Monday, September 21, 2020 | 2:15 p.m.

Technical Session

Calibration Methods Using Celestial Objects

Presentation of radiometric measurements and calibration methods using the Sun, Moon, stars, and other celestial objects in the ultra-violet, visible, and infrared wavelengths

- Characterization and calibration of celestial sources for on-orbit sensor calibration
- Post-launch calibration and long-term trending using celestial observations
- Calibration accuracy using celestial objects
- Real-life experience and lessons learned using celestial objects for radiometric sensor calibration

2:20

The SLIM Lunar Irradiance Model, a Single Fit to 9 Instruments - Many Observations, One Moon

Hugh Kieffer – Celestial Reasonings

ABSTRACT: Lunar calibration has the potential to put all participating instruments on the same long-term stable radiometric scale. Realizing this involves significant effort on the part of instrument teams and calibration community. Among the challenges are: improving the lunar spectral-irradiance model, extracting the measured irradiance from an instrument observation, and understanding any response differences between a normal nadir observation and a lunar view. This work addresses the first of these; this year's CALCON workshop will help address the other two.

A problem with the ROLO lunar calibration model is 'jumps' between its underlying 32 bands, especially at longer wavelengths. This issue is also contained in the initial version of the SLIM (Spacecraft and earth- base Lunar Irradiance Model); a band-by-band methodology. By normalizing instrument measurements to a high-spectral-resolution lunar reflectance spectrum, a model has now been developed that is continuous in wavelength as well as geometry.

The SLIM system allows scaling each instrument band by a constant gain factor, which is found by iterative modeling. SLIM models can be polynomial to a modest power in each of the five geometric angles; phase angle, selenographic solar longitude and latitude, selenographic viewer longitude and latitude; and each of these terms can be independently be multiplied by a polynomial up to cubic in 'wave'; wavelength λ in μm, $1/\lambda$ or $\ln \lambda$. A variety of numerical tools have been developed to aid in choosing which combination from this large zoo of terms works well in minimizing both residuals and the number of coefficients.

Currently, data from ROLO, Landsat-8 OLI, Hyperion, MODIS-Aqua, MODIS-Terra, SNPP-VIIRS, SeaW-IFS, PLEIADES-A, PLEIADES-B go into the model, about 87,000 points. If the instrument team supplies trends that they feel should be applied to the measurements, that is done at data ingest. Data are automatically processed for wild-points. Overall weights can be assigned to each instrument, and relative weights to each band.

After a model fit, all instruments are calibrated with that model, the empirical gain factors for each band and instrument are revised, trends can be assessed (five possible models) and applied; weights can also be revised. Residual seasonal oscillations can be quantified and applied. Then the fit process is iterated until convergence.

The calibration spectrum of all instruments mentioned plus five GOES instruments and NIST telescope observations, will be presented, revealing their relative scales. All spacecraft teams with lunar observations are invited to participate.

2:40

The East-West Response Versus Scan-angle Performance of GOES-16/17 ABI Solar Reflective Bands

Fangfang Yu – Xi Shao, Haifeng Qian – University of Maryland; Xiangqian Wu – NOAA/NESDIS/STAR

ABSTRACT: The scan mirror reflectivity of the Advanced Baseline Imager (ABI) solar reflective bands was characterized before launch to ensure calibration uniformity. To verify, a series of lunar images were collected during the GOES-16/17 ABI post-launch test/post-launch product test (PLT/PLPT) periods while the Moon transited the space within the ABI field of regard (FOR). The irradiance of each lunar image was measured by ABI and simulated by the Global Space-based Inter-Calibration System (GSICS) Implementation of the ROLO (GIRO) model. The ratio of these irradiances was used to evaluate the ABI Response versus Scan-angle (RVS) performance along the EW direction. It was found that lunar irradiance measured by ABI is very sensitive to straylight. In this study, the straylight correction algorithms were developed to remove its impacts on the illuminated lunar pixels at the shorter wavelength images. After the straylight corrections, the RVS variation along the EW direction is well within 1% for all the GOES-16/17 ABI solar reflective bands within the FOR.

3:00

Airborne LUnar Spectral Irradiance (air-LUSI) Mission – Capability Demonstration

Kevin Turpie – University of Maryland, Baltimore County; Steven Brown, John Woodward, Steve Grantham, Stephen Maxwell, Thomas Larason – National Institute of Standards and Technology (NIST); Tom Stone – U.S. Geological Survey; Andrew Gadsden, Andrew Newton – University of Guelph

ABSTRACT: The Moon is a very useful calibration target for Earth-observing sensors in orbit because its surface is radiometrically stable and it has a radiant flux comparable to Earth scenes. To predict the lunar irradiance given an illumination and viewing geometry, the United States Geological Survey (USGS) has developed the Robotic Lunar Observatory (ROLO) Model of exo-atmospheric lunar spectral irradiance. The USGS ROLO model represents the current most precise knowledge of lunar spectral irradiance and is used frequently as a relative calibration standard by space-borne Earth-observing sensors. However, instrument calibration teams have expressed the need for an absolute lunar reference with higher accuracy.

The objective of the airborne LUnar Spectral Irradiance (air-LUSI) mission is to make highly accurate, SI-traceable measurements of lunar spectral irradiance in the VNIR spectral region from NASA's high-altitude ER-2 aircraft. To that end, the air-LUSI system employs an autonomous, robotic telescope system that tracks the Moon in flight, and a stable spectrometer housed in an enclosure providing a robustly controlled environment. These instrument subsystems are situated in a wing pod of the ER-2 aircraft with a small dorsal view port. Through this port, the telescope can observe the Moon from above 95% of the Earth's atmosphere.

air-LUSI successfully conducted a Demonstration Flight Campaign on five consecutive nights from 12 to 17 November 2019. Each night, the air-LUSI system observed the Moon at about 68,000 feet altitude. Each observation period lasted 30 to 40 minutes and measured the lunar spectral irradiance at wavelengths from about 380 to 1000 nm. The five flights corresponded to lunar phase angles of 10°, 21°, 34°, 46° and 59°. The measurement uncertainty is currently estimated to be about 0.8% or less through the mid-visible range. With this new capability, the air-LUSI team plans to acquire additional lunar spectral irradiance measurements and apply this state-of-the-art data set to improve the accuracy of ROLO predictions. This paper will summarize the air-LUSI objectives and provide an overview of the Demonstration Flight Campaign and lessons learned that could further improve air-LUSI accuracy in future flights.

3:20

ARCSTONE: Calibration of Lunar Spectral Reflectance from Space

Cindy Young, Constantine Lukashin, Trevor Jackson, Jacob Benheim, Michael Cooney, Warren Davis, Thuan Nguyen, Noah Ryan, David Taylor – NASA Langley Research Center; Tom Stone – U.S. Geological Survey; Greg Kopp, Alan Hoskins, Paul Smith – Laboratory for Atmospheric and Space Physics (LASP), University of Colorado; Rand Swanson, Hans Courrier, Michael Kehoe, Michael Stebbins – Resonon; Elise Minda, Christine Buleri, Alex Halterman, Tim Christianson – Quartus Engineering

ABSTRACT: Detecting and improving the scientific understanding of global trends in complex Earth systems, such as climate, increasingly depends on assimilating datasets from multiple instruments and platforms over decadal timescales. Calibration accuracy, stability, and inter-consistency among different instruments are key to developing reliable composite data records from sensors in low Earth and geostationary orbits, but achieving sufficiently low uncertainties for these performance metrics poses a significant challenge. Space-borne instruments commonly carry on-board references for calibration at various wavelengths, but these increase mass and mission complexity, and are subject to degradation in the space environment.

The Moon can be considered a natural solar diffuser which can be observed as a calibration target by most spaceborne Earth-observing instruments. Since the lunar surface reflectance is effectively time-invariant, establishing the Moon as a high-accuracy calibration reference enables broad inter-calibration opportunities even between temporally non-overlapping instruments and provides an exo-atmospheric absolute radiometric standard. The ARCSTONE mission goal is to establish the Moon as a reliable reference for high-accuracy on-orbit calibration in the visible and near-infrared spectral region. The ARCSTONE instrument is a compact spectrometer, which will be packaged on a CubeSat intended for low Earth orbit. It will measure the lunar spectral reflectance with accuracy < 0.5% (k=1), sufficient to establish an SI-traceable absolute lunar calibration standard when referenced to the spectral solar irradiance across the 350 to 2300 nm spectral range. This lunar reference will help to enable high-accuracy absolute calibration and inter-calibration of past, current, and future Earth-observing sensors, meteorological imagers, and long-term climate monitoring satellite systems.

The ARCSTONE team will present the laboratory characterization results from two prototyped instruments, one operating in the UV-VNIR and the other in the SWIR. The development status of a next-generation full-spectral-range instrument, the intended approach to calibration and characterization, and the planned path toward mission implementation will also be discussed.