traceable references and cross-sensor comparisons

MONITORING
Ongoing stability and performance tracking

DOCUMENTATION
Transparent, complete, and accessible ATBDs and uncertainty frameworks

And critically— meaningful performance metrics.
Metrics must reflect real-world product performance that users care about.

Key Questions for the Community

- How should we standardize radiometric performance metrics?
- Is RE90 (or similar application-driven metrics) the right direction?
- Include standardized error in real products in addition to accuracy metrics.

Next Steps

1. **Apply CEOS ARD Surface Reflectance Self-Assessment**
   Evaluate conformance and identify improvement areas.
2. **Establish a central location on the CEOS ARD webpage**
   for the documentation that are required.
3. **Ensure documentation is accessible and usable**
   Complete ATBDs, uncertainty frameworks, validation results, and performance metrics.

ARD radiometric quality = Traceable + Quantified + Validated + Monitored + Application-relevant
Delivering trust, transparency, and impact for the users who rely on our data.

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Together, let's define performance in terms of what matters most—the real world.

Advancing Radiometric Performance for ARD

Thank you!

Multi-temporal comparison:
original imagery (top) vs
ACOMP surface reflectance (bottom)

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