A New Reference Instrument for Reflective Solar Inter-Calibration: from MODIS to VIIRS

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- **Motivations (why?)**
  - From MODIS to VIIRS
- **Calibration Approaches for MODIS and VIIRS (make sense?)**
- **Inter-Calibration and Reference Transfer Approaches (how?)**
  - For most spectral bands, VIIRS is more suitable as a reference sensor for inter-calibration
- **Future Considerations (what else?)**

X. Xiong, A. Angal, J. Butler, C. Cao, D. R. Doelling, A. Wu, and X. Wu, "Global Space-based Inter-Calibration System Reflective Solar Calibration Reference: From Aqua MODIS to S-NPP VIIRS", Proc. of SPIE, 2016.

Motivations

- **Aqua MODIS has been (was) used as the reflective solar (RS) calibration reference for many years by many users, including GSICS community**
  - "Best" characterized and validated earth-observing sensor at the time
    - ✓ Extensive pre-launch calibration/characterization with lessons from Terra MODIS
    - ✓ Traceable to NIST reflectance standard
    - ✓ Stringent calibration requirements (±2% in reflectance)
    - ✓ A set of on-board calibrators, including SD, SDSM, and SRCA
    - ✓ Scheduled lunar observations through the entire mission
    - ✓ Better performance than Terra MODIS in the RS spectral region
  - Successfully operated since 2002 with mission likely to be extended beyond 2023 (NASA HQ Senior Review, 2017)
  - Dedicated efforts for instrument operation and calibration (MCST)
  - Consistently produced long-term data records enabling a broad range of applications
- **Many new missions/sensors have been launched and operated by different countries/agencies in recently years, including VIIRS, OLI, AHI, ABI, and sensors on Sentinels => need for a new reference instrument**

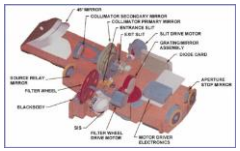
Motivations

- **VIIRS can and should be used as a new RS calibration reference**
  - Designed with strong MODIS heritage by the same instrument vendor
  - Operated and calibrated based on lessons and strategies from MODIS
  - Applied similar solar and lunar calibration approaches and methodologies
  - S-NPP VIIRS, launched in 2011, provides critical linkage between data records derived from EOS Terra/Aqua MODIS and future JPSS VIIRS sensors
    - JPSS-1 launch: Nov 15, 2017
    - J2/J3/J4 launch: 2021/2026/2031
  - Dedicated calibration effort by NOAA and NASA, including data reprocessing
    - NASA VIIRS SDR and L1B reprocessing; NOAA VIIRS SDR reprocessing
- **Issues to be addressed**
  - For previous sensors already used Aqua MODIS as inter-calibration reference
  - For future sensors likely to use J1 or even J2/J3/J4 VIIRS for inter-calibration
  - **Which VIIRS and what VIIRS data (from NOAA IDPS, NASA SIPS, …)?**
  - **What about the Moon?**

Calibration Approaches for MODIS and VIIRS

Solar diffuser (SD) and solar diffuser stability monitor (SDSM) for RSB calibration

Spectroradiometric Calibration Assembly (SRCA) for sensor spectral and spatial characterization

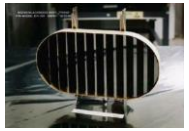


Solar Diffuser

SDSM

SRCA

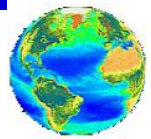
Blackbody



Scan Mirror

Space View

Reflectance-based Calibration (reference to SD BRDF)



Blackbody (BB) for TEB calibration

Lunar Calibration

Similar Calibration Methodologies

MODIS

VIIRS

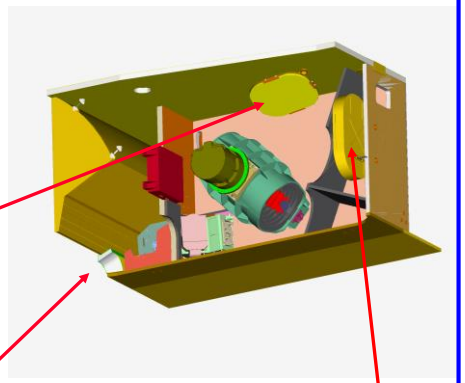
VIIRS: strong MODIS heritage

- Instrument Design (OBC)
- Operation
- Calibration

Solar Diffuser Stability Monitor

Solar Diffuser

Extended SV Port

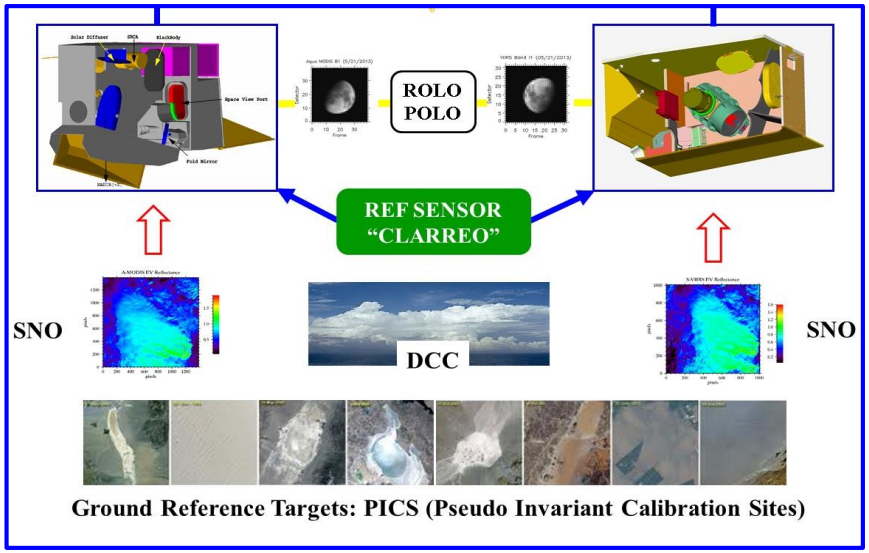


Blackbody

Inter-Calibration and Reference Transfer Approaches

- **Two most popular (if not the best) approaches to transfer calibration reference:**
- DCC Method
  - MODIS: works for B1, B3-7, B18, and B26 (not for B2, B8-16, B17, and B19 due to saturation)
  - VIIRS: works for all bands except for M6 (roll over saturation)
- Lunar Calibration
  - MODIS: works for B1-B4, B8-B12, and B17-19* (*no matching VIIRS bands); relative approach for B13-16 due to saturation; xtalk correction needed for SWIR bands
  - VIIRS: works for all bands

VIIRS is more suitable as the new GSICS reference sensor



VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500

Future Considerations

What should be done?

- For previous sensors already used Aqua MODIS as reference: calibration consistency between Aqua MODIS and S-NPP VIIRS
- For future sensors likely to use J1 or J2/J3/J4 VIIRS as reference: calibration consistency between S-NPP and future JPSS VIIRS
- For current sensors: directly use S-NPP VIIRS
- Ideally, a set of inter-calibration coefficients from Aqua MODIS to S-NPP VIIRS and from S-NPP VIIRS to future JPSS VIIRS can be made available to all users (independently validated and reviewed)

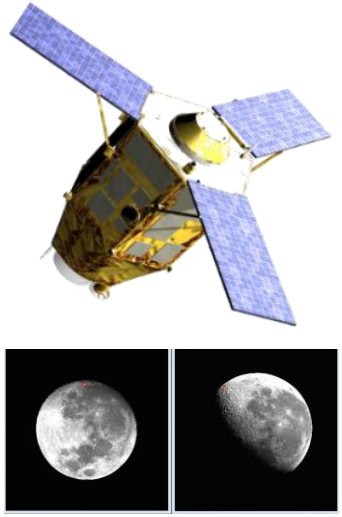
Alternative approaches

- Transfer reference sensor (either MODIS or VIIRS) calibration to DCC and Moon (pros and cons)
- Future CLARREO or TRUTH type of instruments with significantly improved calibration traceability and accuracy, thus much reduced inter-calibration uncertainty

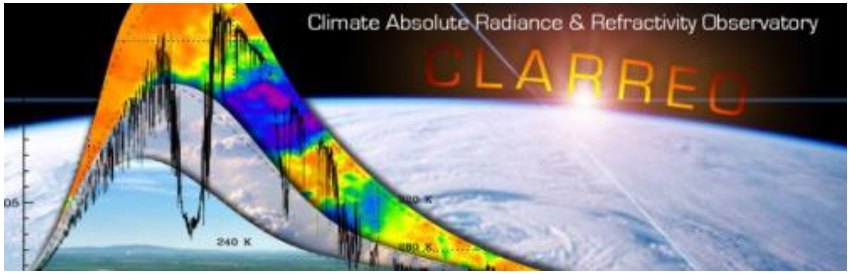
Coordinated efforts

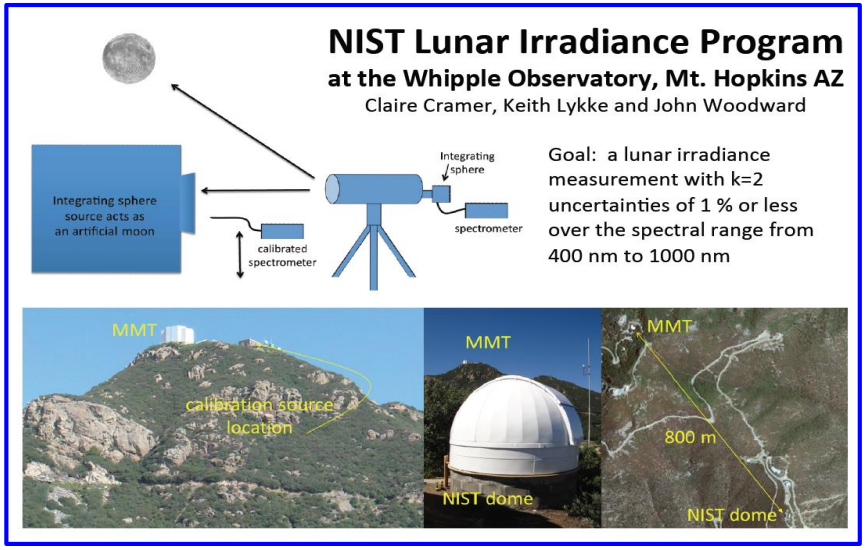
What About the Moon?

- **Presentations in this workshop**
  - Lunar observations made and used by more and more sensors
  - Easy access to the lunar models
    - ROLO
    - GIRO
    - SELENE/SP
    - POLO: Pleiades Orbital Lunar Observations (CNES)



- **Potential improvements of lunar model (irradiance) absolute accuracy**
  - NASA effort (e.g. CLARREO)
  - NIST effort
  - USGS effort
  - Other efforts





Questions?