Hyperspectral Radiometric Accuracy Improvements

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Abstract: Using on-orbit solar cross calibrations, the HyperSpectral Imager for Climate Science improves radiometric accuracy of measured Earth scenes to <0.5%, helping establish benchmark measurements for space-borne climate studies in the 350-2300 nm spectral range.

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1. Long-term climate studies require radiometrically accurate hyperspectral measurements

Understanding the Earth’s climate system requires acquiring benchmark measurements of shortwave reflected Earth spectral radiances with improved absolute radiometric accuracies tied to international standards in order to track the influence of various forcings on long-term climate changes and to improve climate models and predictions [1],[2]. To help attribute the causes of changes over time, these measurements must include both spatial resolution to identify land use changes, cloud boundaries, and terrain type, as well as spectral resolution to identify vegetation type, clouds vs. snow, ocean color, and atmospheric constituents. Since climate data sets are inherently long-duration and may span multiple non-overlapping instruments, radiometric accuracy is critical to discern changes.

Current space-based Earth observing spectral imagers have radiometric uncertainties of ~2% or greater limited by on-board calibration lamps, diffuser degradation, and atmospheric transmission knowledge, so improved imaging spectrometry instrumentation methods are sought. We present flight calibration results from one such instrument.

2. HySICS uses solar cross-calibrations for improved on-orbit radiometric measurement accuracies

The HyperSpectral Imager for Climate Science (HySICS) is a spatial/spectral imaging spectrometer with an emphasis on radiometric accuracy. Covering the 350-2300 nm spectral region with 6 nm resolution and a nearly 10° FOV with a 2.5 arc-minuteIFOV using a single focal plane array reduces mass, power, and volume [3].

Two high-altitude balloon flights with the instrument have demonstrated a 4× improvement in radiometric accuracy over existing instruments, and further improvements are possible. The HySICS uses a novel method of ratio- ing incoming to outgoing shortwave radiances using on-orbit measurements of spectral solar radiances acquired by directly viewing the Sun to avoid the large uncertainties associated with solar diffusers. Solar. To accomplish direct solar cross-calibrations, which have radiances ~10^5 greater than those of typical Earth scenes, the HySICS uses solar calibrations that provide a precisely known 10^5 calibration via:

1) Reduced aperture sizes to limit the light that enters the optical system, achieving attenuations >10^3;
2) Reduced integration times using an electronically shuttered focal plane array, providing attenuations >10^2;
3) Absorptive filters spectrally calibrated on-orbit via lunar observations, providing attenuations of ~10^{-1}.

3. Two high-altitude balloon flights have demonstrated <0.5% radiometric accuracies with HySICS

The HySICS has completed two balloon flights at altitudes of 37 km to acquire space-like measurements of both the Earth and the Sun [4]. The ~8-hour flights were in Sept. 2013 and Aug. 2014 from Fort Sumner, NM using the NASA Wallops Arc-Second Pointing (WASP) system for fine pointing control. The spectrometer performed on-orbit calibrations including flat fields, filter transmissions, diffraction corrections, and spectral lunar and solar radiance and irradiance measurements. Analyses indicate <0.5% (1σ) radiometric uncertainty relating incoming to outgoing shortwave radiances. We present the calibration results of these flights.

4. References