

Discussion on White Paper
Contributions:
Reflected Solar & Lunar

Chinese Benchmark Satellite(CRABS)

- Chinese National projects on space-based radiometric benchmark
 - Since 2018, four years
 - Phase A: SI-traceable Standard source development (since 2015,done)
 - Phase B: Prototype model of SI-traceable IR and Solar hyperspectral instruments; Retrospective calibration; transfer method and verification
 - Phase C: Benchmark satellite mission
- FTS IR techniques were utilized on FY-4 and FY-3 hyperspectral sounders
- RSB has two kinds of technique mechanism and demonstration instrument on FY-3R rainfall mission
- Recalibration : 16 atmosphere, 3 marine and 9 land resource satellites. The challenges including: no good calibrator, nonlinearity... Solution 3:
- *How we can share data and analysis?*

CLARREO Pathfinder

- Reflected solar: Demonstrate high accuracy SI-traceable calibration and reference intercalibration capabilities 350-2300nm; 0.3% (k=1)
- Support from GSICS, WMO2040 WIGGOS, GCOS,
- Science Value Matrix, QUantitative earth science, Utility and Quality, Climate science
- Launch in 2023, 1 year operation, demonstrate SI traceability and intercalibration reference, L0 processing, Planning budgets
- HySICS Hyper-Spectral Imager for Climate Science
- Calibration Risk Mitigation and resolution,
- Viewing Models: Lunar, solar calibration Limb viewing, Nadir benchmarking, cross-calibration; Pitch and rolling on ISS
- Intercalibration sensors: VIIRS and CERES sampling 45% margin for CERES and factor of 10 margin for VIIRS
- *What to do when we have multiple SITSATs?*

HySICS

- 4-8 times better accuracies; ELC site 3#, 6nm resolution, 0.5km, 70km swath
- SI traceability come from Spectral solar irradiance, no diffuser or scatter, relectivity measurement traceable to solar irradiances (earth,solar irradiance, Apture ratio, integration time ratio(unitless) , Attenuation
- Provide intercalibration for GEO and LEO, co-aligned observation
- Two high altitude ballon flight demonstrate, 2013 and 2014
- Solar irradiance scan and solar flat field scan 0.5nm apture
- Low inherent polarization sensitivity , 4 MA, Pen-ray provide on-orbit spectral calibration, uncertainty budget less than 0.3% in middle wavelength, ISS 2023
- *How can its return post-flight for re-testing be funded?*

TRUTHS

- 10 times more accuracies, primarily climate mission, snapshot of the state, solar impact on earth, focus in needs of ECV
- Hyperspectral application in surface reflectance, for inter-operability, reference calibration, enable harmonisation, traceability to CEOS CAL/VAL infras
- User requirements: Climate and reference calibration
- Small/Medium Agile satellite 5-8 lifetime, 90 degree at 609Km
- Industry team: Provisional thermal/orbit analysis, HIS imager 320-2450nm, 0.5% polarization, Chroma D(vis-SWIR) and Sicicon CMOS (UV), 50m GIFOV, SNR 100@, 1000@, 1500@
- Optical radiometric traceability for EO sensor : Electrical substitution radiometry, 100yrs, Cryogenic operation benefit, CSAR v-2 space engineering model, Carbon Nano-tube black coating,
- Cooler, CSAR stability Uncertainty for TSI, uniformity of diffuser illumination, imager uncertainty 0.16-0.26%; Reliability assessment, uncertainty budget propagation, chain
- *Input for User Requirements Survey?*

Preflight calibration

- Geometric characterization: FOV, ILS, inter-band, intra-band, ...
Radiometric characterization
- STAR-CC-OGSE system: Collimator, Large radiance sphere, polariser, shutter, field mask, 260-2700
- New technology—new CW Tuneable laser system: high power;
- --new approach Detector-based SI-Traceability; Custom field mask; Transportable 2.5m*1m*1m +laser, 500KG; New space- new approach

Balloon-based demonstration system for CAL/VAL

- Space-based radiometric measurement benchmark sensor and transfer calibration: 2%, 0.2K, how to validate full chain of spaceborne radiometric benchmark transfer
- Issues: cross-calibration on medium resolution and low resolution, wide dynamic stable targets, RadCalNets, Products validation sites.
- Components: Platform, Cabin, Scientific instrument, data processing subsystem; flight control system for specific targets, Flight attitude control
- Reference sensors: Earth-Lunar Hyperspectral image ELHI, Reference spectroradiometer,
- Flight model in Qinghai gobi and Lakes

Defining Cross-calibration strategy

- Support the TRUTHS mission and maximise the return of investment: Match criteri, Ground processing correction, match up correlation
- Global inter-cal simulation: Products, scenarios trade-off, ... Flow diagram, Matchup products database:atmosphere, cloud, surface DEM, Error matchup generator(spectral, spatial and temporal), Uncertainty assessment(0.4-0.5-0.7% S2)
- Error generator: Temporal scence variation, adjacency, Polarization, Viewing angle
- Orbit modeling, S2-like dem for 5 minutes ; temporal delay,

SLI Cross-calibrating Radiometer concept

- Landsat MSS Era 1970, 23% error, Recalibration ~5%
- Landsat TM Era, 16% error, Recalibration 5%
- Landsat OLI Era, 3% , closer to 2.5%, Largest change 1% during lifetime, blue bands 1% offset leads to 10% error of ocean products
- Interoperability requirement: accuracy from 3% to 1%; VSWIR, 100m 400nm-2400nm TIR,
- VSSWIR:TRL 6-7, TIR: Compact infrared Radiometer in Space (CIRIS) , 2019 launch, Preliminary design concepts suggest small hyperspectral package, low-cost instrument possible
- Free Flyers: Provide a constellation of SCRs, Small SWaP 16U, one-month intersections Sentinel-2 and Flock-3P Dove, ISS
- Relation to CLARREO/TRUTHS: Primary calibration layer, Transfer calibration layer (SCRs), Imaging layer, SCR provides needed transfer radiometry layer between TRUTHS/CLARREO and optical imaging systems, moves large observatories to 1% accuracy

Polarization distribution models for CLARREO intercalibration

- POLDER3 I,Q,U,V
- ADRTM compare with PARASOL data for ocean (well) and clear desert(

Scott's Lunar Calibration Discussion topics

- What observations are needed to refine the current lunar calibration reference?
- What instrument specifications should be developed ?
- How to establish traceability to SI?
- Data processing (atm correction, pre-processing, geometric calibration, ...)
- Inter-comparison method from different instruments?
- How to use these observations to improve model or fit new model?

Nigel's discussion topics

- How to communicate the global-ness of these activities?
- Are we in the position to say define *desired* and *threshold* requirements for SCOS?
 - Currently all SITSATs have similar requirements
 - because they copied from CLARREO
 - based on a lot of detailed analysis
 - covered a range of different application areas – with similar conclusions
 - already peer-reviewed
 - Is this good enough? - can base decision on how long it takes to achieve
 - Do we need other studies? E.g. Chemistry, ...

Discussion

- Requirements and approaches taken between China, UK, and US for Earth-viewing and solar-irradiance measurements are nearly identical (and largely follow CLARREO on requirements)
 - Teams (other than CLARREO) should produce independent measurement requirements
 - Chemistry and atmospheric community would be good to include
 - Specify ground sampling requirements
 - Solar irradiances have already been done independently (solar- and climate-based)
- Inter-comparisons between flight CRBS, HySICS, TRUTHS
 - Inter-comparisons have to be done on-orbit
 - That's where the instruments get their calibrations
 - If instruments observe contemporally, direct inter-comparisons should be done with direct overlap sites on-orbit; if not, then use on-orbit sources (Sun, Moon, vicarious Earth sites, DCCs, etc.) to enable non-cotemporal inter-comparisons
- There is no currently-known means of getting to 1% accuracy with traditional approaches
- There may be inexpensive SmallSat means of filling potential gaps between HySICS, TRUTHS, and CRBS
- Recommend all Earth-observing instruments acquire lunar measurements that could retroactively benefit from future ROLO improvements
 - Recommended lunar phases for these observations are $\pm 7^\circ$ and 2x/month