Review of Standards and Best Practices related to Remote Sensing Calibration/Validation

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Working Group on Calibration/Validation
CEOS/WGCV workshop

NIST, Gaithersburg, Maryland

May 6-8 2008

Outline

- Why calibration standards?
- International Standards Organizations
  - ISO TC 211 standards related to calibration
- IEEE Supports GEOSS Standards and Interoperability
  - IEEE Committee on Earth Observations (ICEO)
  - ICEO Standards Working Group
  - GEO ADC Standards & Interoperability Forum
  - GEOSS Standards and Special Arrangements Registry
  - GEOSS Best Practices Wiki
- Calibration traceability to SI standards
  - NIST and other international organizations
  - SI traceable instruments/standards (EO, microwave)
- Recommendations

Why calibration standards? Connections to international standards bodies

- One of GEO/CEOS's key responsibilities is to facilitate the acquisition and dissemination of data from many sources and to assure end-users the quality of that data, so that they have faith in its veracity.
- The endorsement of critical Cal/Val data and best practices by some authority, yet to be determined, is an important step in assuring overall data quality.
- WGCV action (WGCV workshop, Geneva, Oct. 2007)
  - A committee should be formed to explore options to establish an authority for the endorsement of best practices for Cal/Val
  - WGCV will identify appropriate reference standards, traceable to SI units (where possible) to underpin a QA framework
- IEEE/ICEO has initiated an effort to produce a short-term survey of existing international standards for Cal/Val processes.
  - This talk presents some of the preliminary findings

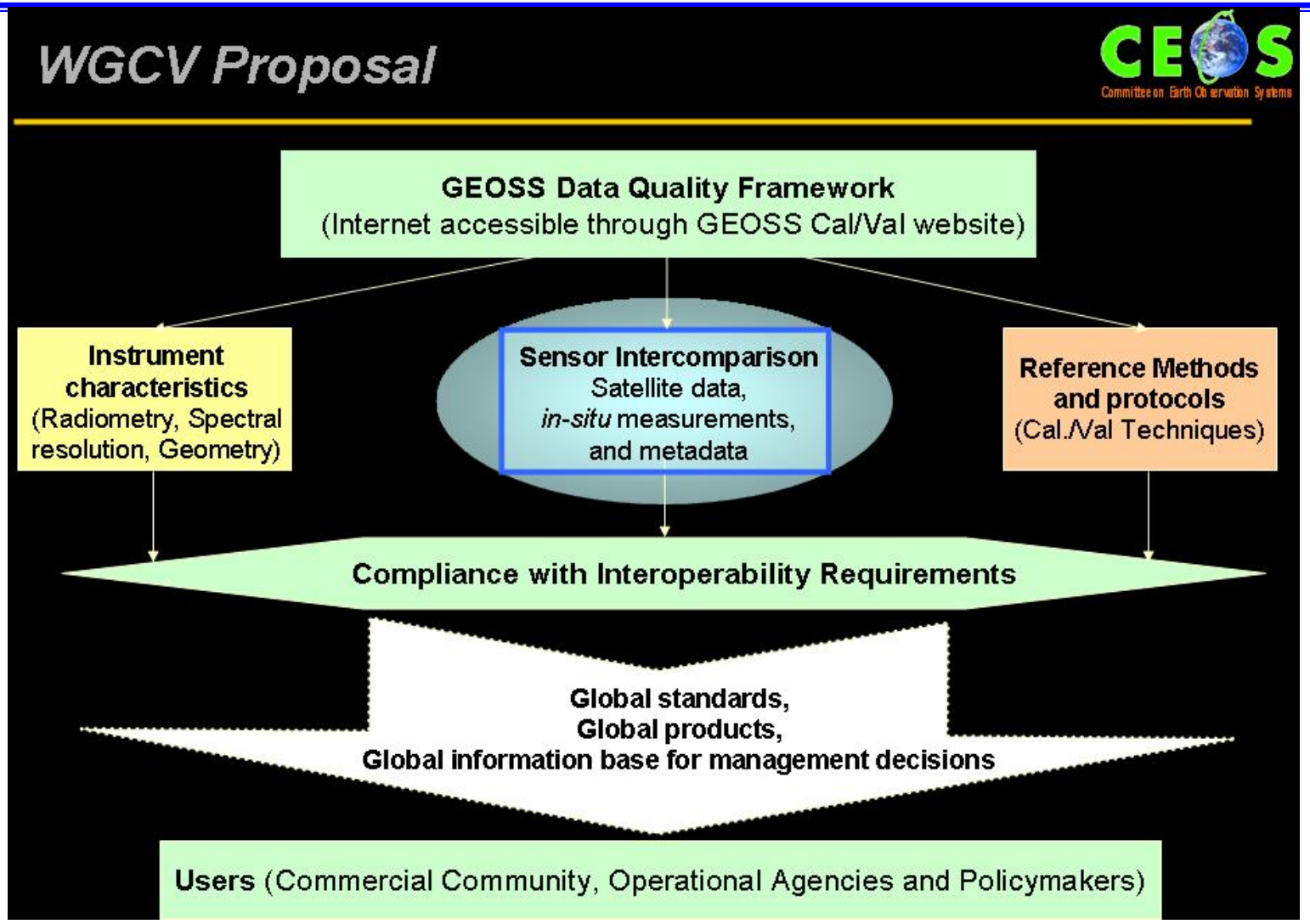
Suggested actions re WGCV Calibration Standards

ref: Ungar preliminary agenda ideas for Feb 08 WGCV mtg. Sanya, China.

- The need for CEOS WGCV standards and a standards technical committee
- Coordination with existing standards bodies
- Inventory of potential WGCV standards and documentation issues
- Develop a CEOS standards factsheet/handbook
- A review of CEOS radiometric reference standards, prior to launch and on-orbit

Inter-calibration scenario/Global standards

re: GEOSS ADC Architecture Workshop Ungar, 2-4-08



Which standards organizations best relate to Remote Sensing Calibration?

- International Organization for Standards, ISO
  - Technical Committee TC 211 (Geographic Information Standards)
  - Technical Committee TC 287 (European Geospatial Standards, CEN)
- Open Geospatial Consortium, OGC
  - Global forum for developers & users of geospatial and spatial data products and services; web oriented
  - Develops international standards for geospatial interoperability
- International Society for Photogrammetry & Remote Sensing
  - ISPRS Commission I: Image Data Acquisition, Sensors & Platforms
    - WG I/1 : Standards Calibration & Validation
- Consultative Committee on Space Data Standards, CCSDS
- National Institute of Standards and Technology, NIST
- National Physical Laboratory, NPL

Which standards organizations best relate to Remote Sensing Calibration? (cont'd)

- IEEE Standards coordinating committee
  - Sponsors standards developments involving one or more of IEEE's 39 technical societies
  - ICEO Interoperability and Standards Working Group, ISWG
- Group on Earth Observation, GEO
  - Standards and Interoperability Forum, SIF

ISO TC 211 Geographic Info Standards

directly or indirectly related to Cal/Val

- ISO TC 211 Develops standards in the field of Geographic Information: Photogrammetry and Remote Sensing subtopics
- CEOS, ISPRS, OGC, WMO external liaison members
- Imagery Standards under development
  - ISO 191xx series of geographic info standards: Establishes structured set of standards for information for objects or phenomena that are directly /indirectly associated with a location re to the Earth (ISO 19101)
- Projects for Remote Sensing & Photogrammetry (new work item proposals)
  - 19129: Imagery gridded, coverage data framework
  - 19130: Sensor and data models for imagery and gridded data
  - 19101-2: Reference model imagery
  - 19115-2: Metadata for imagery and gridded data
  - Calibration/Validation of Sensors (TC211 WG6 planned effort)
  - 19113: Principles describing the Quality of Geographic Data

ISO 19130 (new work item proposal, due 5-20-08)

Sensor and data models for imagery

- ISO 19130 specifies the geolocation information that an imagery data provider shall supply a user to find the geographic location of the data. Sensor models are defined for each kind of remote sensing sensor system that produces imagery data. (relates to image/band-band registration)
  - Passive EO/IR sensor models: frame, pushbroom, whiskbroom
  - Active Microwave sensor model: SAR
- Goal:
  - Standardize sensor descriptions
  - Specify minimum geolocation metadata requirements
- Standard models and metadata allow agencies and contractors to develop generalized software products
  - Leads to interoperability between application systems and facilitates data exchange

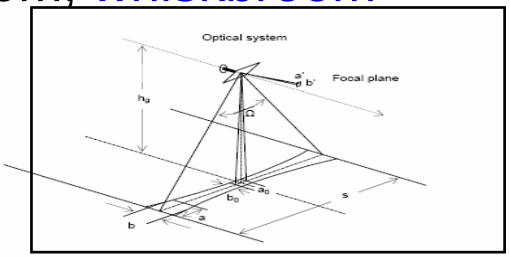


Figure 4 – Optical layout of a whiskbroom scanning sensor

New ISO TC211 work item on Cal/Val
(estimated due by 2009)

- ISO TC 211 WG6 plans to develop a standard for the Radiometric calibration and validation of remote sensing data
- The original plan was to start the Cal/Val project after TC211 WG6 finishes with ISO19130 under the chairmanship of
  - Professor Liping Di is Director of the Center for Spatial Information Science and Systems (CSISS) George Mason University
- It is possible that the ISO work item for the Cal/Val project will start next year provided that financial support is available
  - Ref: L.Di chair TC211 WG6

ISO 19113 (2002, rev. 2007)

Principles for describing the Quality of Geographic Data

- Description: Establishes the principles for describing the quality of geographic data and specifies components for reporting quality information. It also provides an approach to organizing information about data quality.
- The principles of this standard can be extended to identify, collect and report the quality information for a geographic dataset.
- This standard does not attempt to define a minimum acceptable level of quality for geographic data.

IEEE Supports Standards and Interoperability for GEOSS

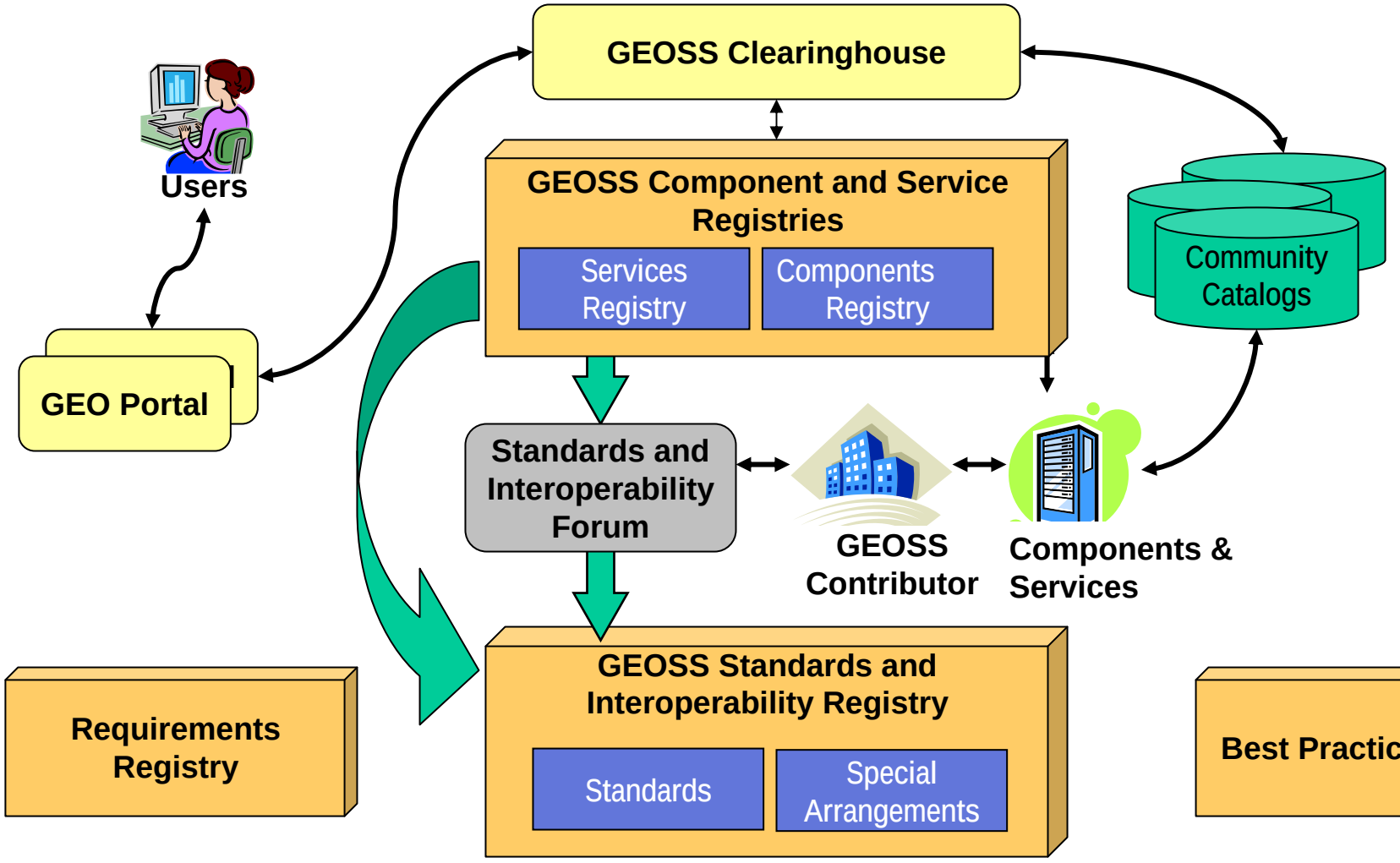
- **The IEEE Committee on Earth Observation (ICEO)**
  - Brings IEEE's broad technical expertise to help in creation of GEOSS
  - Leading several architecture development tasks
  - Created new technical journal and online magazine
  - Leading the GEO Energy community of practice; created energy strategic plan
  - Organizing GEOSS workshops

- **ICEO Standards Working Group (ISWG)**
  - Created in 2005 to begin working standards issues for GEOSS
  - Produce global survey of existing portals serving Earth Observation data
  - Develop taxonomy of standards in use by EO systems
  - Profiled Standards Development Organizations relevant to GEOSS
  - Now oversees operational aspects of the Standards and Special Arrangements Registry

IEEE Support of Standards and Interoperability (cont'd)

- **Leads the GEO ADC Standards and Interoperability Forum (SIF)**
  - Assist the GEO in establishing and overseeing GEOSS interoperability arrangements (Harmonization)
  - Facilitate linkages, partnerships between Standards Development Organizations, users, and other groups interested in GEOSS standards
  - Encourage and guide creation of new standards and with GEO approval, oversee the process
- **Leads the GEOSS Interoperability Process Pilot Projects**
- **Created the IEEE Standards Coordination Committee (SCC)**
  - Can sponsor a standards development effort involving one or more of IEEE's 39 technical societies

GEOSS Core Architecture



GEOSS Standards Registry

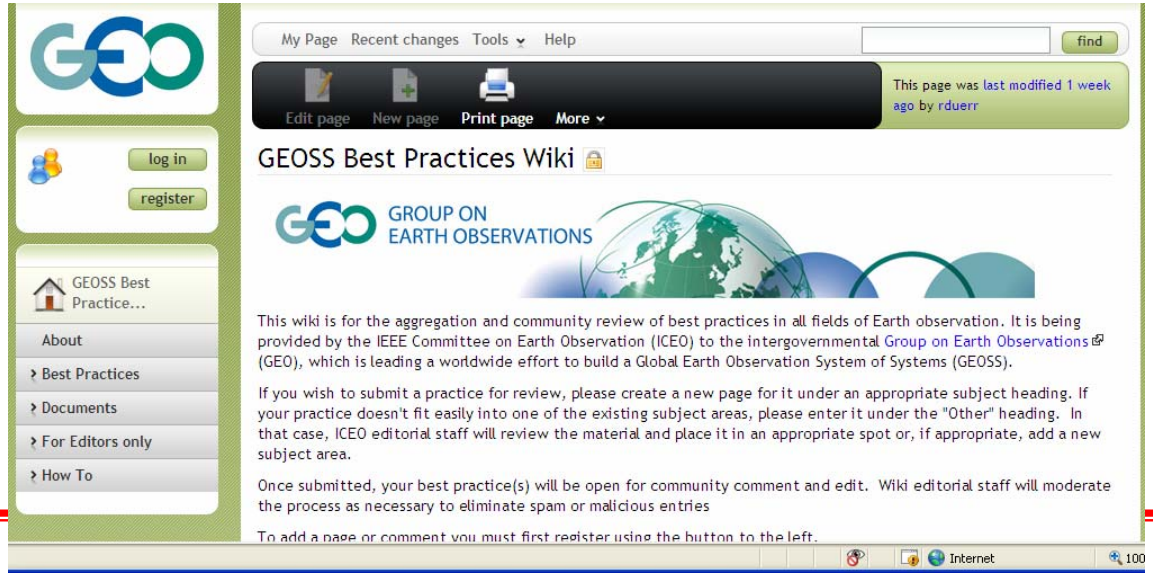
GEOSS Standards and Interoperability Registry
GEOSS Components and Services Registry

- The GEOSS Standards Registry, created and hosted by the IEEE, is a reference database of interoperability arrangements that are registered to GEOSS components and their services
  - It is here that GEOSS stores information on service types, access protocols, data formats, schemas, and other standards in use. Services in the Service Registry reference standards are registered in the Standards Registry
- There are currently 60 components registered in the GEOSS Components Registry (at least 2 are test entries), 70 services registered in the Services registry, and 90 standards and special arrangements (at least 3 are test entries) registered in the Standards and Interoperability Registry. <http://geossregistries.info/>

GEOSS Best Practices Wiki

Provided by IEEE/ICEO to GEO

- This wiki is for the aggregation and community review of best practices in all fields of Earth observation. It is being provided by the IEEE Committee on Earth Observation to the Intergovernmental Group on Earth Observations (GEO).
- http://wiki.ieee-earth.org/
- Once submitted, your best practices will be open for community comment and edit. Include examples, source documents



Microwave Radiometer Best Practices Calibration Steps Inter-Calibrating Satellite Sensors (Consistency, all steps the same)

Ref: Validating Calibration of Satellite Microwave Radiometers on Decadal Time Series Frank Wentz et al, IGARSS07, July 2007 (Chart #4)

STEP-1: Level-1 data reverse engineered back to radiometer counts

STEP-2: Produce a Calibrated Brightness Temperature. Nine steps.

	Geolocation Analysis	Attitude Adjustment	Along-Scan Correction	Absolute Calibration	Hot Load Correction	Antenna Emissivity	Resampling Algorithm	Rain Threshold	Out of Bounds Detection Q/C
SSM/I	NRL/RSS	No	Yes	TA Offsets	No see note 1	0	Optimal Interp.	0.18 mm	Ocean RTM
TMI	Goddard	Dynamic	Yes	TA Offsets	No	3.5%	Optimal Interp.	0.18 mm	Ocean RTM
AMSR-E	RSS	Fixed	Yes	APC	Yes	0	Optimal Interp.	0.18 mm	Ocean RTM
AMSR-A	RSS	Dynamic	Yes	APC	Yes	0	Optimal Interp.	0.18 mm	Ocean RTM
WindSat	NRL/RSS	Fixed	Yes	APC	Yes	0	Earth Grid Weighted Avg.	0.18 mm	Ocean RTM
SSMIS	RSS	No	Yes	APC	Yes	TBD	Optimal Interp.	0.18 mm	Ocean RTM

Note-1: Error due to Hot Load are removed when doing the zonal TB intercalibration

Best Practices for Generic Portals

Ref: REPORT FOR EARTH OBSERVATIONS PORTALS – VERSION 1.0, March 3rd, 2008
IEEE ICEO/ ISWG, June R. Massoud, Earth Obs. Portals Committee Chair

- Usability Characteristics
  - Access to Supporting Data (Required)
  - Consistency in terminology and behavior (Strongly Suggested)
  - Site Maps, Use Cases, Good Response Time, Feedback, FAQ, Help (Strongly Suggested)
  - Finalize Portal Based on User Testing (Required)
- Technology Characteristics
  - Browser Based (Strongly Suggested)
  - Degradability (Required)
- Functional Characteristics
  - Content, Content Search (Required)
  - Spatial (Required)
  - Temporal (Required)
  - Data Visualization (Required)
- Evaluation of ESA Cal/Val portal relative to portal characteristics initiated

Calibration traceability to SI standards

Standards Laboratory resources for radiometric calibration

- CEOS Plenary Resolution 14 on traceability to SI (2000):
  - All EO measurement systems should be traceable to SI units for all appropriate measureands
  - Prelaunch calibration should be performed using equipment and techniques that can demonstrably be traceable to and consistent with the SI system of units; traceability should be maintained throughout the lifetime of the mission
    - Ref: Nigel Fox, Validated data and removal of bias through traceability to SI units in "Post-launch calibration of satellite sensors", Morain & Budge, 2004
  - Inter-satellite biases are very difficult to characterize due to the lack of commonly traceable on-orbit calibration standards
  - ASIC3 called for the establishment of a U.S. interagency National Center for Calibration composed of NASA and NOAA linked with NIST, the agency responsible for establishing measurement standards
    - Ref: ASIC3 – Calibration for Climate Change, Meeting of May 2006

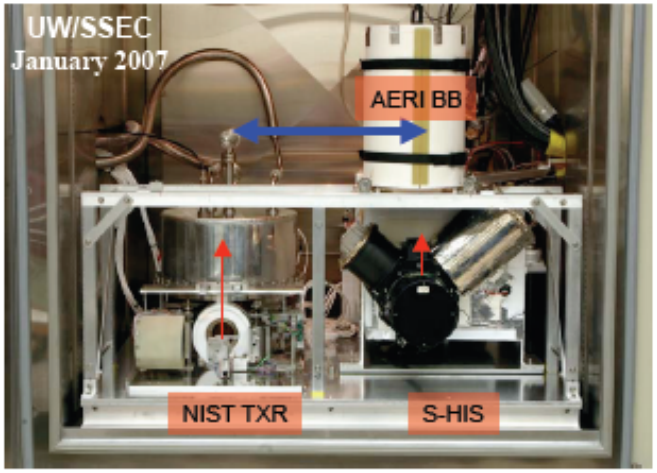
NIST measurement standard programs Electro-Optical

- NIST has the responsibility to support calibration standards development and dissemination to satisfy the requirements of various agencies for remote sensing instrumentation
  - Standard NIST lab devices, have known measurement characteristics
- NIST expertise in designing SI traceable instrument design is extensive
  - NIST has developed state of the art cryogenic radiometers as absolute standards and Uniform Sources (SIRCUS cal facility)
  - NIST has developed a number of portable transfer radiometers that travel to satellite calibration facilities and validate the radiance scale of calibration sources.
    - VNIR radiance values are traceable to NIST standards using a chain of measurement steps using spectral irradiance standards lamps and diffuse reflectance standards (e.g. EOS/NIST visible transfer radiometer, VXR)
    - IR sensors are calibrated using blackbodies for which the spectral radiance values are traceable to NIST temperature standards (e.g. TXR)

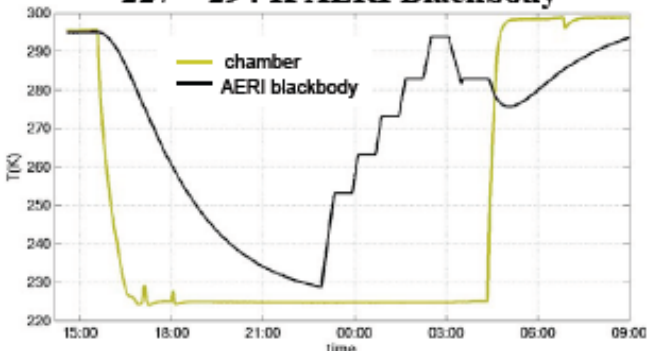
Univ. Wisconsin IR interferometer radiances traceable to NIST scale using NIST transfer sensor (TXR)

UW S-HIS & AERI Blackbody Absolute Accuracy: The NIST Connection for true SI Traceability

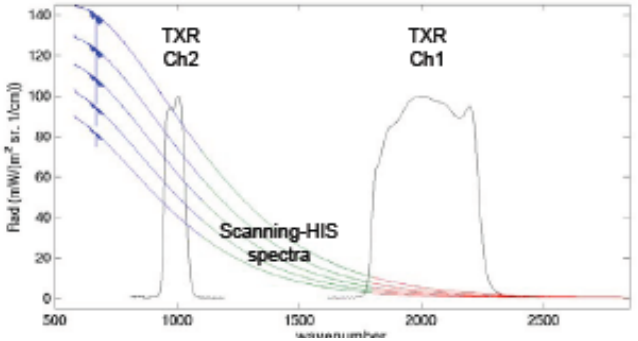
Recent end-to-end radiance evaluations conducted under S-HIS flight-like conditions with NIST transfer sensor (TXR) such that S-HIS satellite validation & AERI observations are traceable to the NIST radiance scale



227 – 294 K AERI Blackbody



10 & 5 μm NIST TXR Channels



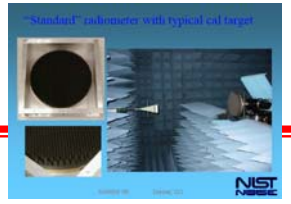
Network Calibration Validation Earth Observation

UK forum devoted to Cal/Val of EO products; Univ. Southampton, NPL, ..
Large UK 2006 Field Experiment; Aerial + ESA PROBA Satellite sensors

- Aims of NCAVEO 2006 field experiment: Chilbolton, U.K.
  - Gain experience in the collection and use of field data to validate radiance and reflectance products, including issues of traceability and the propagation of error;
  - Gain experience in methods to validate the LAI (leaf area index) of agricultural crops derived from EO;
  - Assemble a quality-controlled multi-scale, multi-sensor data set for algorithm development and testing.
- Calibration lab on-site: radiometric traceability chain
  - NPL Transfer Standard Absolute Radiance Source (TSARS).
  - Wavelength calibration standards.
  - Reference panel calibration: on-site using ASD contact probe, post-hoc at FSF, Edinburgh

Microwave
NIST measurement standard programs

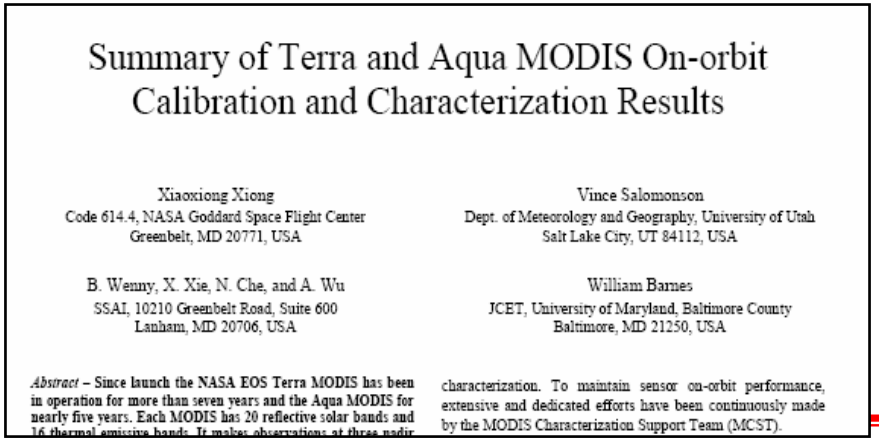
- There are currently no national standards for Microwave (or terrahertz) brightness temperatures, BT
  - There is a drive to develop such a standard since new microwave radiometer designs have specifications for BT uncertainties < 0.5K and there is a need to harmonize data between different sensors
- NIST's Electromagnetics division has proposed the development of standards for microwave brightness temperature (e.g. for use in satellite weather observations)
  - Standards to be based on those already adopted by NIST for EM noise in waveguide systems
  - Connection to brightness temperature will be via a well characterized antenna, supplemented by a heated calibration target
  - Ref: Standards for Remote Sensing at Microwave Frequencies, NIST paper, 2007, J. Randa et al



Other calibration forums pertinent to WGCV

- CalCon annual conference on characterization and radiometric calibration for remote sensing within the microwave, IR, visible, UV spectrums.
  - CalCon 2008 August 25, 2008 Utah State University
- ASIC3 – Calibration for Climate Change, May 2006
  - Formulate roadmap for developing calibration systems to monitor long-term global climate change
- IEEE Geoscience and Remote Sensing Symposia, IGARSS

Sessions on GEOSS, Calibration of EO, Microwave Sensors



Summary of Terra and Aqua MODIS On-orbit Calibration and Characterization Results

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Abstract – Since launch the NASA EOS Terra MODIS has been in operation for more than seven years and the Aqua MODIS for nearly five years. Each MODIS has 20 reflective solar bands and 16 thermal emissive bands. It makes observations at three nadir

characterization. To maintain sensor on-orbit performance, extensive and dedicated efforts have been continuously made by the MODIS Characterization Support Team (MCST).

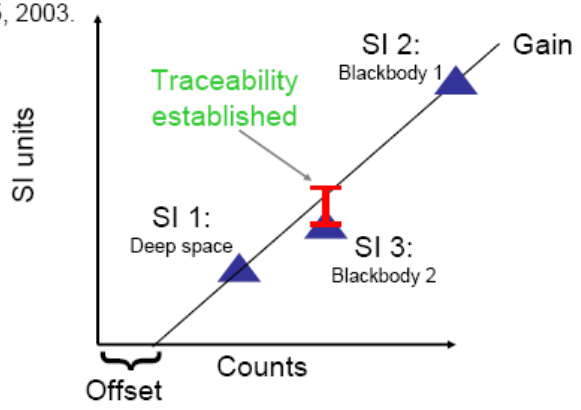
IGARSS 07 Barcelona, July 2007

Other calibration forums pertinent to WGCV (cont'd)
CLARREO (aka NBS in Space)

- CLARREO '07 Workshop **(Climate Absolute Radiance & Refractivity Observatory)**
  - CLARREO mission is recommended to provide on-orbit calibration laboratories to calibrate other solar and IR space-borne sensors (VIIRS, CrIS, ..) for decadal international climate monitoring (SI traceable benchmarks, absolute accuracy 0.1 deg K, 5 – 50 microns). Decadal survey mission 11 instruments, 3 satellites
  - NPL TRUTHS satellite component (SI traceable, 380 – 2500nm, spectral radiance uncertainty < 0.5%) Ref: (Nigel Fox, CLARREO 2007)

Achieving SI traceability

- SI traceability *on-orbit* requires one additional SI traceable standard: Pollock, D. B., T. L. Murdock, R. U. Datla, and A. Thompson, Data uncertainty traced to SI units. Results reported in the International System of Units, *International Journal of Remote Sensing, 24*(2), 225-235, 2003.



Ref: IR Breakout discussion
Recap of **CLARREO workshop July, 2007**

Recommendations

- **WGCV to review the work on standards, best practices, and interoperability that currently exist**
  - **Create an inventory of potential WGCV standards and possible alignment with established or proposed standards; ISO, OGC. Develop CEOS standards handbook**
- **WGCV should consider using established GEO Core Infrastructure Components**
  - **(Component, Service and Standards Registries, Best Practices Wiki)**

  as the repository for information it produces and manages
- **WGCV to compose a white paper on recommended methods and organizational structures needed to establish an authority and set of standards and best Cal/Val practices**
- **CEOS/WGCV to be recognized as a standardizing body with specific responsibilities for defining Cal/Val best practices and reference standards**
- **CEOS/WGCV to work jointly with ISO/OGC and other international standards organizations to review, publish, and maintain CEOS/WGCV initiated standards (Steve Ungar reports this effort is underway)**

Implementation of Guidelines
Thoughts on Developing an Implementation Roadmap

- The technology roadmapping process provides a way to identify, evaluate, and select strategic alternatives that can be used to achieve a desired set of objectives
  - Laying the path for the construction work to follow
- **Implementing key CEOS/WGCV processes and activities**
  - Establishing the definition of and metrics for a Cal/Val Quality Index (QI) for a sensor data product
  - Identifying and utilizing specific reference standards for Cal/Val
    - Establishing a standards authority
  - Identifying and assessing the processes for the "quantitative evidence of traceability". What quantitative error measures are recommended?
  - Cal/Val and the nine societal benefit areas. Establishing a connection?