National Environmental Satellite, Data, and Information Service

NOAA Cal/Val Update

Changyong Cao and Mitch Goldberg

NOAA/NESDIS

Presented at the CEOS/WGCV26, Chiang Mai, Thailand, Oct. 31 – Nov. 3, 2006

Global Space-based Inter-Calibration System (GSICS)

•Sponsored by WMO and CGMS, GSICS will inter-calibrate instruments of the international constellation of operational LEO and GEO satellites, and tie these to common reference standards.

•Chaired by Mitch Goldberg, the Executive panel kicks off in Geneva, Switzerland Oct. 11-13, 2006.

•Inter-comparability will result in more accurate observations for weather, water, and climate applications.

•Current members include: Eumetsat, Russian Federation, Japan, China, and the US.

•NOAA/NESDIS becomes the GSICS Coordination Center.

GSICS Calibration Support Segments (CSS)

- The GSICS Calibration Support Segments (CSS) will be carried out by participating satellite agencies, national standards laboratories, major NWP centers, and national research laboratories. CSS activities are:
  - ✓ **Earth-based reference sites,** such as stable desert areas, long-term specially equipped ground sites, and special field campaigns, will be used to monitor satellite instrument performance.
  - ✓ **Extra-terrestrial calibration sources,** such as the sun, the moon, and the stars, will provide stable calibration targets for on-orbit monitoring of instrument calibration
  - ✓ **Model simulations** will allow comparisons of radiances computed from NWP analyses of atmospheric conditions with those observed by satellite instruments
  - ✓ **Benchmark measurements** of the highest accuracy by special satellite and ground-based instruments will help nail down satellite instrument calibrations
- WMO, CGMS, satellite agencies, national standards institutes, national data centers, major NWP centers, and national research laboratories will carry out the GSICS.

Achieving Satellite Instrument Calibration for Climate Change (ASIC^3)

- **ASIC^3 workshop was held at the National Conference Center in Virginia, May 16-18, as a follow-up to the 2002 Workshop.**

- **To formulate a national roadmap for developing calibration systems that will enable us to monitor long-term global climate change.**

- **Established goal for satellite-based climate monitoring system:**

  Design of climate observing and monitoring systems must ensure global, long-term climate records that are of *high accuracy, tested for systematic errors on-orbit, and tied to irrefutable international standards* such as those maintained in the U.S. by the National Institute of Standards and Technology.

Two overarching recommendations:

- Conduct satellite benchmark missions to create irrefutable records and calibrate other satellite sensors
- Establish a U.S. Joint Center for Satellite Instrument Calibration (JCSIC)

ASIC^3 workshop

- **Break-out groups: Infrared, UV, VIS/NIR, Microwave, Broadband, intercalibration, and national roadmap**
- **Each group identified**
  - Current status
  - Impediments to progress
  - Recommendations to accelerate progress
- **A complete Workshop Report is being prepared and will be published by NOAA.**
- **Workshop sponsored by NOAA, NASA, NIST, IPO, and the Space Dynamics Lab of USU.**

GOES-R cal/val

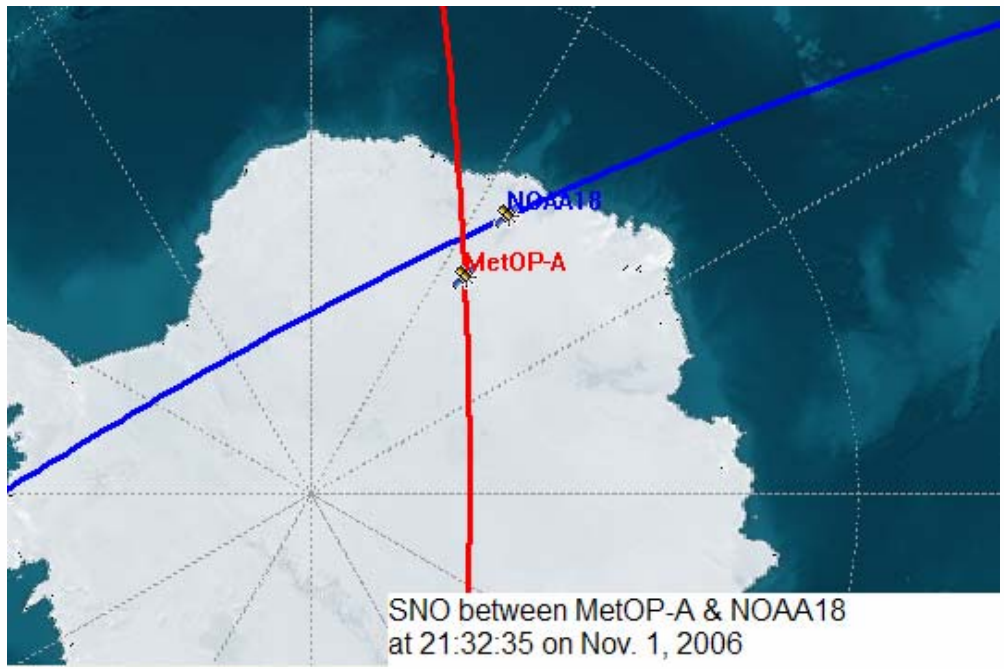
- GOES-R: first launch is scheduled for the 2012 time frame.

- GOES-R payloads:
  - Advanced Baseline Imager (ABI) with 16 channels (0.47 – 13.3 um) - on schedule
  - Hyperspectral Environmental Suite (HES) – cutback
  - GEO Lightning Mapper (GLM)
  - Space Environment In-Situ Suite (SEISS)
  - Solar Imaging Suite (SIS)
  - Extreme Ultraviolet Sensor (EUS)

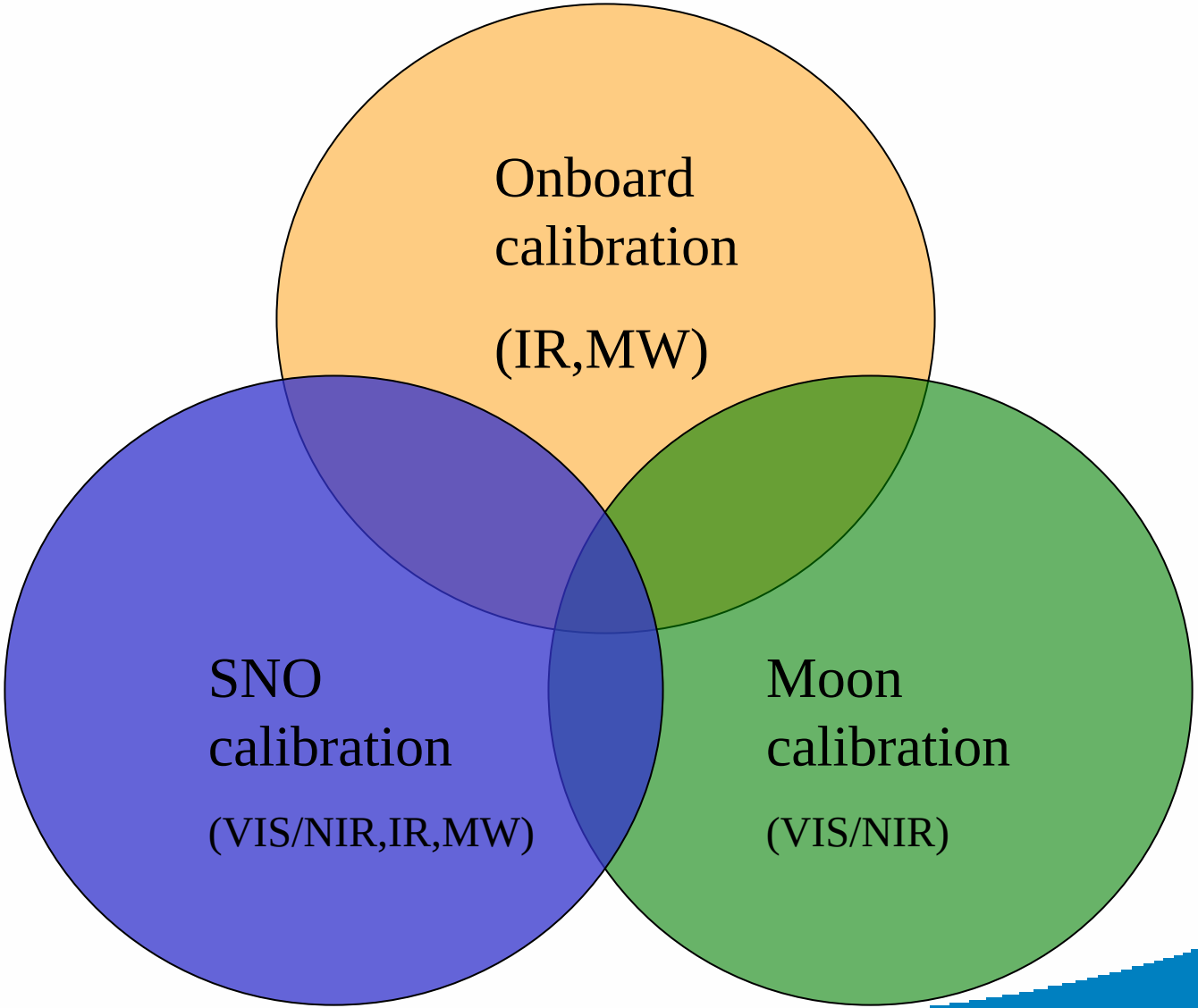
- Risk reduction study in progress.
- Cal/Val requirement analysis initiated; Cal/Val workshop to be held in Spring, 2007.
- Risk reduction studies: onboard calibration for the VIS/NIR channels.

MetOP-A Cal/Val

- NOAA instruments on MetOP-A: AVHRR, HIRS, and AMSU
- AMSU and AVHRR VIS/NIR channels are switched on. Infrared channels/instruments outgassing.
- MetOP-A Cal/Val started at NOAA.
- SNOs between MetOP-A and NOAA-18 are routinely produced for intercalibration



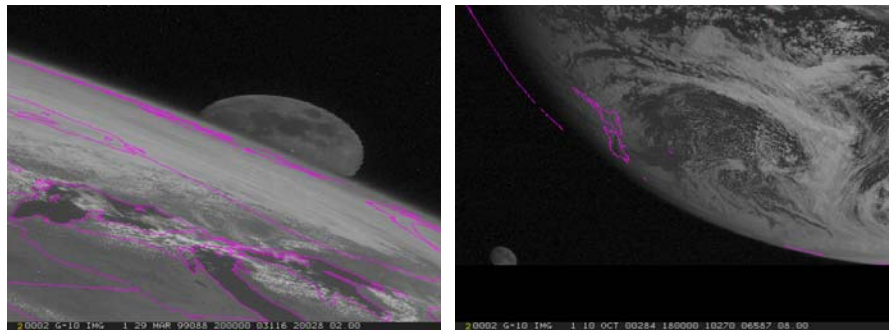
Enabling calibration methodologies at NOAA/NESDIS



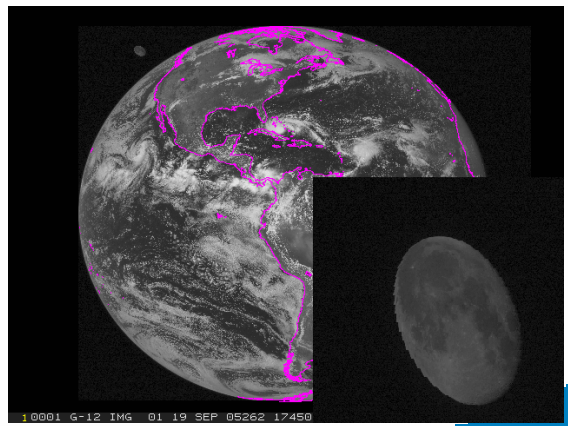
Lunar Calibration of the Solar Reflective Band

-Risk Reduction for GOES-R using Current GOES

- Implemented routine operational lunar view for the calibration of current GOES
- Preliminary study has demonstrated a ~3% capability in stability trending
- Very useful for GOES-R moon calibration & early preparation
- Work with USGS, NASA, NIST to further improve accuracy

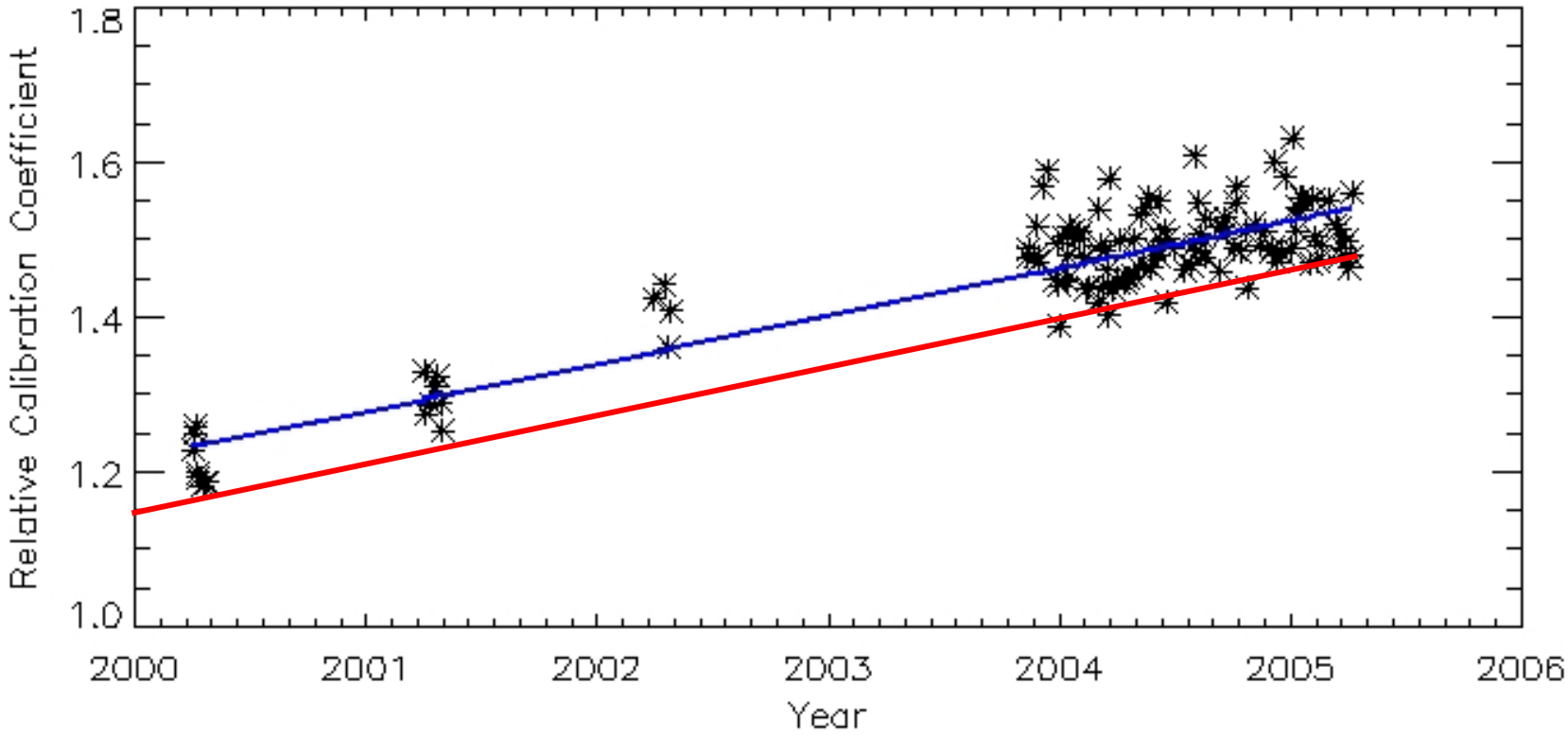


Unscheduled moon views



Scheduled moon view

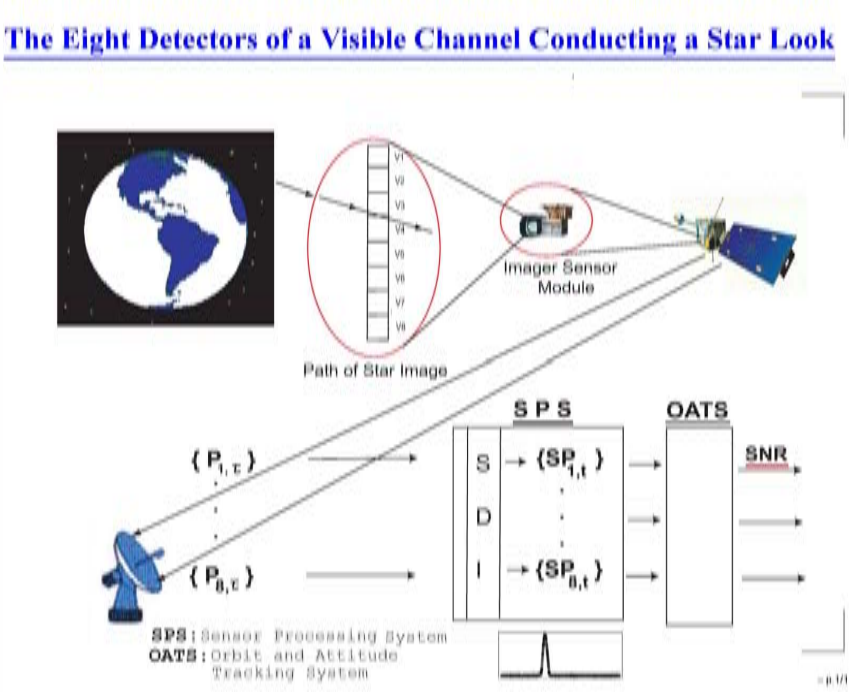
Comparison with MODIS/GOES inter-calibration

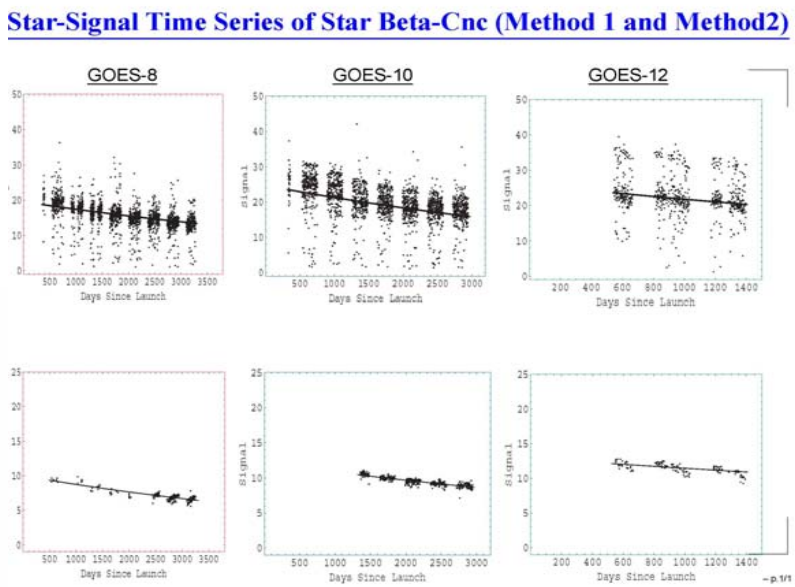


Degradation Rate for the Period: 4.4%/yr (MODIS) vs. 4.5%/yr (Moon)

Accuracy ~5% Precision ~3.5% **(preliminary)**

Comparison with Star Calibration

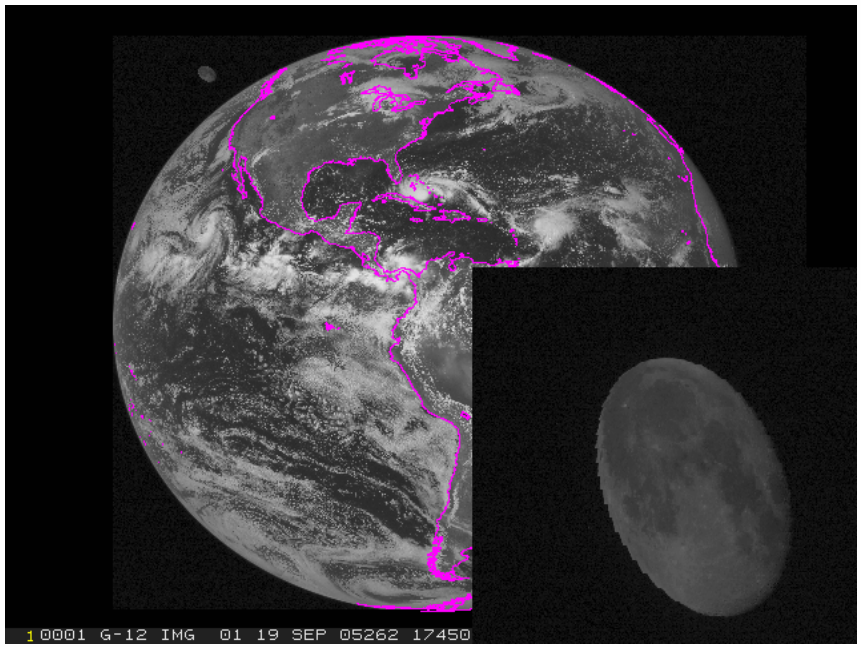




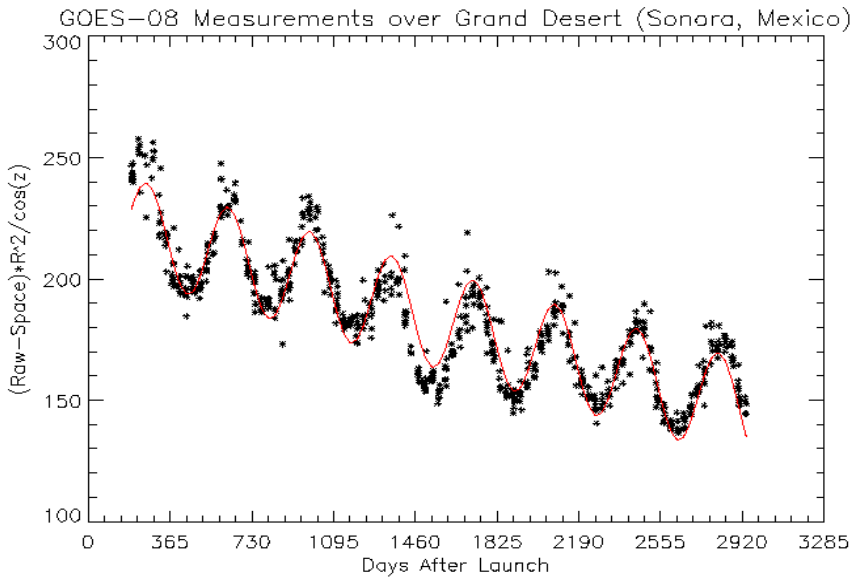
Mar 1998 – Apr 2006: 5.1%/year

Jan 2001 – Apr 2006: 3.9%/year

Comparison with Desert Calibration



GOES-8 calibration using Sonora Desert



Jul 1999 – Jun 2003: 3.5%/year

97-98 El Niño may be a factor

On-orbit calibration traceability and standards

Climate requirements are challenging the current state of the art in **on-orbit** calibration. **Climate quality** on-orbit calibration source appears to be the key for meeting the absolute calibration requirements. What are our options ?

Lunar calibration:

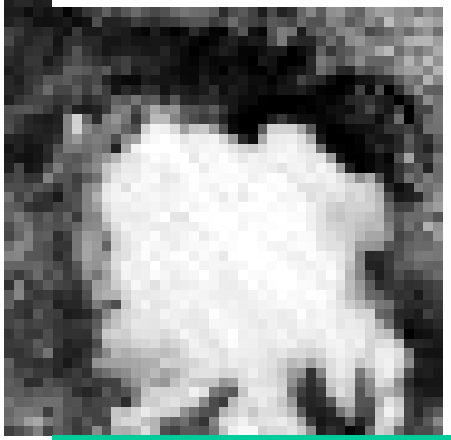
- The lunar surface is considered photometrically stable to < 10^{-8} per year (USGS).
- Moon calibration has been studied extensively by NASA for most major research instruments. Current conclusion: moon is excellent for stability trending but not good **yet** for absolute calibration.
- The USGS ROLO model has been used extensively but it has a number of limitations.
- NOAA has implemented operational moon calibration for GOES and is very interested in working with NIST, USGS, and NASA to develop the moon standard for on-orbit calibration.
- This is highly relevant to both GEO task DA-06-02(develop a GEO data quality assurance strategy), and WMO's GSICS (extra-terrestrial calibration sources).

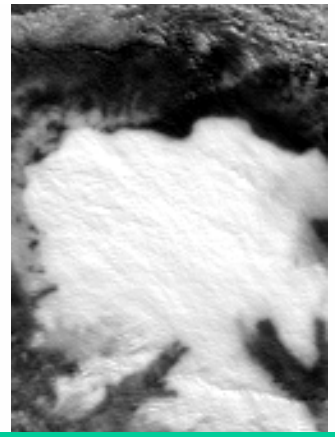
- Questions for CEOS/WGCV/IVOS:
  - What needs to be done to establish the moon as an absolute standard?
  - Is a better lunar model such as LUSI the answer?
  - Interest from other agencies?
  - Explore moon calibration in the infrared, microwave, and UV?

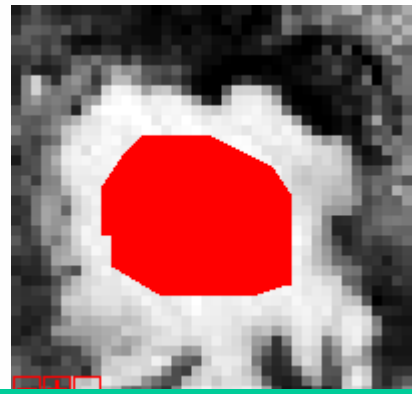
Vicarious calibration using stable earth targets

IVOS has done a tremendous amount of work and will contribute greatly to **GSICS and GEO**

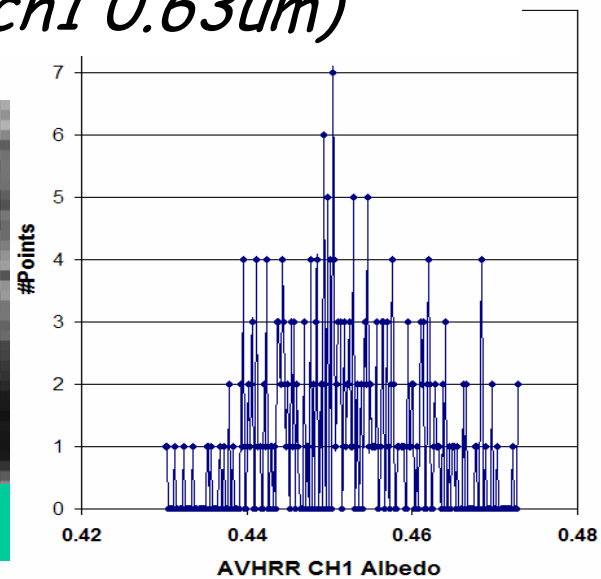
Progress in using the SNO (Simultaneous Nadir Overpass) method: AVHRR/MODIS comparison (ch1 0.63um)







AVHRR/N18 MODIS/Aqua Sample area

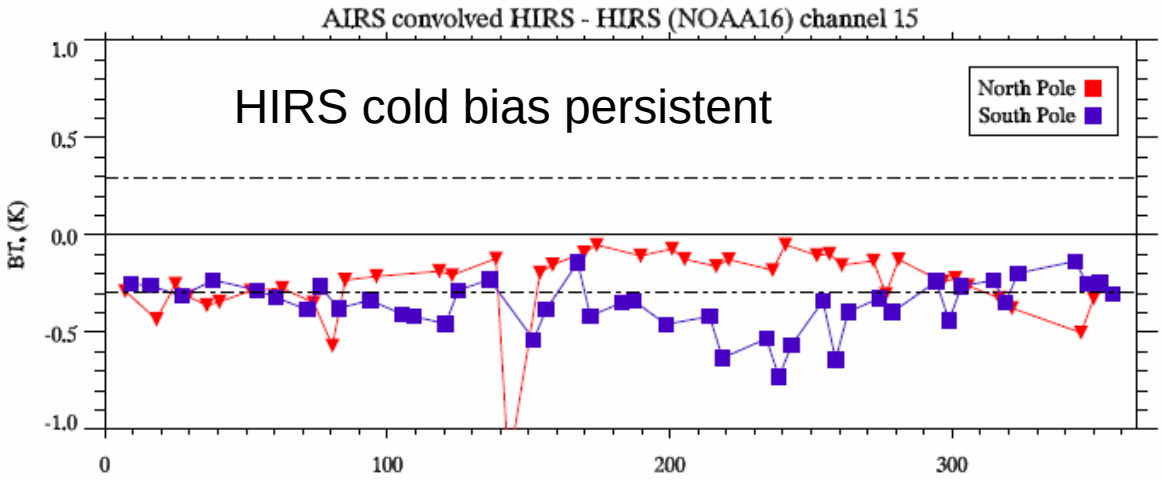


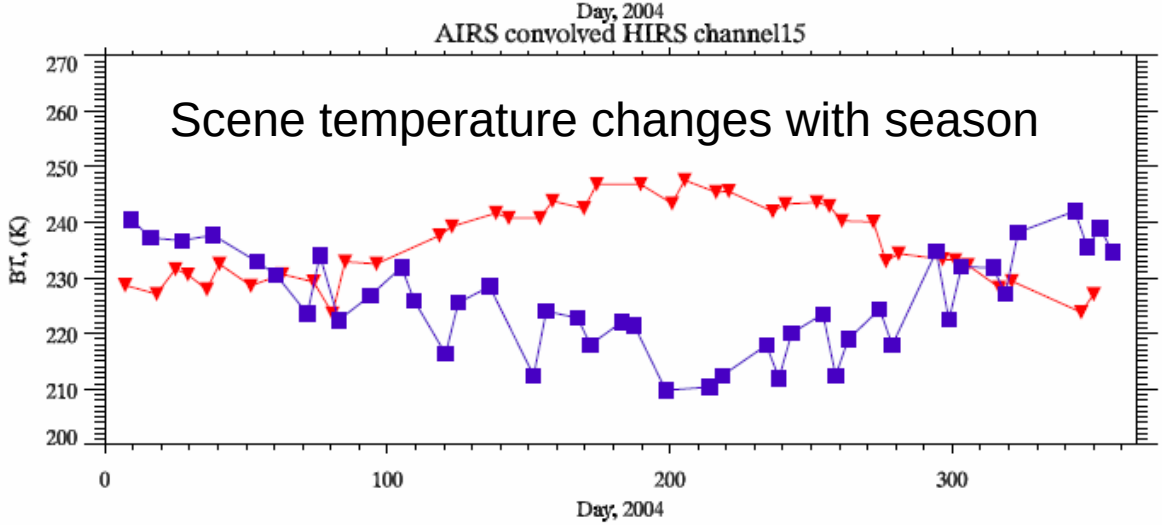
Reflectance	Min	Max	Mean	Stdev
Band 1 AVHRR	0.4301	0.4728	0.4523	0.008894
Band 1 MODIS	0.4800	0.5401	0.5113	0.012135

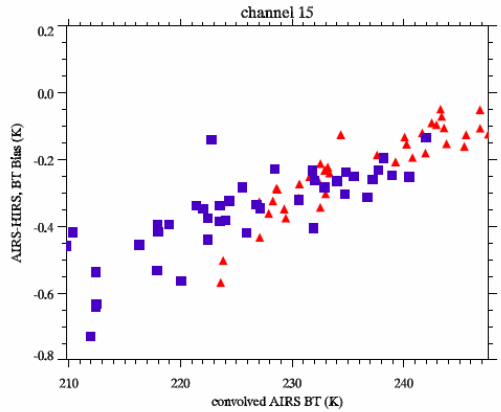
For the sample area with 205 samples, the difference between MODIS and AVHRR reflectance is about **13%, at 99%** confidence level with uncertainty **+/-0.4%**. Spectral differences is not the main contributor to the this discrepancy, based on radiative transfer calculations.

Lat=79.82, SZA=82.339996, cos(sza)=0.13, TimeDiff 26 sec, Uncertainty due to SZA diff 0.1%,

Inter-comparison between AIRS and HIRS radiances





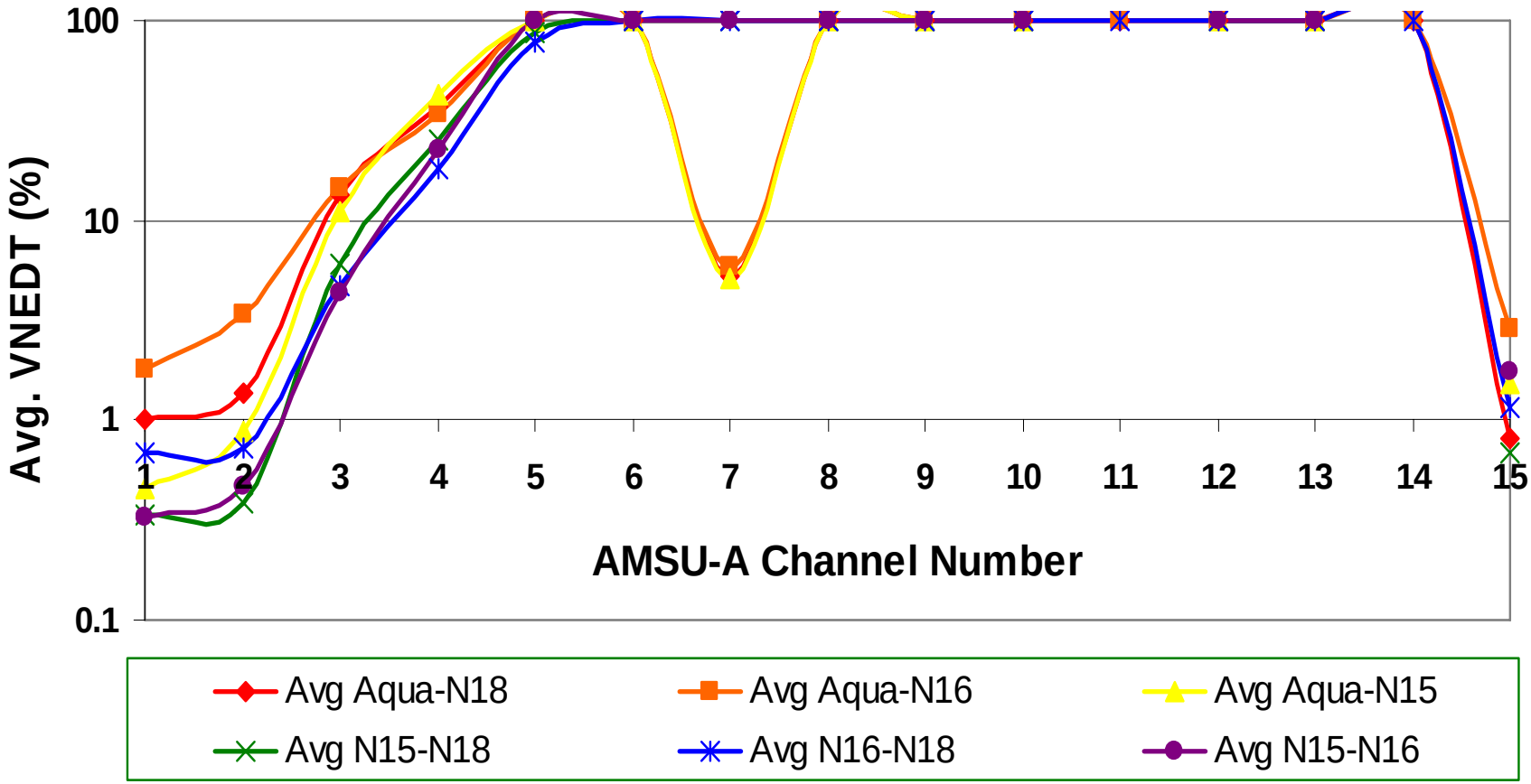


- Bias is scene temperature dependent
- Possible causes: nonlinearity or spectral response uncertainties?
- Without correcting for HIRS nonlinearity, HIRS would be warmer by +0.1K @250K

SNO Uncertainty Analysis for Microwave Sounders

Percentage of SNO Bias Variance due to NEDT

$$V_{NEDT} = 100 \times \sum_{N=1}^{N_{sno}} \left(\frac{\sigma^2_{NEDT}(Sat1) + \sigma^2_{NEDT}(Sat2)}{\sigma^2_{N}(Sat1 - Sat2)} \right) \Big/ N_{sno}$$



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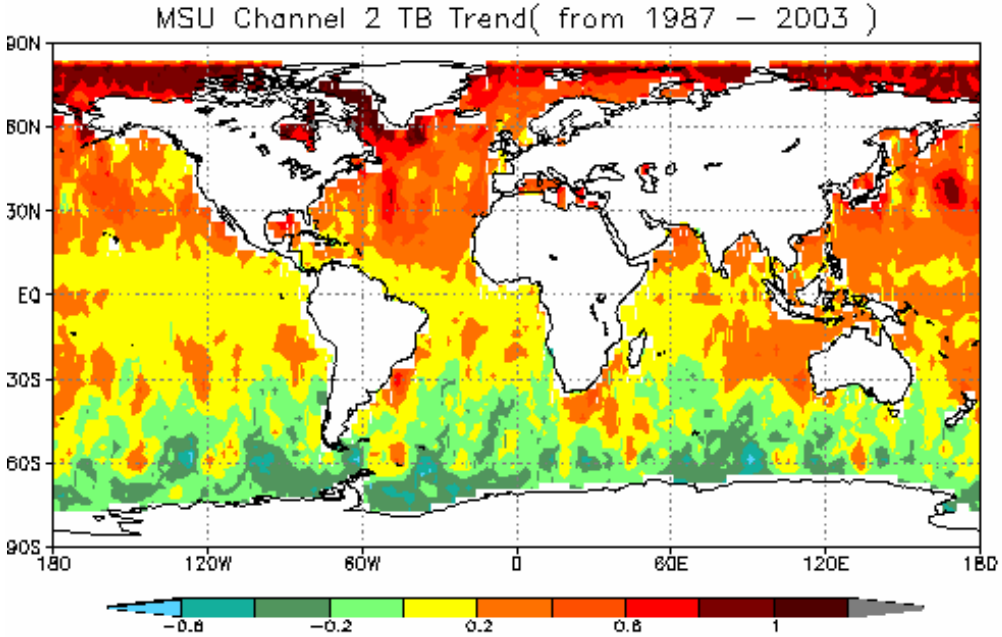
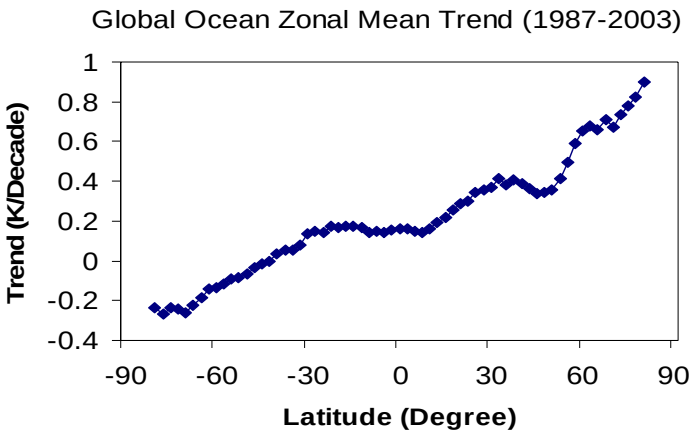
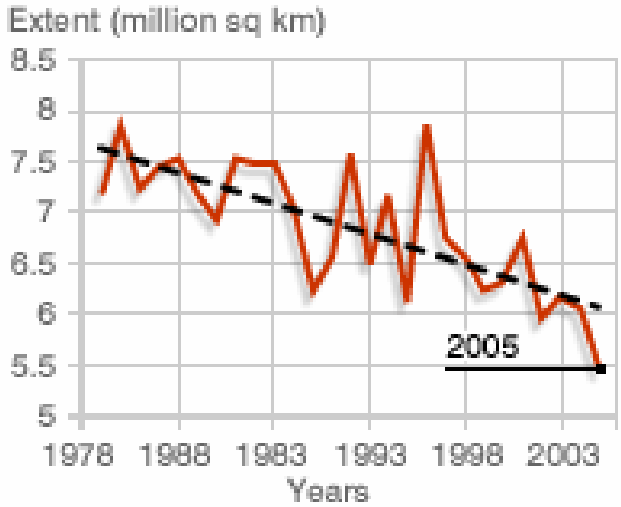
Calibration for Climate Change Detection

MSU channel 2 recalibration using the SNO method





ARCTIC SEA ICE EXTENT - SEPTEMBER TREND, 1978-2005
(http://nsidc.org/news/press/20050928_trends_fig1.html)

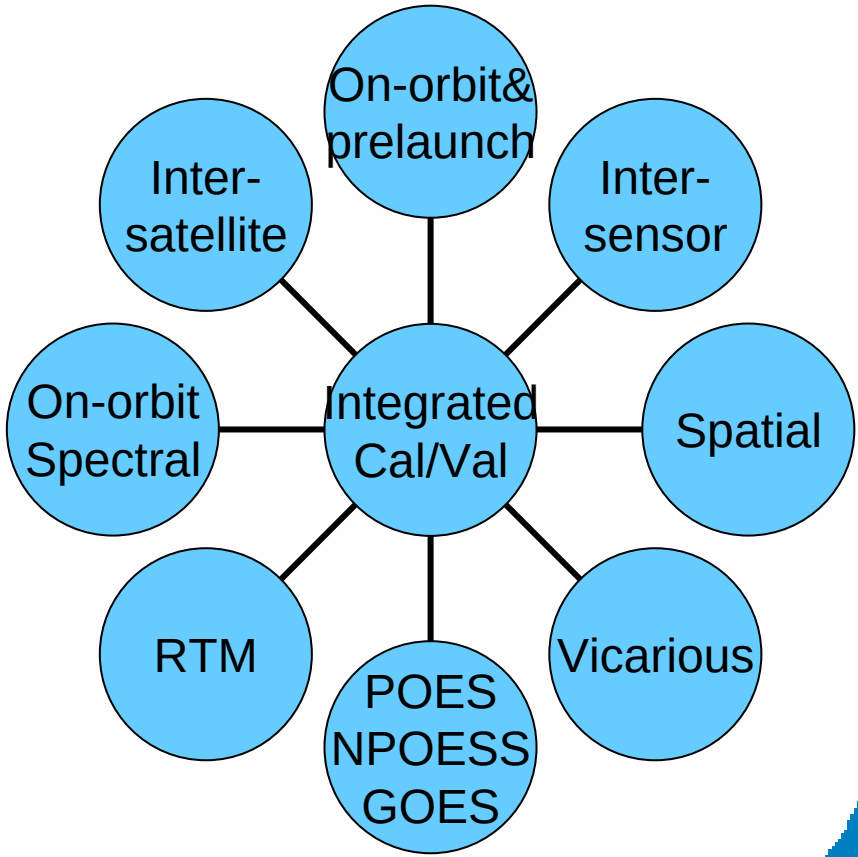


SOURCE: National Snow and Ice Data Center (NSIDC)

The straight line tracks a more than 8% decline per decade
(http://nsidc.org/news/press/20050928_trends_fig1.html)

Integrated Cal/Val System

- Independently verify radiances by inter-satellite calibration using the SNO/SCO method
- Monitor instrument performance with an on-line instrument performance trending system
- Develop inter-sensor calibration capabilities, which includes the intercomparison between imager and sounder channels, and inter-channel calibration to monitor the radiometric and spectral calibration stability in the longterm.
- Integrate our vicarious calibration capabilities, including using the desert sites for visible/near-infrared channels, and using the mid and upper atmosphere to check for scan asymmetry of sounding channels.
- Integrate state-of-the-science radiative transfer models, which will allow us to resolve spectral induced biases, and perform regular validations at selected sites, such as the ARM sites.
- Establish calibration consistency and traceability among NPOESS, POES, and GOES.



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Web Interface to the Integrated Cal/Val System

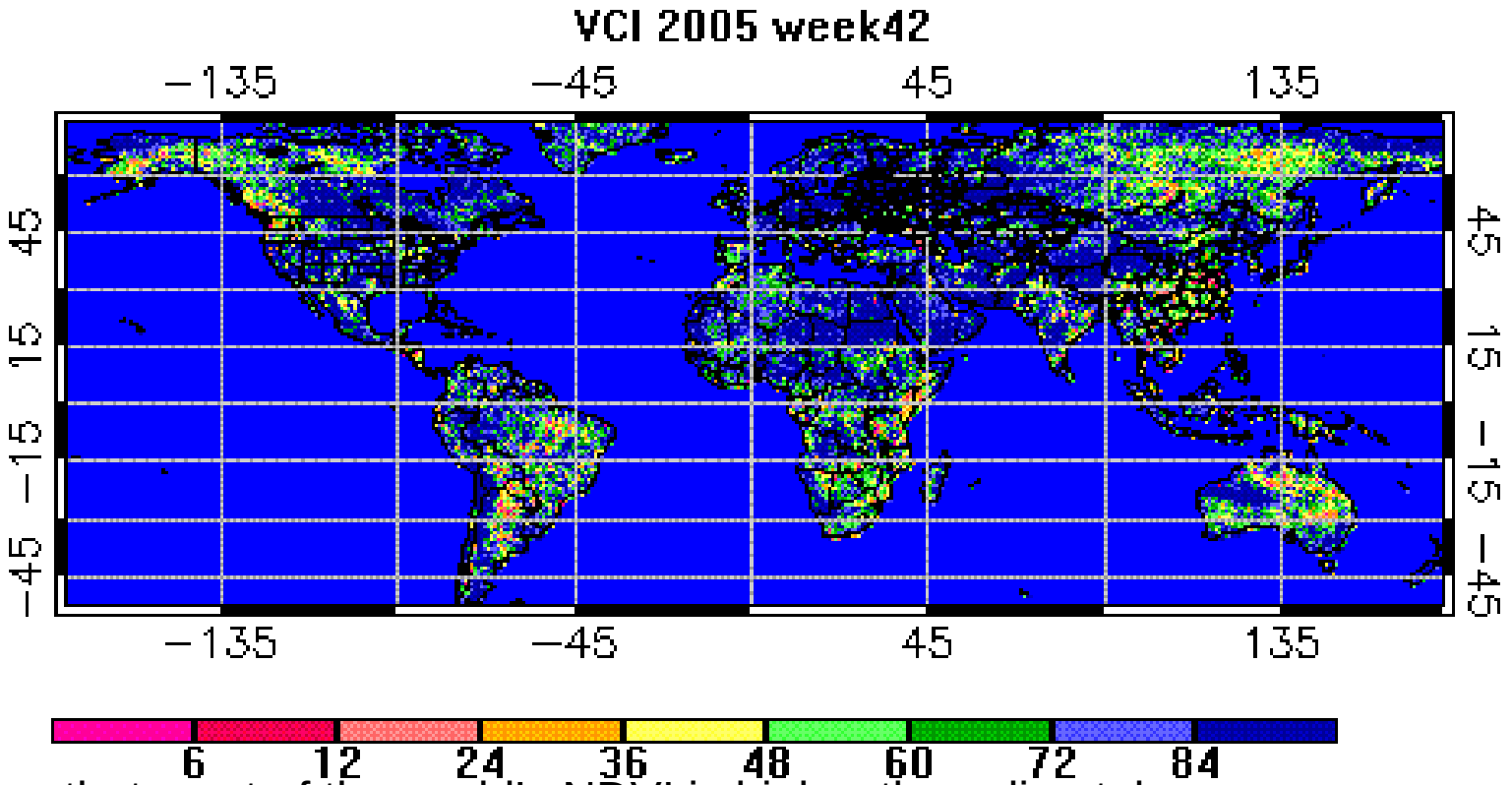
NOAA chaired calibration sessions at conferences

- ASIC^3 (Achieving Satellite Instrument Calibration for Climate Change), May, 2006, NCC, VA
- AGU (American Geophysical Union), Spring, 2006, Baltimore
- WPGM (Western Pacific Geophysics Meeting), July, 2006, Beijing. Visit to Dunhuang and Qinghai calibration sites
- SPIE (Society for Optical Engineering), Aug. 2006, San Diego
- Calcon (Technical Conference on Characterization and Radiometric Calibration for Remote Sensing), Oct. 2006, Logan, Utah; Moon calibration workshop by USGS.

Dunhuang calibration site

USGS ROLO

AVHRR-based VCI, mid-October 2005, NOAA-18
(Deviation of NDVI from Climatology)



- Image indicates that most of the world's NDVI is higher than climatology
- This is not correct
- It is suspected that AVHRR-3 is not calibrated properly

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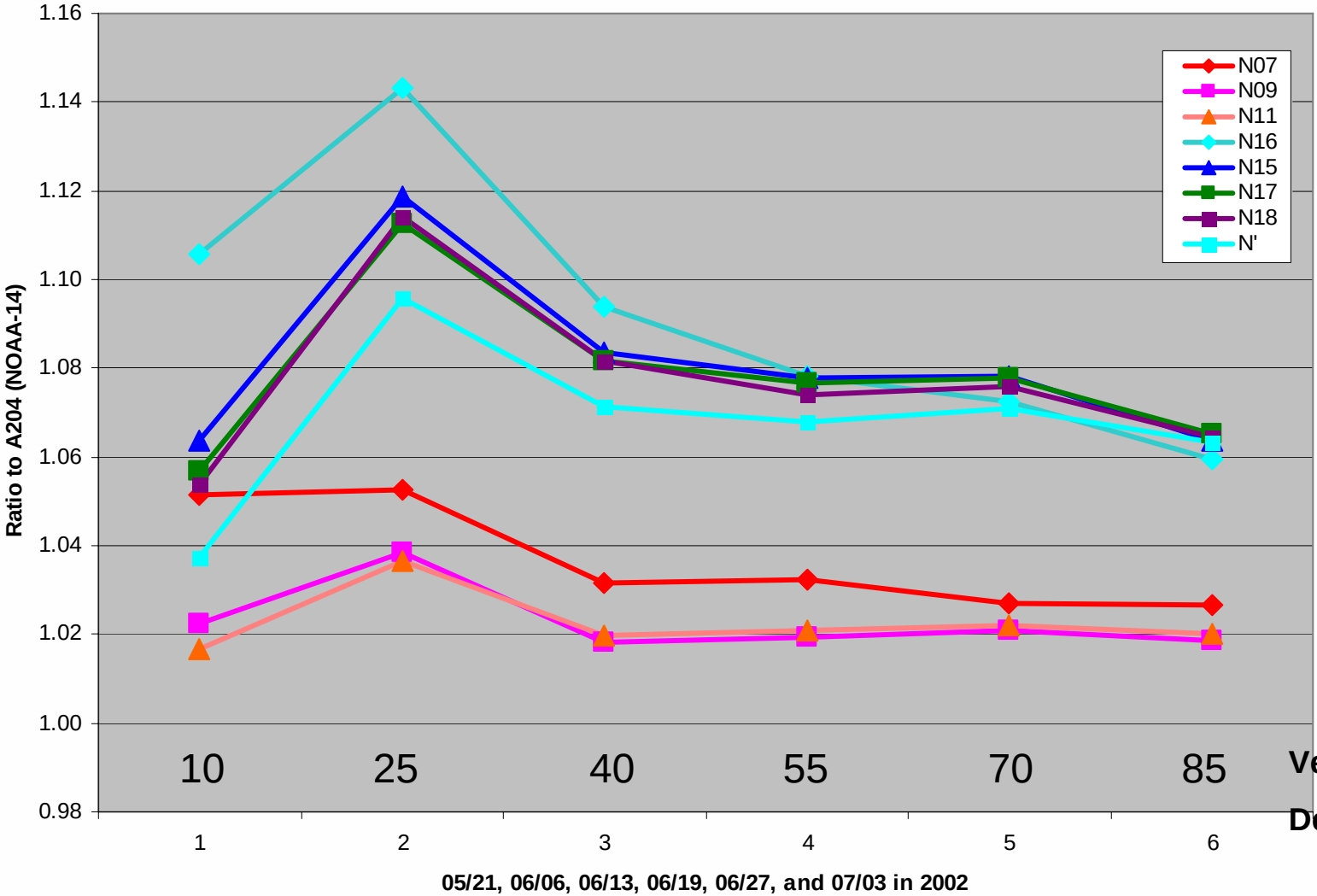
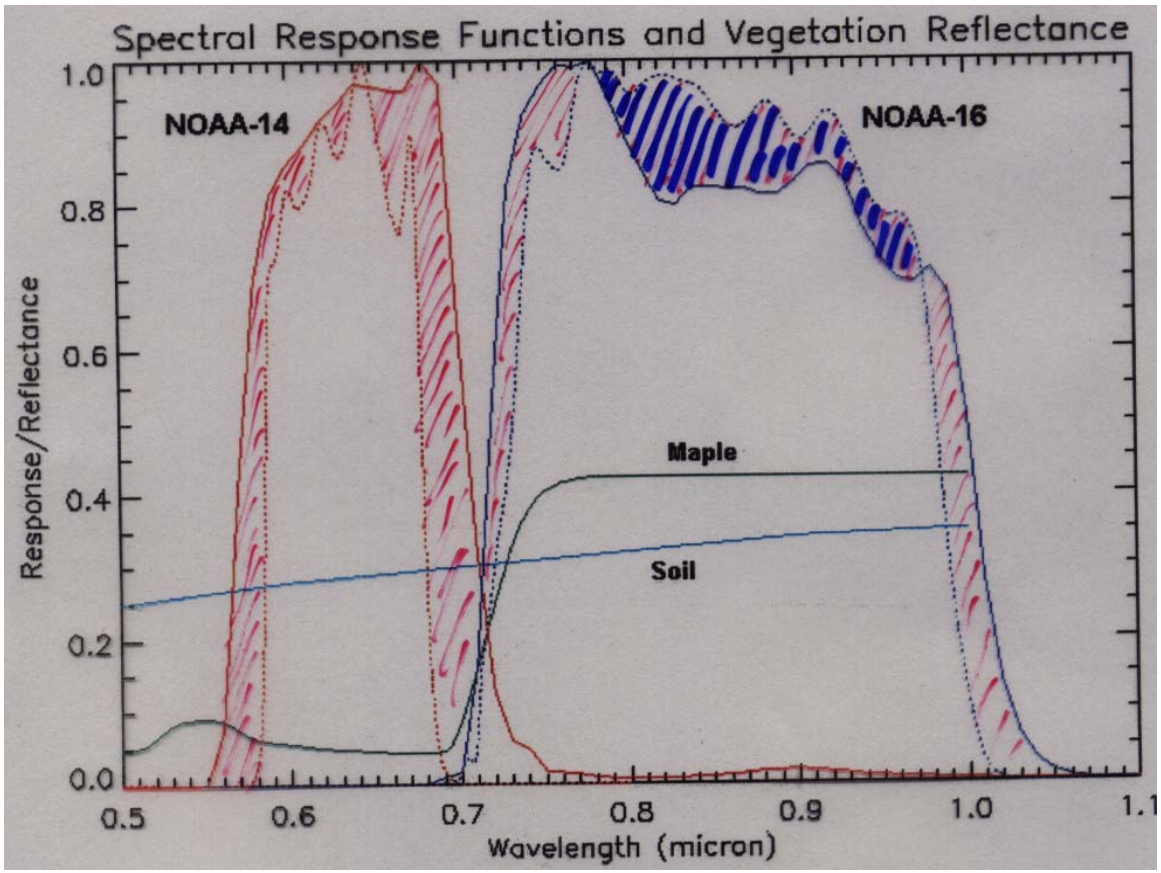
NDVI of a Corn Field Relative to NOAA-14 Estimate
(due to differences among sensors' spectral response functions)



Difference in response function between AVHRR-2 (NOAA-14) and AVHRR-3 (NOAA-16)



Summary

- A very active and productive year for satellite instrument calibration at NOAA.
- Many opportunities and challenges have been identified in support of climate quality calibration.
- On-orbit traceability and standards are needed to support several program initiatives.
- NOAA cal/val teams are interested in working with the CEOS subgroups to leverage existing cal/val efforts.

Acknowledgements

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- US Geological Survey
- Contributors to this report include:
  - Dr. Fuzhong Weng
  - Dr. Fred Wu
  - Dr. Robert Iacovazzi
  - Dr. Felix Kogan
  - Dr. Chengzi Zou
  - Dr. George Ohring