SI-Traceability for Earth Observations – Tying It All Together

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Recommendation

Earth-Observing Instruments Should Measure Solar and Lunar Irradiances for On-Orbit Radiometric Spectral Calibrations

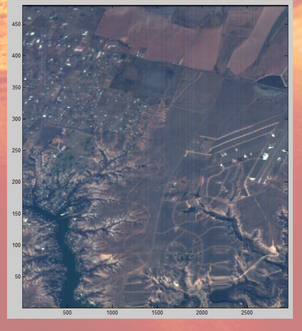
CLARREO Pathfinder Measures Outgoing Earth-Reflected Radiances

Using the Sun as a calibration source, the CLARREO Pathfinder (CPF) HyperSpectral Imager for Climate Science (HySICS) directly measures solar incoming and Earth-reflected radiation to < 0.3 % (k=1) uncertainty from 350 – 2300 nm with $\Delta\lambda$ = 6 nm and provides high-accuracy radiometry of Earth scenes.

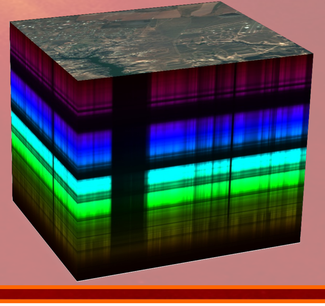
On-orbit HySICS calibrations using direct measurements of the Sun tied to SI-traceable solar-irradiance measurements obviate reliance on pre-launch radiometric calibrations, improving on-orbit accuracy and stability

HySICS calibrations rely on measurements of ratios, not absolute calibrations and intrinsic instrument stability

HySICS Performance Goals	
Parameter	**Performance**
Spectral Range	**350 – 2300 nm**
Spectral Resolution	**6 nm** constant
Spatial Resolution IFOV	**< 2.5 arcmin** (< 0.25 km)
Field of View (cross track)	**10°** (~ 70 km at nadir)
Radiometric Accuracy	**< 0.3 %**



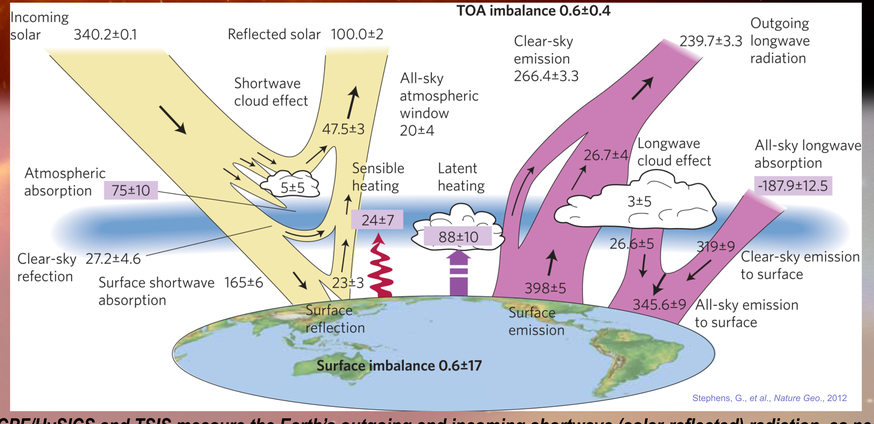
The HySICS provides spatially- and spectrally-resolved ground-scene measurements with high radiometric accuracy tied to SI-traceable solar irradiances



Earth Observations Tied to Solar-Irradiance Measurements

Direct measurements of the *ratios* of incoming solar to outgoing reflected-solar radiation can be more accurate than the difference of their individual measurements by eliminating common-mode errors, improving on-orbit radiometric accuracy for Earth observations

- The CPF/HySICS ratios Earth's outgoing to incoming shortwave spectral reflectances
- ARCSTONE ratios lunar reflectances, enabling the Moon to be used as a high-accuracy on-orbit spectral calibration source by most Earth-viewing instruments
- SI-traceable solar-irradiance measurements link these high-accuracy direct reflectance measurements to radiances and irradiances



The CPF/HySICS and TSIS measure the Earth's outgoing and incoming shortwave (solar-reflected) radiation, as needed for climate studies. ARCSTONE transfers lunar-irradiance cross-calibrations to most Earth-observing instruments.

Advantages of Solar Cross-Calibration Approach

The Sun is the best-known and most stable on-orbit source in the visible & NIR

- Direct solar and scene measurements with common optics give reflectances with high accuracy
- Scene and Sun measurements in close succession compensate for instrument degradation
- Reliance on ground-based measurements and subsequent on-orbit instrument stability is reduced
- Reflectance measurements are independent of solar variability
- Internal flight-instrument primary calibration sources are not needed

ARCSTONE Extends Lunar Calibrations to Most Earth-Observing Instruments

The ARCSTONE directly measures solar-incident and lunar-reflected radiation to < 0.5 % (k=1) uncertainty from 350 – 2300 nm with $\Delta\lambda$ = 8 nm from a 6U CubeSat. Having similar radiances as Earth scenes, the Moon can be used by most Earth-observing sensors for on-orbit radiometric calibrations with improved accuracy provided by ARCSTONE.

On-orbit ARCSTONE calibrations using direct measurements of spectral solar irradiances are transferred to lunar irradiances as a function of phase and libration, improving lunar-irradiance model accuracies

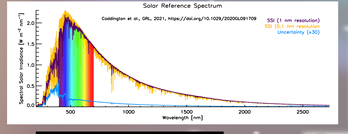
ARCSTONE calibrations rely on measurements of ratios, not absolute calibrations and intrinsic instrument stability

Lunar-irradiance models can extend the ARCSTONE's lunar measurements to any era, enabling calibrations of non-co-temporal instruments

ARCSTONE Performance Goals	
Parameter	**Performance**
Spectral Range	**350 – 2300 nm**
Spectral Resolution	**8 nm** constant
Radiometric Accuracy	**< 0.5 %**

TSIS Measures Incoming Solar Irradiances

The Total and Spectral Solar Irradiance Sensor (TSIS) measures total and spectral solar irradiance, allowing high-accuracy HySICS and ARCSTONE reflectance measurements to be converted to high-accuracy SI-traceable radiances and irradiances



TSIS–1 measures TSI and SSI from the ISS

TSIS Performance		
Measurement	**Spectral Range [nm]**	**Absolute Accuracy [1-σ]**
TSI total solar irradiance	total solar spectrum	0.015 %
SSI spectral solar irradiance	200-2400	0.3 – 0.5 %

The TSIS-1 measures total solar irradiance with ~0.015 % uncertainty and spectral solar irradiance over 200 – 2400 nm with ~0.3 to 0.5 % uncertainty