

Summary of ASIC³ Workshop

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CLARREO Workshop
University of Maryland
July 17, 2007

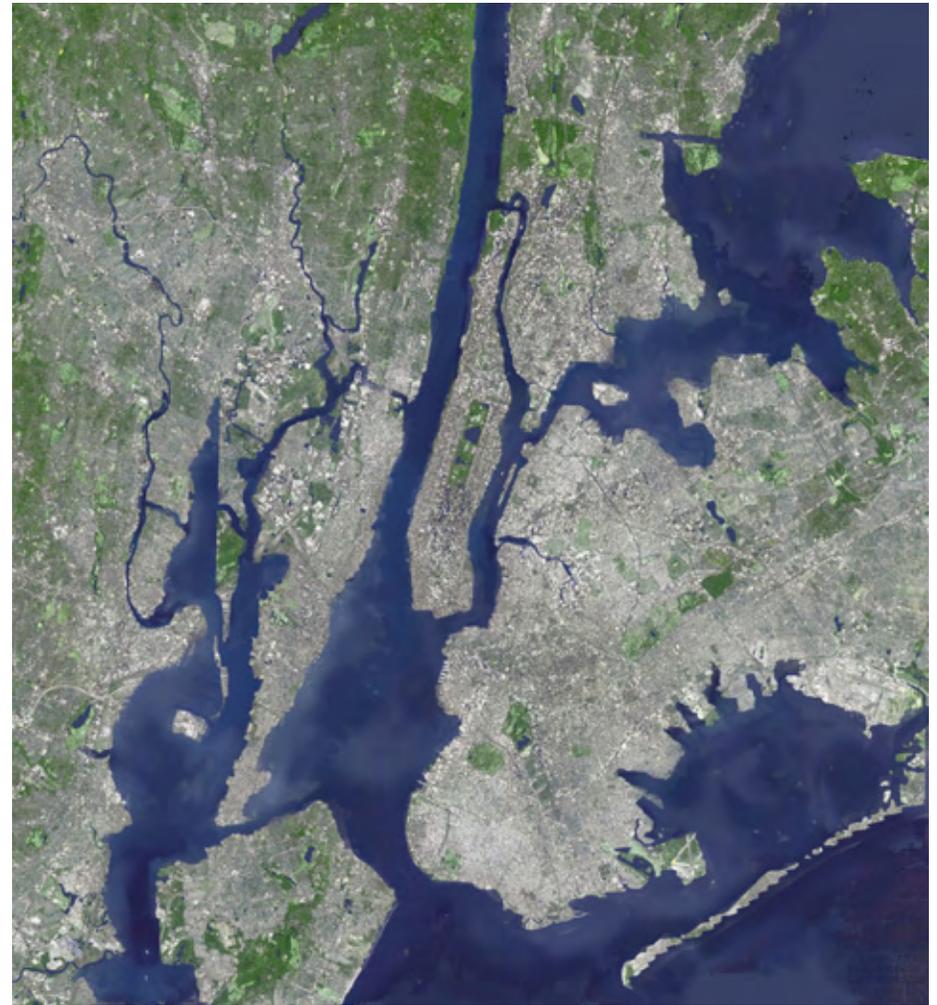
The Questions

- Is the Earth's climate changing?
- If so, at what rate?
- Are the causes natural or human-induced?
- What will the climate be like in the future?



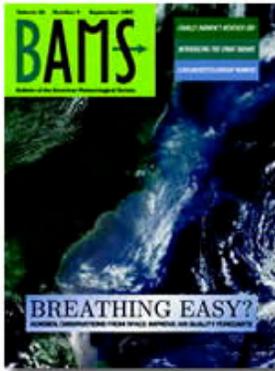
New York City: Before and After Global Warming

(After Anderson, 2006)



Background

MEETING SUMMARIES



Satellite Instrument Calibration for Measuring Global Climate Change Report of a Workshop

BY GEORGE OHRING, BRUCE WILCOX, ROY SPENCER, BILL EMERY, AND RAJU DATLA

Is the earth's climate changing? If so, at what rate? Are the causes natural or human induced? What will the climate be like in the future? These are critical environmental and geopolitical issues of our times. Increased knowledge, in the form of answers to these questions, is the foundation for developing appropriate response strategies to global climate change. Accurate global observations from space are a critical part of the needed knowledge base.

Measuring the small changes associated with long-term global climate change from space is a daunting task. For example, the satellite instruments must be capable of observing atmospheric and surface temperature trends as small as 0.1°C decade⁻¹, ozone changes as little as 1% decade⁻¹, and variations in the sun's output as tiny as 0.1% decade⁻¹.

The importance of understanding and predicting climate variation and change has escalated significantly in the last decade. In 2001, the White House requested that the National Academy of Sciences (NAS) National Research Council (NRC) (NRC 2001a)

WORKSHOP ON SATELLITE INSTRUMENT CALIBRATION FOR MEASURING GLOBAL CLIMATE CHANGE

Who: About 75 scientists specializing in satellite calibration and researchers who develop and analyze long-term satellite data used to recommend instrument improvements to accurately measure Earth's changing climate.

When: 12–14 November 2002
Where: College Park, Maryland

review the uncertainties in climate change science. One of the three key recommendations from the NRC's report is to "ensure the existence of a long-term monitoring system that provides a more definitive observational foundation to evaluate decadal- to century-scale changes, including observations of key state variables and more comprehensive regional measurements." To accelerate federal research and reduce uncertainties in climate change science, in June 2001, President George W. Bush created the Climate Change Research Initiative (CCRI).

To develop recommendations for improving the calibration of satellite instruments to meet the challenge of measuring global climate change, the National Institute of Standards and Technology (NIST), the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA) organized a workshop at the University of Maryland Inn and Conference Center, College

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Satellite Instrument Calibration for Measuring Global Climate Change



Report of a Workshop at the
University of Maryland Inn and Conference Center
College Park, MD

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

ASIC³ is a follow-on workshop to the 2002 workshop “Satellite Instrument Calibration for Measuring Global Climate Change”

2002 Workshop

- Define absolute accuracies and long-term stabilities needed to detect expected trends
- Scales of interest
 - Spatial: Global
 - Temporal: Decadal



2002 Workshop focused on observational requirements

How to Estimate Expected Decadal Climate Change?

**The starting point for instrument specifications:
What are we trying to measure?**

Three approaches:

- Climate model predictions
- Changes in climate forcing or feedback comparable to CO₂ forcing
- Trend similar to those observed in past decades

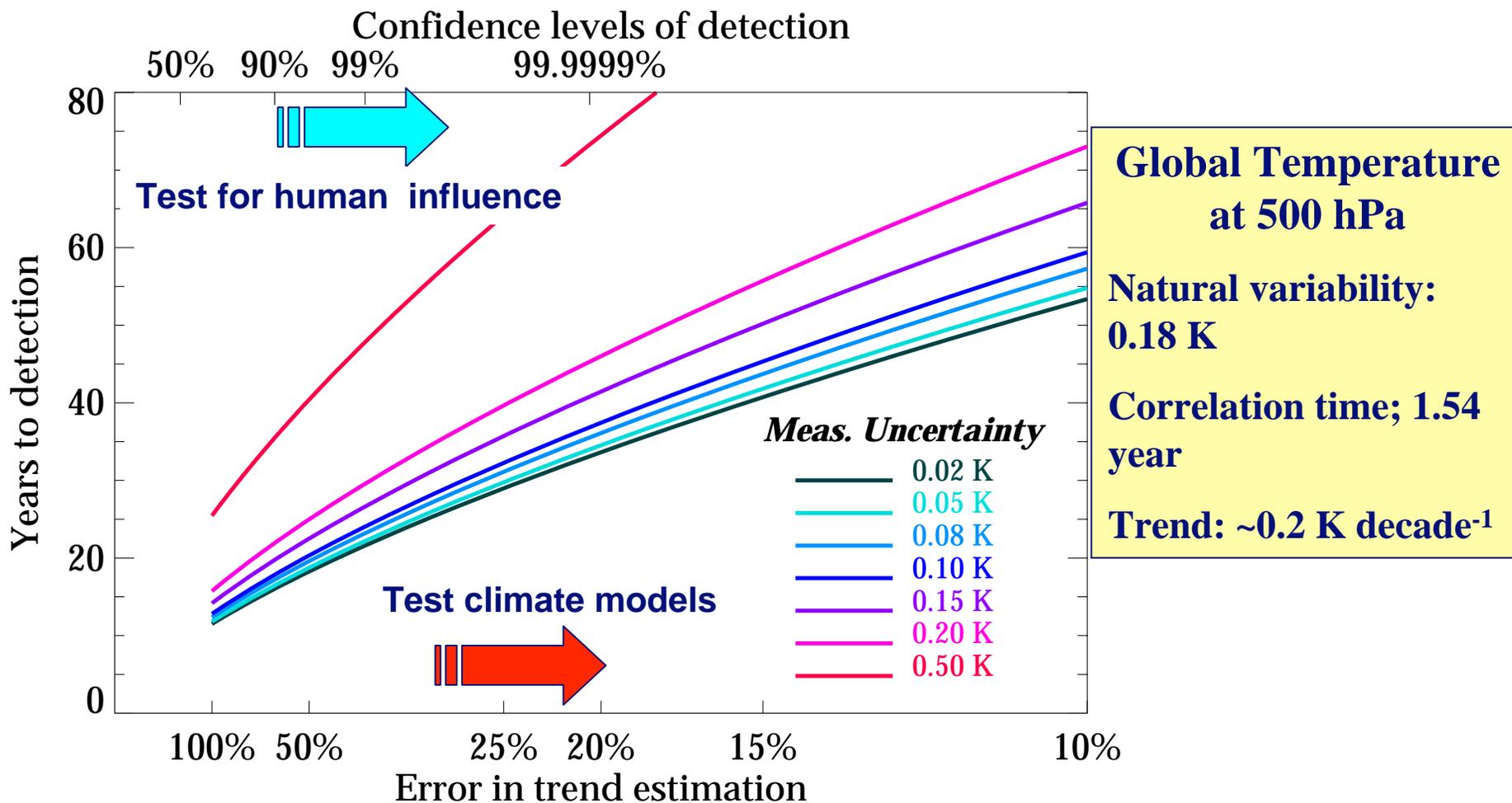
Estimated Expected Decadal Changes

Solar Irradiance	0.3 W/m ²
Reflected solar radiation	1.5 W/m ²
Outgoing longwave radiation	1.0 W/m ²
Atmospheric temperature	0.2 °C
Sea surface temperature	0.2 °C
Water vapor	1.3 %
Precipitation	0.015 mm/hr
Cloud amount	0.015

Satellite instruments should have accuracies or stabilities that are a fraction of these climate changes....Tough measurement requirements

Measurement Uncertainty & Detection Times

(Leroy, S.S., J.G. Anderson, and G. Ohring, 2007: Climate signal detection times and constraints on climate benchmark accuracy requirements. *J. Climate*, in press.)





Achieving Satellite Instrument Calibration for Climate Change (ASIC³)

Report of a Workshop Organized by
National Oceanic and Atmospheric Administration
National Institute of Standards and Technology
National Aeronautics and Space Administration
National Polar-orbiting Operational Environmental Satellite System-Integrated Program Office
Space Dynamics Laboratory of Utah State University

At the National Conference Center, Lansdowne, VA, May 16-18, 2006

DRAFT
July 2007

Edited by George Ohring

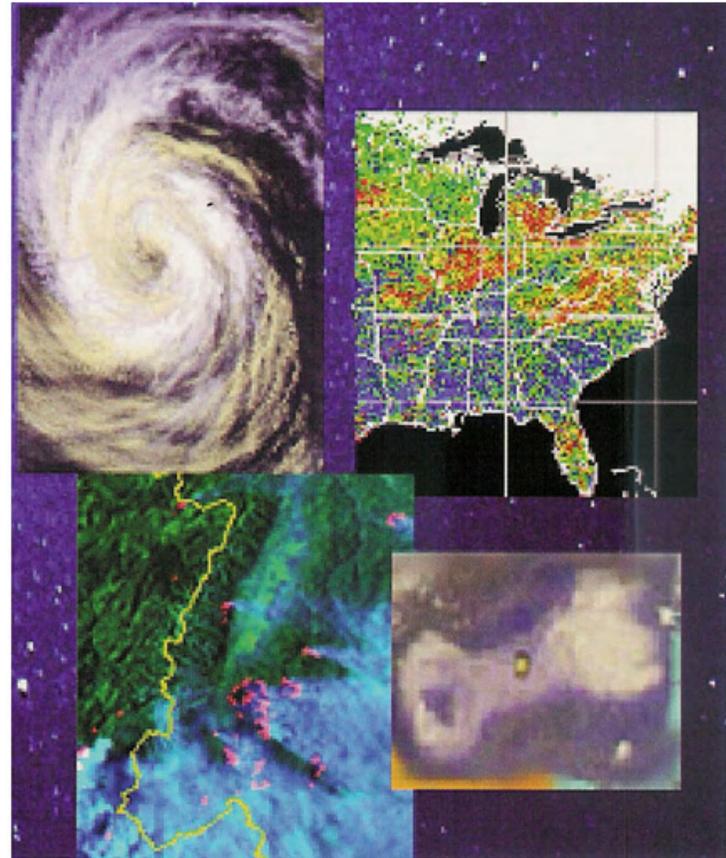
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ASIC³ Workshop

- Primary workshop objective
 - Formulate a national roadmap for developing calibration systems to monitor long-term global climate change
- 100 experts
 - Climate analysis
 - Satellite instrument calibration
 - Metrology
 - Remote Sensing



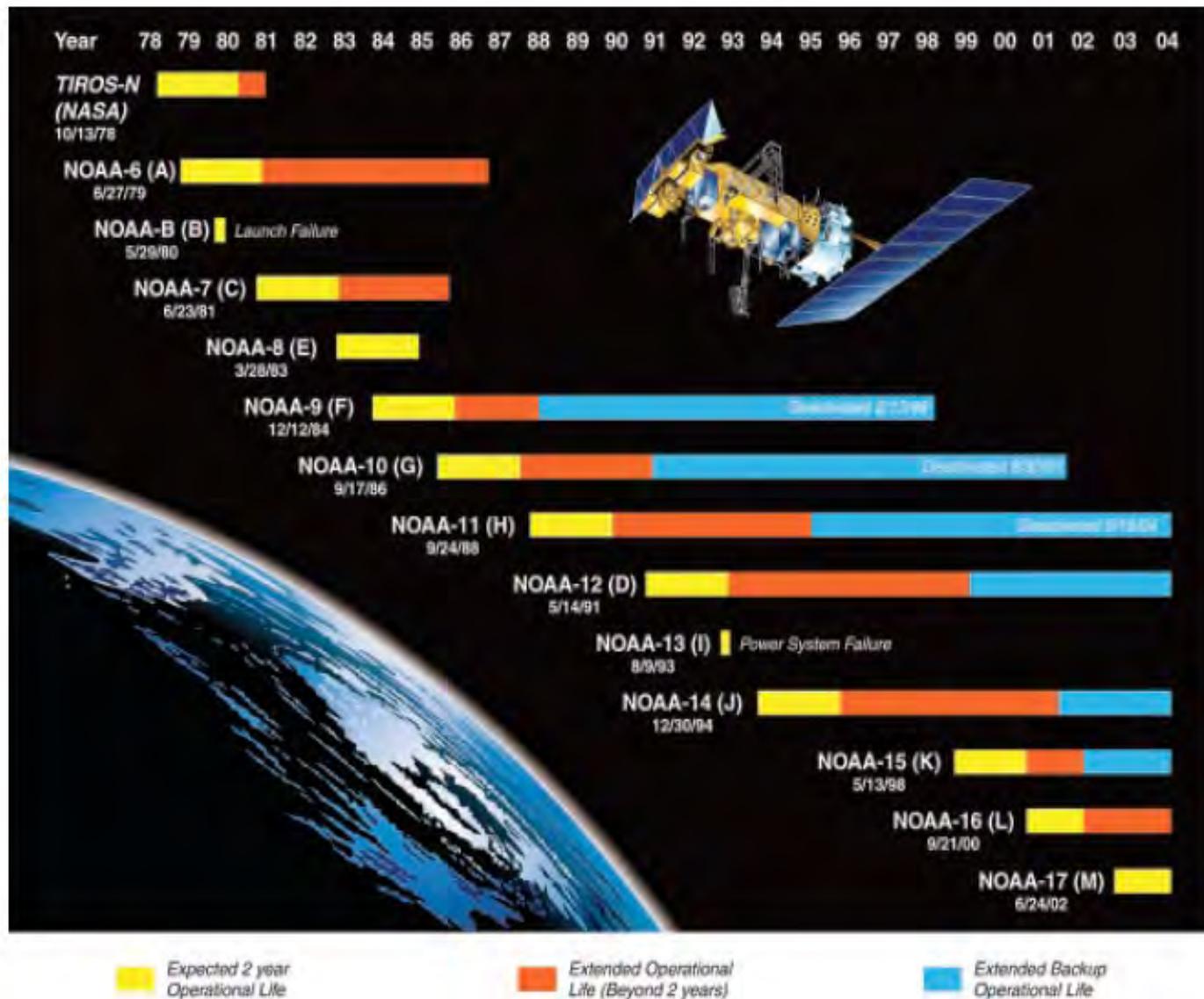
Why Now?

- **Climate change is a compelling issue, affecting all of humanity**
- **The magnitude and impact of climate change are not clearly understood**
 - Climate is not presently observed with sufficient accuracy to establish a climate record that is tested and trusted
 - Climate observations are not in place that can adequately constrain climate model predictions.

The Problem

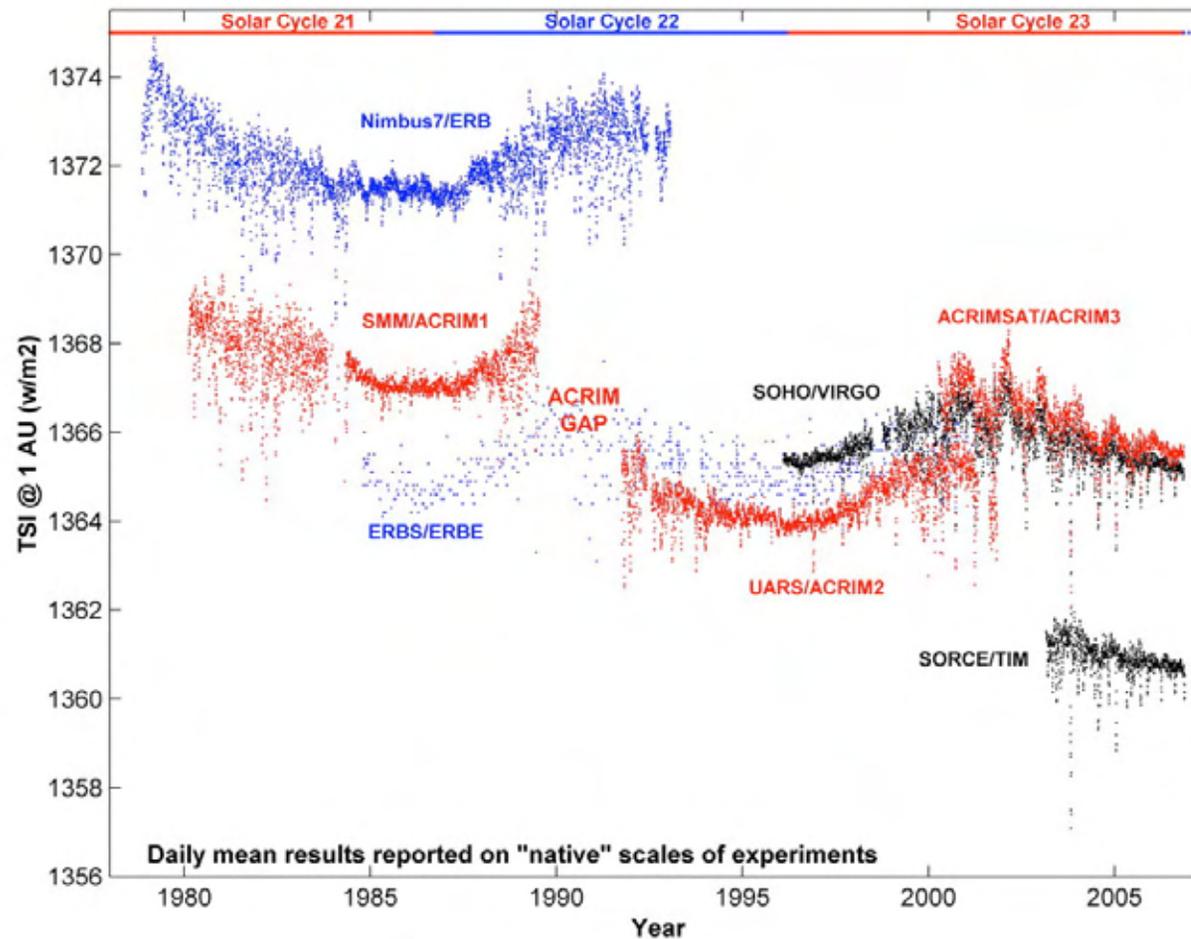
- Small climate trends
- Satellite system problems
 - Lack of on-orbit traceability to international standards (SI)
 - Sensors degrade in space
 - Time series produced by stitching together data from sequence of satellite instruments
 - Orbit drift

Climate Data Records Constructed from Series of Overlapping Satellites



Monitoring Solar Irradiance

TOTAL SOLAR IRRADIANCE MONITORING RESULTS: 1978 to Present

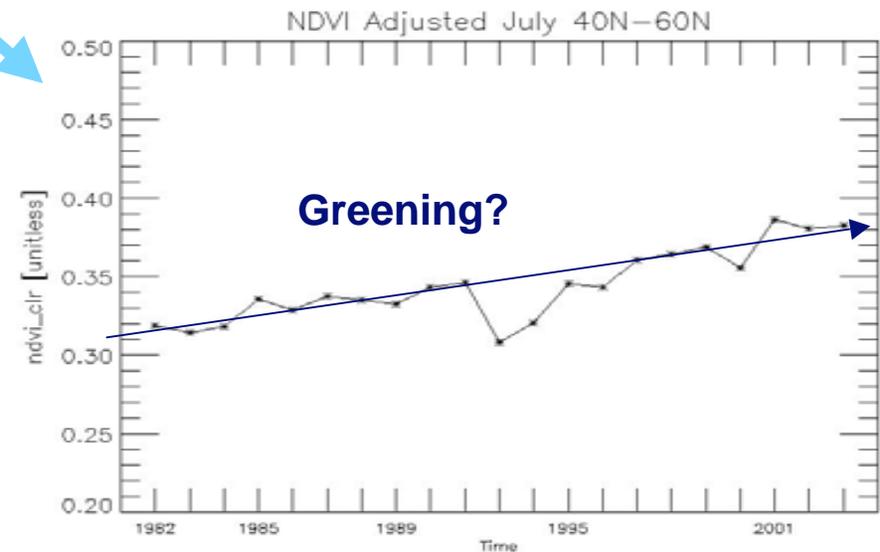
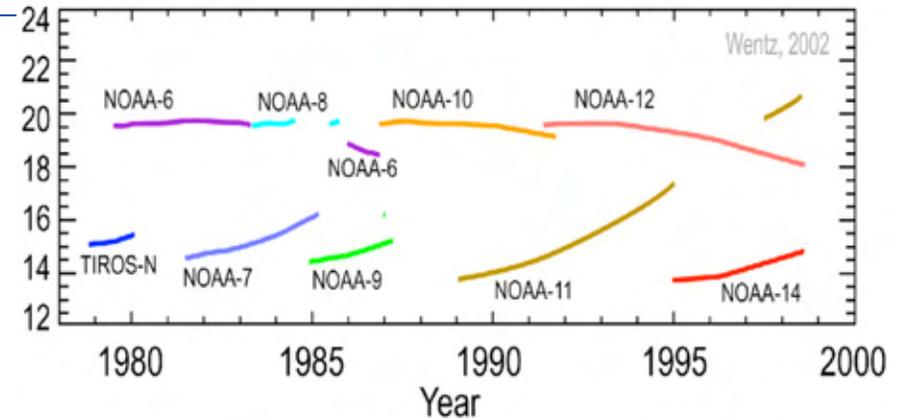


RC Willson, earth_obs_fig1 11/30/2006

We don't know the absolute solar forcing to better than 5 W/m²!

Is the Earth Greening?

- NOAA's AVHRRs have been used to construct a time series of Vegetation Index that indicates a greening Earth



(After Heidinger)

Because of uncertainties in calibration and intercalibration of the different satellites we don't know if the Earth's vegetation is really increasing

Goal for Climate Monitoring Systems

Climate monitoring systems must ensure:

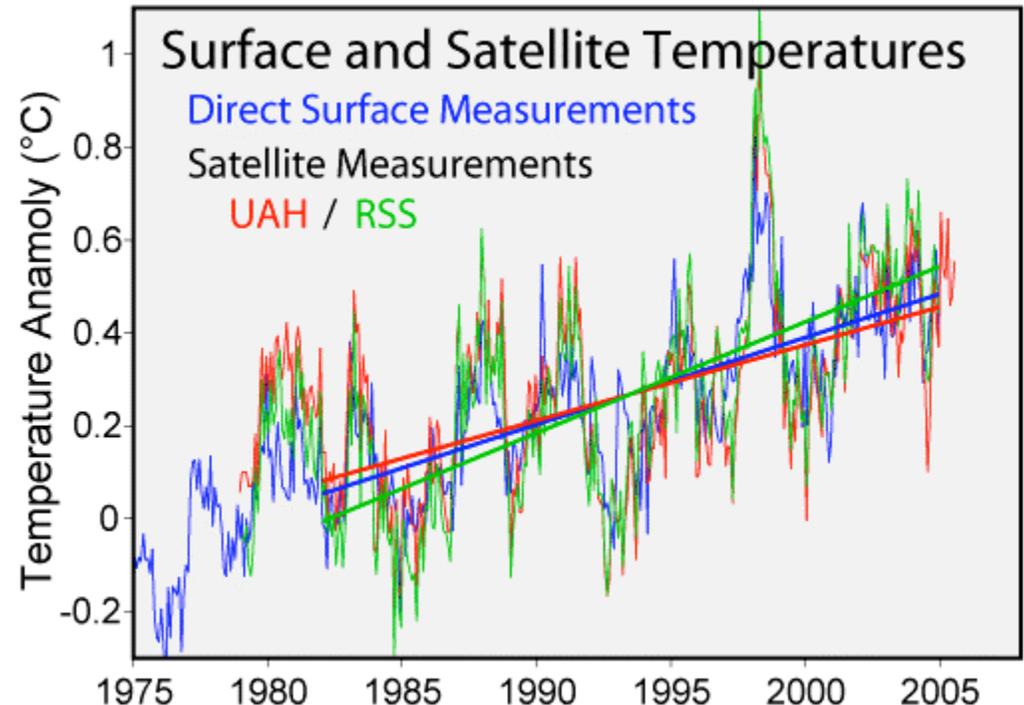
- global, long-term climate records
- of *high accuracy*
- *tested for systematic errors on-orbit*
- *and tied to irrefutable international standards* maintained in the U.S. by the National Institute of Standards and Technology (NIST)

Conduct satellite benchmark missions to create irrefutable records and calibrate other satellite sensors

- Initiate absolute spectrally resolved measurements of Earth's emission spectrum
- Initiate spectrally resolved measurements of Earth's solar reflectance spectrum simultaneously calibrated/validated against multiple/redundant calibration targets (multiple diffusers, lamps, Moon, selected Earth targets)

Assessing Global Temperature Trends

- **Surface**
 - 0.17 C/decade
- **Atmosphere**
 - RSS: 0.19 C/decade
 - UAH: 0.12 C/decade
- **We don't know whether the atmosphere is warming faster or slower than Earth's surface air. Reason: Major factor is uncertainty in calibration and intercalibration**

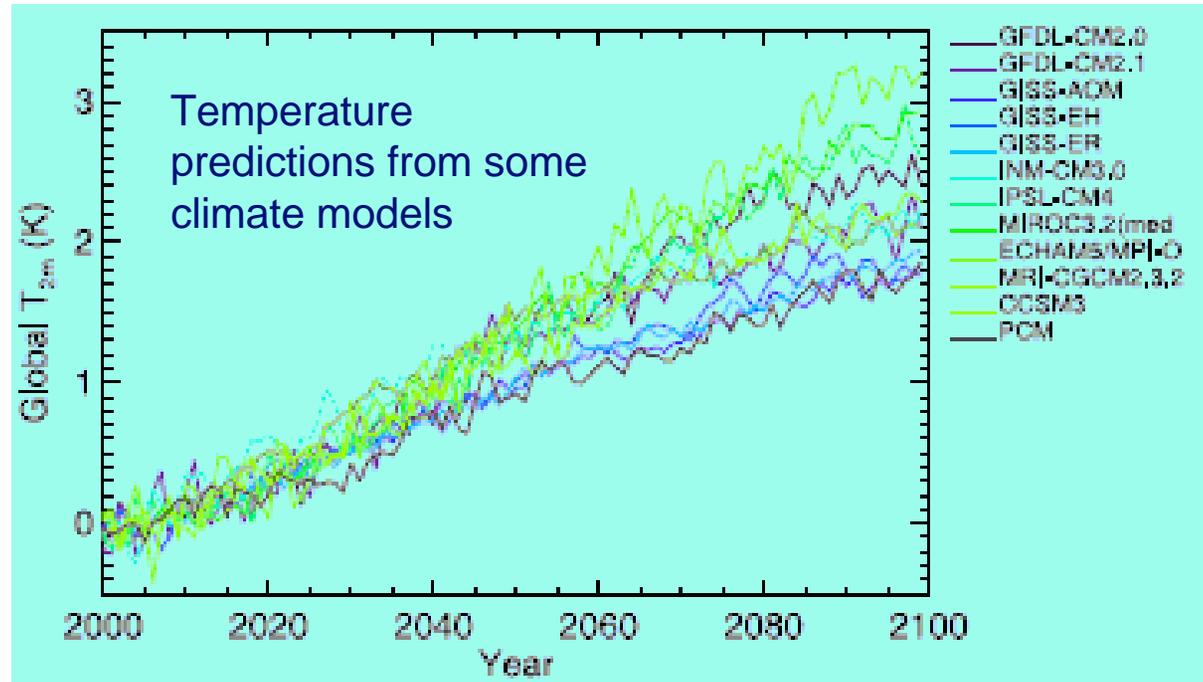


Benchmark instruments will provide reliable records of climate change

Comparison of ground based (blue) and satellite based (red: UAH; green: RSS) records of temperature variations since 1979. Trends plotted since January 1982.

Testing Climate Model Predictions

- Predicted temperature increase by 2100 varies by factor >2
- Which model is correct?
- Need extremely well calibrated satellite measurements to test model predictions



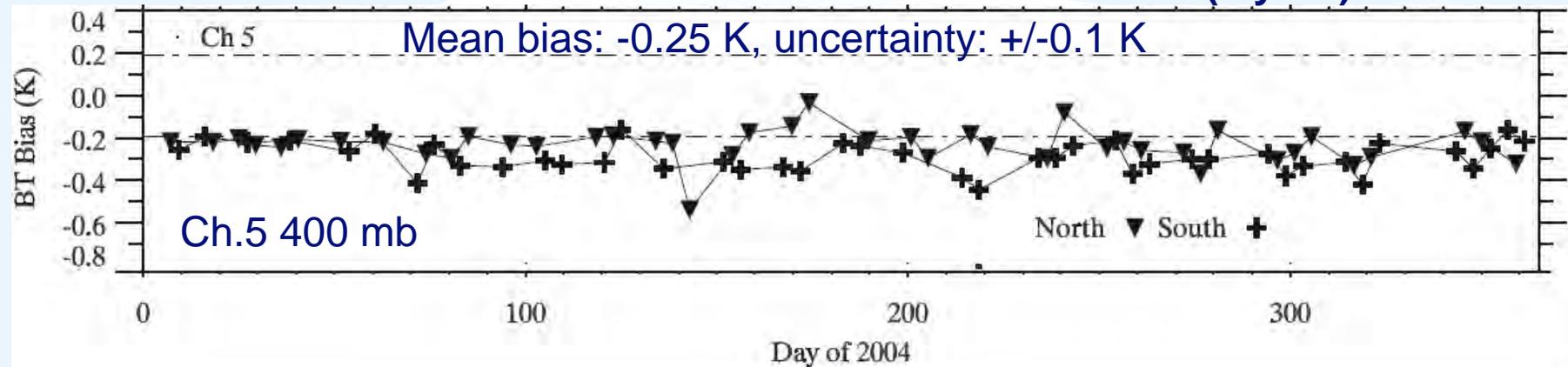
(After Leroy et al., 2006)

Benchmark instruments covering the entire emission and reflectance spectrum at high spectral resolution and accuracy will lead to more reliable prediction of climate change

Illustration: Use of a Benchmark Instrument to Calibrate Other Sensors

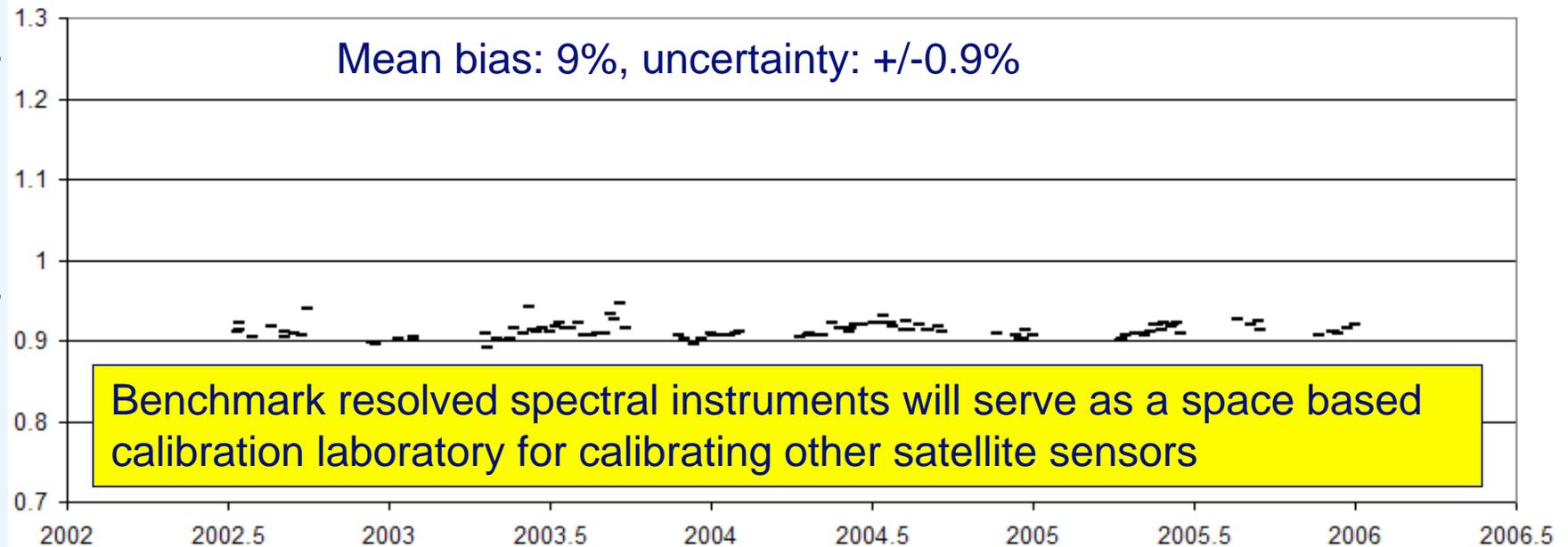
(After Cao et al.)

AIRS/AQUA and HIRS/NOAA16 SNO time Series (1 year)



MODIS/AQUA and AVHRR/NOAA16 SNO Time Series (3.5 years)

AVHRR/MODIS radiance ratio (0.63um band)



Additional Benchmark Measurements

- Ensure continuity of global sea level measurements with overlap of altimeter missions
- Ensure continuity of overlapped Broadband Earth Radiation Budget measurements
- Ensure continuity of overlapped Total Solar Irradiance (TSI) observations

Above 3 are especially critical given NPOESS elimination of climate instruments

ASIC³ Overarching Recommendations (cont.)



NIST
**National Institute of
Standards and Technology**
Technology Administration
U.S. Department of Commerce



Establish a U.S. National Center for Calibration (NCC)

- Organization
 - Distributed Center
 - NOAA (Lead), NIST, NASA, others?

- Mission
 - Champion satellite benchmark observations
 - Implement U.S. Component of the WMO's Global Satellite Inter-Calibration System (GSICS)
 - Advance the state of the art of satellite instrument calibration

Benefits



- Reliable detection of climate change
- Verification of climate model predictions
- More credible information for decision makers
- More accurate observations for weather, ocean, and other environmental applications

Backup Slides

Detection Time in the Presence of Natural Variability

- Any time series of climate data includes both natural variability with standard deviation σ_v , timescale τ_v , and measurement uncertainty (σ_m and τ_m).
- With a time series of length T , the uncertainty (δm) in the determination of the slope m is

$$(\delta m)^2 = 12 (T)^{-3} \left(\sigma_v^2 \tau_v + \sigma_m^2 \tau_m \right)$$

Leroy, S.S., J.G. Anderson, and G. Ohring, 2007: Climate signal detection times and constraints on climate benchmark accuracy requirements. *J. Climate*, in press.

Accuracy, Variability, and Detection Time

- Assumed trend (500 mb): ~0.2 K/decade
- Measure trend with 20 % error
- Natural interannual variability: 0.18 K
- Correlation time: 1.54 year (UKMO HadCM₃)

Measurement Accuracy	Detection time (2-yr missions)	Detection time (6-yr missions)
0.00 K	33.4 yrs	33.4 yrs
0.02 K	33.6 yrs	34.0 yrs
0.05 K	34.5 yrs	36.5 yrs
0.10 K	37.4 yrs	43.5 yrs
0.20 K	46.0 yrs	60.1 yrs
0.50 K	74.4 yrs	105.1 yrs

Next Steps: Global Space-based Inter-Calibration System (GSICS)

- **GSICS: A new World Meteorological Organization (WMO) program**
- **Overarching Goal: Ensure the comparability of satellite measurements provided at different times, by different instruments under the responsibility of different satellite operators**
- **Participants: WMO, satellite agencies, national standards institutes, national data centers, major NWP centers, and national research laboratories**
- **NOAA is taking a leading role**