Global Space-based Inter-Calibration System (GSICS)

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Motivation

• Applications are becoming more demanding

• Demanding applications require accurate, well calibrated & characterized measurements

• Reduce measurement uncertainty

• Growing global observing system
GEOSS

- GEOSS – international coordinated effort to share Earth observations to provide a level of information about the Earth not previously achieved.
Nine Societal Benefits

• Improve Weather Forecasting
• Reduce Loss of Life and Property from Disasters
• Protect and Monitor Our Ocean Resource
• Understand, Assess, Predict, Mitigate and Adapt to Climate Variability and Change
• Support Sustainable Agriculture and Forestry and Combat Land Degradation
• Understand the Effect of Environmental Factors on Human Health and Well-Being
• Develop the Capacity to Make Ecological Forecasts
• Protect and Monitor Water Resources
• Monitor and Manage Energy Resources
Science Requirements for GEOSS to meet the 9 societal benefits:

- Satellite Intercalibration & Sensor characterization
- Data Fusion & Integrated Products, including CDRs
- Data Assimilation & Modeling
What is GSICS?

• Global Space-based Inter-Calibration System (GSICS)

• WMO sponsored

• Goal - Enhance calibration and validation of satellite observations and to intercalibrate critical components global observing system
The GCOS Climate Monitoring Principles (GCMPs) were extended to address the problems associated with developing long-term climate data records from satellite observations:

- Stable orbits
- Continuity and adequate overlap of satellite observations
- Improved calibration and validation

CGMS tasked the WMO Space Programme to build an international consensus and consortium for a global space-based inter-calibration system for the World Weather Watch (WWW)/Global Observing System (GOS).
Formulation Team

- Mitch Goldberg – NOAA/NESDIS (Chair)
- Gerald Frazer – NIST
- Donald Hinsman – WMO (Space Program Director)
- Xu Jianmin (CMA)
- Toshiyuki Kurino (JMA)
- John LeMarshall - JC Sat. Data Assimilation
- Paul Menzel – NOAA/NESDIS
- Tillmann Mohr – WMO
- Hank Revercomb – Univ. of Wisconsin
- Johannes Schmetz – Eumetsat
- Jörg Schulz – DWD, CM SAF
- William Smith – Hampton University
- Steve Ungar – CEO, Chairman WG Cal/Val
Climate & Weather Requirements

- Need excellent accuracy and long-term stability
- Instruments must be inter-calibrated
- Need high precision (low noise)
- Measurements must be well characterized
Error Characteristics

- Accuracy (bias)
- Precision (standard deviation)
- Stability
GSICS Objectives

• To improve the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of satellite sensors.

• To provide for the ability to re-calibrate archived satellite data using the GSICS intercalibration system to enable the creation of stable long-term climate data sets

• To ensure that instruments meet specification, pre-launch tests are traceable to SI standards, and the on-orbit satellite instrument observations are well calibrated by means of careful analysis of instrument performance, satellite intercalibration, and validation with reference sites
Space-based Observing Systems
Operational Environmental Satellites
Outcome

- Coordinated international cal/val program
- Exchange of critical datasets for cal/val
- Best practices/requirements for monitoring observing system performance
- Best practices/requirements for prelaunch characterisation
- Establish requirements for cal/val
- Advocate for benchmark systems
- Quarterly reports of observing system performance and recommended solutions
- Improved sensor characterisation
- High quality radiances for NWP & CDRs
Prerequisites

• Extensive pre-launch characterization of all instruments traceable to SI standards

• Benchmark instruments in space with appropriate accuracy, spectral coverage and resolution to act as a standard for inter-calibration

• Independent observations (calibration/validation sites – ground based, aircraft)
Building Blocks for Satellite Intercalibration

• **Collocation**
  – Determination and distribution of locations for simultaneous observations by different sensors (space-based and in-situ)
  – Collocation with benchmark measurements

• **Data collection**
  – Archive, metadata - easily accessible

• **Coordinated operational data analyses**
  – Processing centers for assembling collocated data
  – Expert teams

• **Assessments**
  – Communication including recommendations
  – Vicarious coefficient updates for “drifting” sensors
GSICS Organizational Chart
GSICS Components

• GSICS Executive Panel – reps from each operational satellite agency
  – Priorities, objectives and agreements
• GSICS Coordination Center (GCC) - NESDIS
  – Transmit intercalibration opportunities to GPRCs
  – Collect data from the GPRCs and provide access
  – Quarterly reports on performance
• GSICS Processing and Research Centers (GPRCs)
  – Operational satellite agencies
  – Activities:
    • Pre-launch calibration
    • Intersatellite calibration
    • Supporting research
Calibration Support Segments (CSS)

- Pre-launch Instrument Characterization
- Earth-based Reference Sites and Natural Calibration Sources
- Extraterrestrial Calibration Sources
- Model Simulations
- Benchmark Measurements (space-based, aircraft, ground-based)
Simultaneous Nadir Overpass (SNO) Method
-a core component in the Integrated Cal/Val System

- Unique capabilities developed at NESDIS
- Has been applied to microwave, vis/nir, and infrared radiometers for on-orbit performance trending and climate calibration support
- Capabilities of 0.1 K for sounders and 1% for vis/nir have been demonstrated in pilot studies
- Method has been adopted by other agencies

• Useful for remote sensing scientists, climatologists, as well as calibration and instrument scientists
• Support new initiatives (GEOSS and GSICS)
• Significant progress are expected in GOES/POES intercal in the near future
Integrated Cal/Val System Architecture

Calibration Opportunity Prediction

Data Acquisition Scheduler

Calibration Opportunity Register (CORE)

Raw Data Acquisition for Calibration Analyses

Stored Raw Data for Calibration Analyses

SNO/SCO Rad. Bias and Spectral Analysis
Calibration Parameter Noise/Stability Monitoring
RTM Model Rad. at Calibration Reference Sites
Inter-sensor Bias and Spectral Analysis
Earth & Lunar Calibration
Geolocation Assessment (Coastlines, etc.)

Assessment Reports and Calibration Updates
Currently about 4 out of the 12 longwave channels meet the specification, including the important water vapor channel (ch12). NOAA18/HIRS is extremely sensitive to vibrations, due to a possible loose part in the aft optics, and the sensitive design with a 10 km resolution.
AVHRR VIS/NIR Vicarious Calibration using the Libyan Desert Target

NOAA 16 AVHRR Albedo

CH1

CH2

CH3

NOAA 17 AVHRR Albedo

Courtesy of X. Wu
Intersatellite Biases from Simultaneous Nadir Overpass (SNO) Observations (updated monthly)

**POES NOAA-16 vs. NOAA-17**

**HIRS**

Select a HIRS Channel:
- CHANNEL 1
- Show Plot

**AMSU-A**

Select an AMSU Channel:
- CHANNEL 1
- Show Plot

**AVHRR GAC**

Select an AVHRR Channel:
- CHANNEL 2
- Show Plot

Time Series of Biases between GHRR/NOAA-16 and NOAA-17 (channel 2)

AVHRR 0.86um channel (with vicarious calibration)

- N-16 coeff. update
- N-17 coeff. update
SNO Events Between Concurrently Operating AMSU-A Instruments

**Time Period:** May 21, 2005 to July 31, 2006  

**Locations:** Mainly Around 80° North and South  

**SNO Time Threshold:** 30 Seconds

**Number of SNOs:**

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POES and Aqua AMSU-A SNO-ensemble Mean Biases and 99% Confidence Intervals
Observed and Predicted AMSU-A SNO biases using Aqua/AMSU-A as a Calibration Transfer Radiometer
SSMIS (54.4 GHz)

• SSMIS is the first conical microwave sounding instrument, precursor of NPOESS CMIS.
• Shown are the differences between observed and simulated measurements. Biases are caused by 1) antenna emission, 2) direct solar heating to warm load and 3) stray light contamination to its calibration targets.
AIRS Noise Monitoring
Fantastic AIRS - MODIS Agreement for Band 22 (4.0μm)!

AIRS Tb (K)

AIRS minus MODIS (K)

AIRS Histogram

Uniform Scenes

MODIS

Selected
MODIS Band 22 (4.0 μm)

AIRS-MODIS mean = -0.05 K

Little Dependence on Scene Temperature

Little Dependence on X-track View Angle

Little Dependence on Solar Zenith Angle
Shifting MODIS Band 35 (13.9 μm) by 0.8 cm$^{-1}$ Works to Remove Mean bias and Scene Tb Dependence

AIRS-MODIS: un-shifted, shifted

(ce (0.21K) not included here)
8 AIRS FOVs and SHIS Data w/in them (448 fovs) used in the following comparisons
“comparison 3”

(AIRSobs - AIRScalc) - (SHISobs - SHIScalc)

wavenumber
TWP versus ECMWF
(ECMWF averaged over ~10-40 deg. Latitude)

(Srow, UMBC)
Frost-Point Observations Show Significant Deviations

Frost-Point Observations by H. Voelmer: NOAA Boulder

Represents far fewer observations than RS-90's and inconsistencies day vs night.

Diamonds are CO₂ Biases for channels with similar peaking weighting functions.
Summary

• GSICS - coordinated effort to better characterise and improve the fundamental measurements of the Global Observing System
• Improve radiance quality >>> reduce uncertainties in forecasts and climate data records
WMO has approved the development of an Implementation Plan

- Co-ordination Group of Meteorological Satellites (CGMS) XXXIII WMO- WP-21 presented a draft concept and strategy for a Global Space-based Inter-calibration System (GSICS)

- Action 33.15: CGMS Members to establish a Task Force lead by NESDIS (Mitch Goldberg) with participation by EUMETSAT (Johannes Schmetz), JMA (Toshiyuki Kurino), CMA (Xu Jianmin) and assisted by the WMO Space Programme to prepare a draft Implementation Plan for GSICS by 1 July 2006 for review by CGMS Members by 1 August 2006 and approval at CGMS XXXIV.
By 2012, Global Environmental Observation System of Systems (GEOSS) data will be calibrated with a high quality for uses in the environmental data stewardship.

Resources:
- Develop FY-3 series, METOP-A IASI and GOME2 calibration algorithms which are part of cal/val system.
- Integrate validation efforts to form prototype cal/val system.
- Integrate DMSP, GOES and EOS into sensor performance monitoring.
- An inter-sensor calibration system for monitoring sensor performance.
- Individual POES/GOES sensor calibration.
- Develop NPP, NPOESS and GOES-R calibration algorithms which are part of Cal/Val.
- New cal/val sites deployed for GEOSS and GHG products.
- More product validation using existing validation sites will lead to robust products in NOAA operational products such as temp/water profiles in storm conditions.
- DMSP microwave sounding instrument bias and anomaly correction algorithms are incorporated. GOES and EOS.
- NOAA POES instrument on-board performance can be monitored with inter-sensor and intra-sensor calibration, radiative transfer simulations. The anomaly can be captured in near-real time and the instrument biases can be corrected.
- Establish a basic infrastructure for operational POES instrument calibrations through on-board calibrators and vicarious technique for quantifying instrument noise and linear and non-linear calibration.

Integrated cal/val enterprise system that delivers to WMO and other users SNO data.

Deficiency:

Resources:

OK