GSICS Executive Panel (EP-12): NASA Report

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May 30-June 1, 2012
• Instrument Status Updates
  – MODIS Terra and Aqua (*J. Xiong-NASA GSFC*)
  – AIRS (*D. Elliott-NASA JPL*)
  – SNPP instruments: VIIRS, CrIS, ATMS, CERES, OMPS (*A cast of thousands*)

• Recent Instrument Inter-comparison Activities
  – NASA GSFC: MODIS Terra and Aqua (*Jack X.*)
  – NASA Langley: GEO & other Sensors (*D. Doelling*)
  – U of Wisconsin: MODIS, AIRS, IASI, & CrIS (*D. Tobin*)

• CLARREO Update (*B. Wielicki-NASA LaRC*)
MODIS Terra and Aqua Instrument Status

• Both MODIS Terra and Aqua continue to operate normally
  – ΔT’s of instrument and warm focal planes < 3.5K for MODIS Terra (12+ years) and <2K for Aqua MODIS (10+ years)
MODIS Terra and Aqua Instrument Status

- Cold FPA temperatures are operated at 83K. Extremely stable for Terra; small increase for Aqua (0.5K in recent years)

Terra MODIS:
- SMIR
- LWIR

Aqua MODIS:
- SMIR
- LWIR

Small increase of CFPA temperatures in recent years (0.5 K)
MODIS Terra and Aqua Instrument Status

- BB temperatures are constantly controlled

**Terra MODIS:** less than 30 mK increase over 12 years

**Aqua MODIS:** extremely stable
MODIS Terra and Aqua Instrument Status

- Solar diffuser stability monitor (SDSM) continues to operate on a regularly basis to track SD on-orbit degradation

- Increased SD degradation due to SD door fixed at “open”

- Gradually reduced SD/SDSM calibration frequency

- Larger degradation at shorter λ
MODIS Terra and Aqua Performance

- Radiometric (36 spectral bands with 490 individual detectors)
  - Only 1 new noisy detector since May 2011
  - 45 noisy detectors (30 from pre-launch; 35 at launch) and no inoperable detectors for Terra MODIS
  - 7 noisy detectors (2 from pre-launch; 3 at launch) and 15 inoperable detectors (13 in band 6) for Aqua MODIS

- Spectral
  - Changes in center wavelengths: < 0.5nm for most VIS/NIR bands (Terra and Aqua)
  - Changes in spectral bandwidths: < 1.0 nm for most VIR/NIR bands (Terra and Aqua)

- Spatial (all bands)
  - On-orbit band-to-band registrations (BBR) in both along-scan and along-track directions have been stable for both MODIS instruments
  - Aqua MODIS has large BBR offsets between cold FPA and warm FPA band pairs (a known problem since pre-launch)

- Geolocation
  - Excellent accuracy and stability: 43 m along track and 44 m along scan for Terra MODIS; 48 m along track and 53 m along scan for Aqua MODIS in C5
  - Additional improvements made for C6 geo-location accuracy
MODIS Level 1B Collection 6 Changes

• Explicit fill value is now used in L1B for inoperable detectors, whereas in collection 5 interpolation was applied

• New detector Quality Assurance (QA) flag for noisy and inoperable sub-samples is applied to bands at 0.466, 0.554, 0.646, 0.857, 1.24, 1.63, 2.11 μm

• Focal Plane Assembly (FPA) temperature correction is applied to the Thermal Emissive Band (TEB) linear calibration coefficient, b1
  – Default b1 used when $T_{BB}$ is above $T_{SAT}$ for Aqua bands at 13.36, 13.90, and 14.19 μm during BlackBody (BB) Warm-Up Cool-Down (WUCD)

• Set Terra MODIS bands 3.78, 3.96, 4.06, 4.47, 4.54 μm and 6.75, 7.33, 8.52, 9.74 μm offset coefficients to 0 for mirror side 1, adjust mirror side 2 offset coefficients to minimize mirror side differences at low temperatures

• Improved algorithms for L1B uncertainty calculation
  – Uncertainty is computed based on L1B calibration, retrieval algorithms and sensor on-orbit performance (i.e. scene, time, Angle Of Incidence (AOI) dependent)

• Solar Diffuser (SD) degradation at 0.936 μm is applied (0.6% over 10 years for Aqua MODIS; 1.6 % over 12 years for Terra MODIS), whereas previously this was normalized at this wavelength

• Time dependent Response Versus Scan (RVS) angle applied to bands at 0.666, 0.677, 0.746, 0.864 μm using lunar views

• Detector dependent RVS applied to MODIS Aqua bands at 0.411, 0.442, 0.487, 0.530, 0.547 μm

• Reflected Solar Band (RSB) calibration coefficients and RVS are derived at the same time using observations of the SD, Moon, and “pseudo-invariant” targets at different AOIs
  – Mainly applied to 0.411 and 0.442 μm MODIS Aqua bands
MODIS C6 Reprocessing Status

- C6 L1 and Cloud Mask/Profiles
  - C6 Aqua L1 and Cloud Mask/Profiles reprocessing completed, and the data is still in validation process by Atmospheres team
  - C6 Terra L1 and CloudMask/Profiles Program Executables (PGEs) are baselined and are being tested by atmosphere and Land science teams
  - Plan to start C6 Terra L1 and Cloud Mask/Profiles data reprocessing in the summer of 2012 with completion in 3 months

- C6 Land and Atmospheres reprocessing
  - Atmospheres C6 reprocessing targeted to start in Fall 2012
  - Land C6 reprocessing targeted to start in October 2012

- All C5/5.1 MODIS products will be archived in the Level 1 and Atmospheres Archive Distribution System (LAADS) until the next complete reprocessing (C6.x or C7)
AIRS Aqua Performance Status

- There have been no changes to the AIRS Level 1B calibration coefficients since launch.

- Later this year new L1C software will be available that can:
  - clean spectra (by replacing dead or noisy channels and by filling in the small inter-module gaps)
  - resample spectra to a fixed frequency grid.
Suomi National Polar-orbiting Partnership (SNPP)

Verner E. Suomi
University of Wisconsin
"the father of satellite meteorology."
## SNPP Instruments and Data Status

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Main Measurements</th>
<th>Channels</th>
<th>Data Status</th>
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</table>
| Advanced Technology Microwave Sounder (ATMS)                             | Global daily observations of temperature and moisture profiles at high temporal resolution | 22 channels: 23GHz - 183GHz                       | • ATMS Sensor Data Record (SDR) ready for Provisional release  
• ATMS data to be used by NCEP Spring 2012                                |
| Cross-track Infrared Sounder (CrIS)                                      |                                                                                   | LWIR: 650-1095 cm\(^{-1}\) MWIR: 1210-1750 cm\(^{-1}\) SWIR: 2155-2550 cm\(^{-1}\) | • Good science data available to users on 1/20/12  
• SDR declared Beta 5/8/2012                                               |
| Clouds and the Earth’s Radiant Energy System (CERES)                     | Global solar reflected and Earth emitted radiation from TOA to Earth’s surface     | 3 channels: Total (0.3 to >50 μm); Shortwave (0.3 to 5 μm); Long wave (8 to 12 μm) | Ops, data processing, products, and science based on 5 previous CERES instruments                                                          |
| Ozone Mapping and Profiler Suite (OMPS)                                  | • Backscattered uv radiance and incident uv solar irradiance (TC & NP)  
• Earth’s limb radiance in the ultra - violet (UV), visible and near infrared | Nadir TC: 300-380 nm Nadir Profiler: 250-310 nm Limb: 290-1000 nm | SDR declared Beta 3/5/2012                                                            |
| Visible Infrared Imaging Radiometer Suite (VIIRS)                        | Global visible and infrared imagery and radiance mmts of Earth’s land, cryosphere, atmosphere and ocean | 21 channels: 411 nm-12.0 μm plus DNB centered at 700 nm | SDR declared Beta 5/2/2012                                                            |

**SNPP SDR Product Maturity Level Definitions:**
- **Beta (L+90d):** Early release product; Initial calibration applied; Minimally validated & still may contain significant errors—rapid changes can be expected & version changes will not be identified as errors are corrected and on-orbit baseline is not established; Available to allow users to gain familiarity with data formats and parameters; Product not appropriate as the basis for quantitative science publication, studied, and applications.
- **Provisional (L+270d):** Product quality may not be optimal; Incremental product improvements still occurring as calibration parameters are adjusted based on sensor on-orbit cal; General research community encouraged to participate in on-going product validation and QA; Users urged to consult SDR product status document prior to use of data in publications; Data ready for operational evaluation.
- **Validated/Calibrated (L+365d):** On-orbit sensor performance calibrated and characterized and SDR parameters accurately adjusted; Date ready for use in applications and scientific publications with the possibility of later improved versions with accompanying documentation.
NASA GSFC Instrument Intercomparisons: MODIS Terra and Aqua Using N15 and N16 AVHRR

- The Terra/Aqua comparison below uses AVHRR as a transfer radiometer and does not depend on an accurate calibration of AVHRR (either N15 or N16)

- Each point is the result of averaging all pixels from an SNO event

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**Aqua MODIS B1 refl higher than Terra by 2.0% (N15)**

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**Aqua MODIS B1 refl larger than Terra by 2.1% (N16)**
NASA GSFC Instrument Intercomparisons: MODIS Terra and Aqua Using Deserts and Dome C

Reflectance factor trends (MODIS reflectance product) over a selected desert site (Libya 4)

MODIS reflectance trends over Dome C (corrected using BRDF derived from the snow site at Dome C)

Degradation not completely calibrated out in C5 will be corrected in C6
NASA GSFC Instrument Intercomparisons: MODIS Aqua and SNPP VIIRS

SNO Reflectance Ratios (2012-03-31)  SNO Temperature Comparisons (2012-04-13)

Each SNO point is averaged over 50 pixel pairs  Each SNO point is averaged over 1.0° x 1.0° grid
### NASA GSFC Instrument Intercomparisons: MODIS Aqua and SNPP VIIRS

#### VIIRS/MODIS reflectance ratio differences (%)

<table>
<thead>
<tr>
<th></th>
<th>640 nm I1</th>
<th>865 nm I2</th>
<th>412 nm M1</th>
<th>445 nm M2</th>
<th>488 nm M3</th>
<th>555 nm M4</th>
<th>672 nm M5</th>
<th>746 nm M6*</th>
<th>865 nm M7</th>
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</thead>
<tbody>
<tr>
<td>MODIS C5</td>
<td>-0.3</td>
<td>1.3</td>
<td>5.0</td>
<td>2.2</td>
<td>1.5</td>
<td>2.5</td>
<td>6.7</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>MODIS C6</td>
<td>-1.1</td>
<td>2.6</td>
<td>0.5</td>
<td>-0.1</td>
<td>2.2</td>
<td>2.4</td>
<td>2.1</td>
<td>3.5</td>
<td>0.7</td>
</tr>
</tbody>
</table>

* Comparison for M6 is less reliable due to MODIS early saturation

#### VIIRS & Aqua MODIS brightness temperature (BT) differences (K)

<table>
<thead>
<tr>
<th>BT (K)</th>
<th>3.70 μm M12</th>
<th>4.05 μm M13</th>
<th>8.55 μm M14</th>
<th>10.76 μm M15</th>
<th>12.01 μm M16</th>
<th>3.74 μm I4</th>
<th>11.45 μm I5</th>
</tr>
</thead>
<tbody>
<tr>
<td>235</td>
<td>0.3</td>
<td>0.2</td>
<td>1.5</td>
<td>1.0</td>
<td>0.6</td>
<td>4.0</td>
<td>1.5</td>
</tr>
<tr>
<td>250</td>
<td>0.1</td>
<td>0.0</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>3.0</td>
<td>0.5</td>
</tr>
<tr>
<td>270</td>
<td>0.0</td>
<td>-0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>1.5</td>
<td>0.4</td>
</tr>
<tr>
<td>285</td>
<td>-0.1</td>
<td>-0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.3</td>
<td>0.4</td>
</tr>
</tbody>
</table>
NASA JPL Instrument Comparisons: AIRS/IASI vs. NOAA
Real Time Global Sea Surface Temperature (RTGSST)

- Single differences at 1231 cm⁻¹—one point per instrument per day
- Relative bias is 106 mK (AIRS colder)

Double difference with 32-day running mean in red
NASA LaRC Calibrations and Intercomparisons: GEO & Other Instruments

- Demonstrated the use of SCIAMACHY visible hyper-spectral reference radiances to calibrate operational geostationary imagers
  - Presented at the March 2012 GSICS annual meeting
  - Determined that the relative calibration of SCIAMACHY/Aqua-MODIS based on SNOs was less than 0.2Wm-2/decade

- Developed a Deep Convective Calibration (DCC) methodology to transfer the calibration reference of Aqua-MODIS to geostationary imagers
  - Presented at the March 2012 GSICS annual meeting and Oct 2011 GSICS telecon
  - Validated the Aqua and Terra-MODIS C5 stability
  - Characterized DCC as an earth view invariant target using Aqua-MODIS radiances

- Developed a desert-based daily TOA GEO radiance model
  - Use a well calibrated reference GEO to calibrate historical GEOs using a desert target, since the daily viewing and solar geometry repeats annually

- The Multi-Instrument Inter-Calibration framework proposal was funded by NASA for the next two years
  - Accesses remote data servers to process SNO radiance pairs allowing the calibration community to improve algorithms and reduce calibration uncertainties and proof of concept for CLARREO

- Calibrated the ISCCP GEO record using DCC, desert and MODIS/GEO and SCIAMACHY/GEO ray-matching
  - As part of the ISCCP recalibration effort, uses Aqua-MODIS C6 as the absolute reference
  - Developed spectral band adjustment factors to account for differences in spectral response for all 3 methods

- Actively involved with the MODIS instrument team in stability monitoring and onboard calibration validation
U of Wisconsin Instrument Intercomparisons: MODIS Aqua & Terra, AIRS, IASI, & CrIS

MODIS Aqua & AIRS

MODIS Terra/Aqua & IASI
CrIS/AIRS SNO Comparisons

25 Feb overlaps for scan angles \( \leq 30 \) deg & scan angle diff \( \leq 5 \) deg

Data screened by time matchup, view angle, etc. and weighted by scene variability to examine biases

### 672-682 cm\(^{-1}\)
- **~75 mK**

### 1585-1600 cm\(^{-1}\)
- **~50 mK**
- **~130 mK**
CLARREO Update

• International Space Station (ISS) CLARREO Orbital Sampling Studies for Climate Studies
  – Used 10 years of CERES/geo merged data for hourly 1 degree gridded data as truth data
  – Subsampled with typical ISS orbits (350 – 400km, 51.5 degree inclination) for CLARREO nadir only viewing
  – ISS orbit covers 50S to 50N: no polar coverage
  – Within 50S to 50N, ISS samples the full diurnal cycle 12 times/yr.
  – Orbit sampling error results:
    • For infrared sampling: no accuracy loss versus CLARREO 90 degree nominal orbit. Time to detect trends increased by less than 5%.
    • For reflected solar sampling: time to detect climate trends at a given confidence level is increased from 10% (90 degree orbit) to 20% (ISS orbit) above that of a perfect observing system: i.e. If a perfect observing system detects a trend in 20 years, it takes 22 yrs (90 deg orbit) or 24 yrs (ISS orbit)
    • Direct determination of the diurnal cycle using CLARREO ISS data may improve accuracy to match the 90 deg orbit. Issue is that the ISS does not have an integer number of diurnal cycle samples in 365.25 days (1 year).

Conclusion: ISS meets CLARREO accuracy goals 50S to 50N for spectral fingerprinting of climate change (66% science value versus original baselined 90 degree orbit)

• ISS CLARREO Sampling Studies for "NIST in Orbit" (i.e. in orbit reference standard)
  – ISS orbit was used to simulate orbit crossing opportunities for all major sun-synchronous orbits (NPP, JPSS, METOP), and all geostationary satellites.
  – ISS provides the same intercalibration orbit sampling opportunities as the CLARREO nominal 90 degree orbit presented at the CLARREO Mission Concept Review for both reflected solar and infrared.
  – It also provides sufficient scene type variations to verify calibration accuracy in a wide range of climate conditions from the tropics to desert to mid latitude winter snow/ice low temperature and low water vapor conditions.
  – Pointing to the sun, moon, and alignment with scanning instruments on LEO and GEO platforms is sufficient for all CLARREO requirements.

Conclusion: ISS meets the CLARREO "NIST in orbit" requirements (100% science value vs. original baselined 90 degree orbit)
CLARREO Update

• ISS Accommodation Studies
  – CLARREO alternative mission studies and the SAGE III ISS accommodation work at Langley, show that the International Space Station provides a viable alternative for achieving a significant portion of the CLARREO science at much lower cost
  – Verify ISS accommodations for:
    • Field of regard. Verified Nadir and zenith pointing for IR, nadir, lunar, solar and intercalibration pointing for RS. Both instruments use 2-axis gimbals for pointing control on ISS.
    • Pointing control, knowledge, jitter. Meets CLARREO requirements.
    • Thermal environment. Instrument and blackbody cooling for IR/RS, thermal control.
    • Mass, power, size, and data rate. For ISS attached payloads on JEM modules and/or ELCs, the capabilities far exceed CLARREO instrument requirements (factors of 5 or more).

  **Conclude that ISS can accommodate CLARREO instruments.**

While Japanese JEM module is shown here, instruments could also be accommodated on the U.S. attached payload locations on ISS.
CLARREO Partnerships and Collaborations

- **NIST continues to be a very active and formal partner**
  - Active participation in Calibration Demonstration Systems at GSFC (reflected solar) and LaRC (infrared)
- **Multiple UK international collaborations on RS and IR spectrometers**
  - Imperial College, NPL, and Hadley Centre are active and formal partners.
  - UK formal agreement has been updated.
  - Working with Nigel Fox at NPL on a UK Space agency funded study of reflected solar science requirements for a potential TRUTHS demonstration mission. TRUTHS finished 3rd in the recent ESA Explorer competition.
  - The nascent UK Space Agency has minimal funding, consequently, they are pursuing funding options via ESA or via space technology demonstration missions for development of TRUTHS.
- **Italian collaboration on IR spectrometer**
  - Working with Italian scientists from the FORUM ESA Explorer proposal on future IR spectrometers for far infrared spectra. (FORUM finished 4th). An Italian proposal with Langley co-authors was submitted to ESA for study of implementation on ISS.
CLARREO Partnerships and Collaborations

– World Meteorological Organization (WMO)
  • GSICS (Global Space based Inter-Calibration System) has strongly endorsed the need for CLARREO as the in-orbit calibration reference to anchor all space based instruments in the infrared and reflected solar spectrum, both for climate change observations as well as operational weather and earth resources instruments. These include ABI, AGRI, AHI, ASI, AVHRR, CERES, CrIS, ETM+, FCI, GIIRS, GOME-2, HIRS, IASI, IRAS, IRS, MERSI-2, MODIS, OLCI, SEVIRI, SGLI, SLSTR, VIIRS, and VIRR.
  • Barbara Ryan, WMO Director for Space and GSICS sent a letter (Jan 2012) to Dr. Freilich at NASA HQ strongly endorsing the need for CLARREO to serve as the calibration anchor for GSICS and the rest of the observing system.
  • WMO has also endorsed CLARREO instruments on the International Space Station as the most effective way to achieve these objectives. A joint white paper on this topic was led by Jerome Lafeuille, Chief, Space-based Observing System Division, WMO Space Programme.

– United Nations (UN)
  • Takao Doi, section chief for the UN Office for Outer Space Affairs has endorsed the white paper led by Jerome Lafeuille of WMO supporting CLARREO instruments on ISS.

– ECMWF
  • ECMWF has written a letter in support of the Zeus proposal (a CLARREO quality IR spectrometer) that it needs higher accuracy IR spectra for weather prediction assimilation and climate re-analyses. They state that these observations would serve as one of their anchor observations that are assimilated without bias adjustment. This would be the first space based instrument used as an anchor for tropospheric weather prediction and re-analyses
Questions?
CLARREO Calibration Demonstration Systems

- CLARREO Calibration Demonstration Systems are currently in integration and test. They are designed to demonstrate and verify planned approaches to calibration on orbit.
NASA GSFC GSICS Calibration Papers

- **Calibration Papers Recently Published or Submitted**


LaRC GSICS Calibration Papers

• **Calibration Papers Recently Published or Submitted**

• **GSICS ATBD’s posted**