# Summary of ASIC$^3$ Workshop

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CLARREO Workshop
University of Maryland
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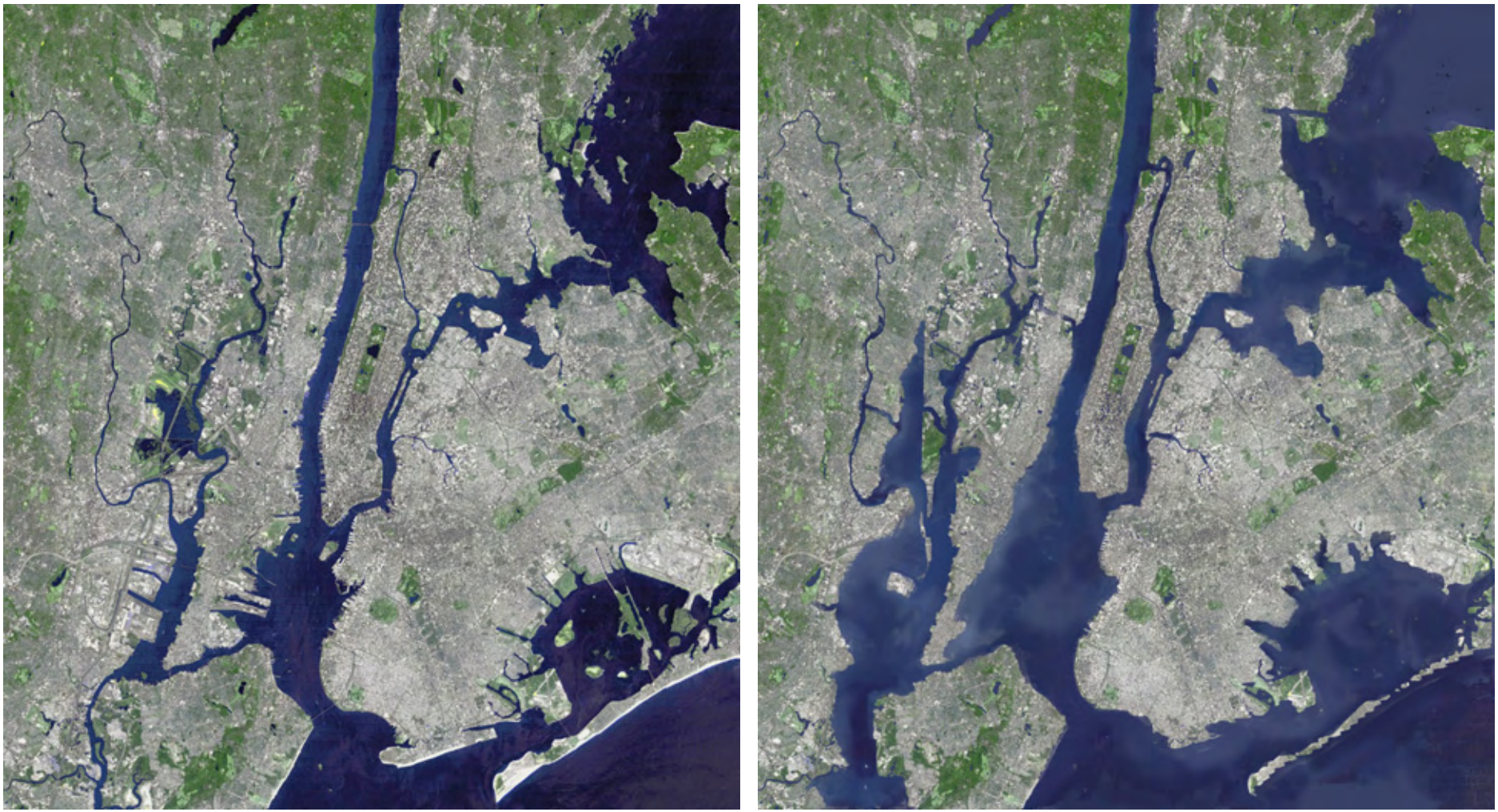
# The Questions

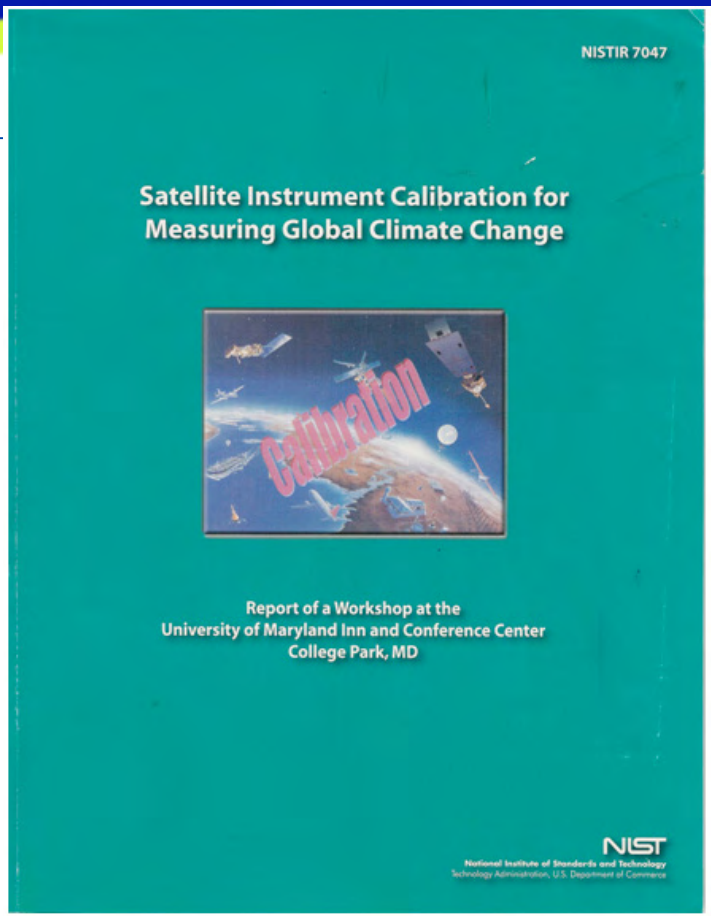
- Is the Earth's climate changing?
- If so, at what rate?
- Are the causes natural or human-induced?
- What will the climate be like in the future?

# New York City: Before and After Global Warming

(After Anderson, 2006)



# Background


**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 $CO_2$ forcing
- Trend similar to those observed in past decades

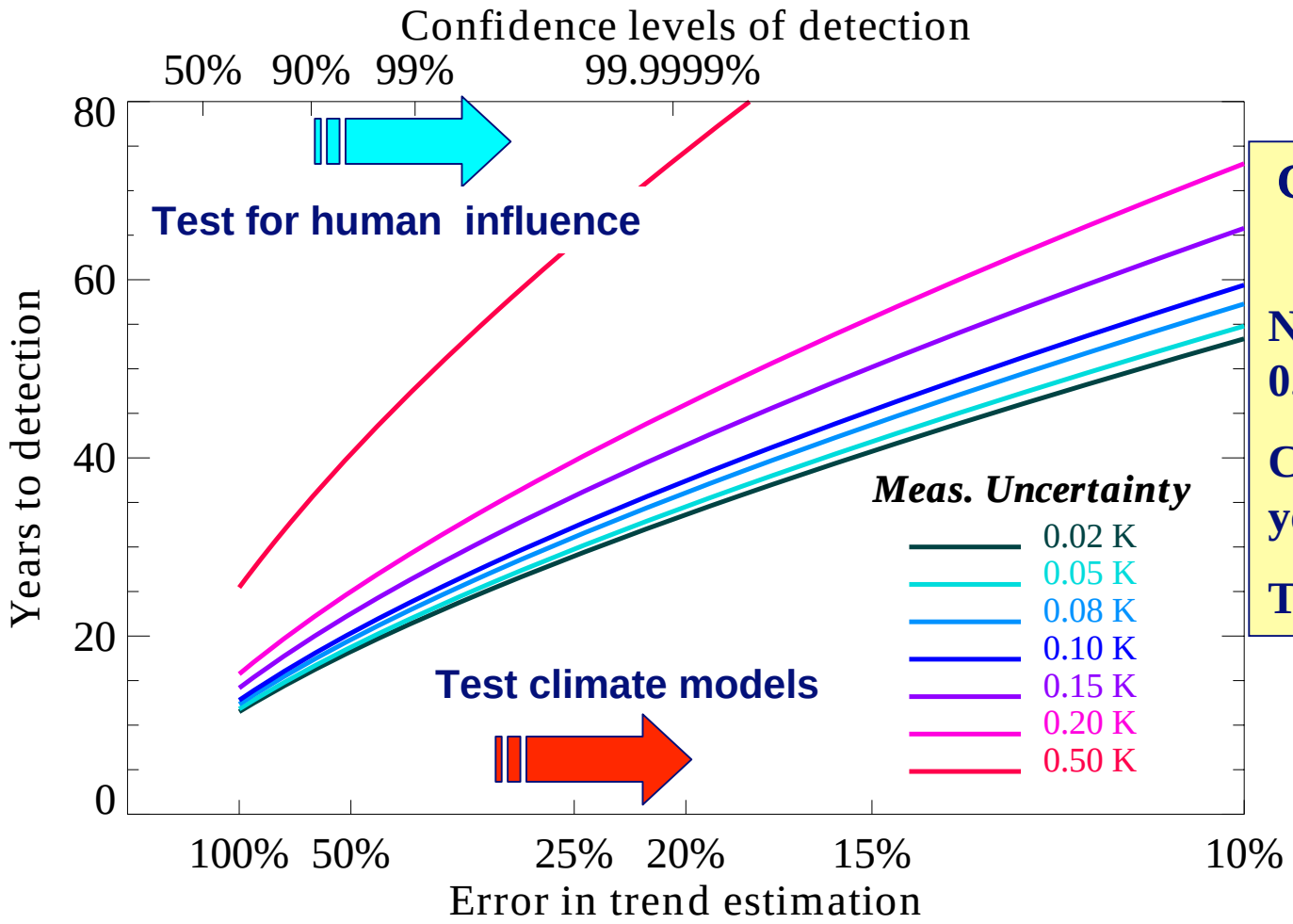
# Estimated Expected Decadal Changes

| | |
|---|---|
| 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 $^0C$ |
| Sea surface temperature | 0.2 $^0C$ |
| 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.)




**Global Temperature at 500 hPa**

**Natural variability: 0.18 K**

**Correlation time; 1.54 year**

**Trend: ~0.2 K decade$^{-1}$**

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

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

**D R A F T**
**July 2007**

Edited by George Ohring

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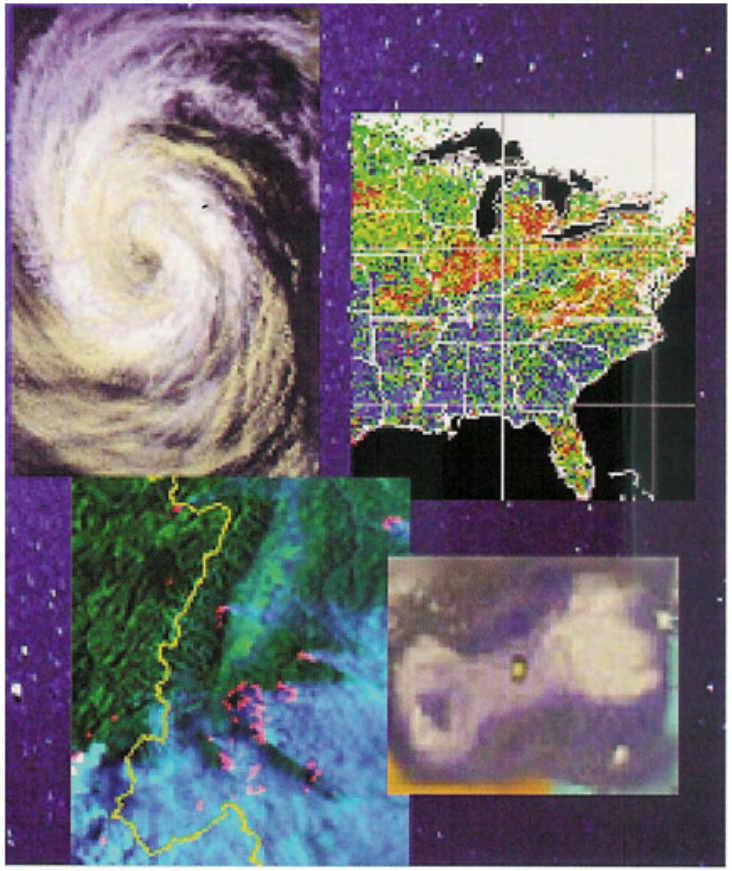
# ASIC$^3$ Workshop

- 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



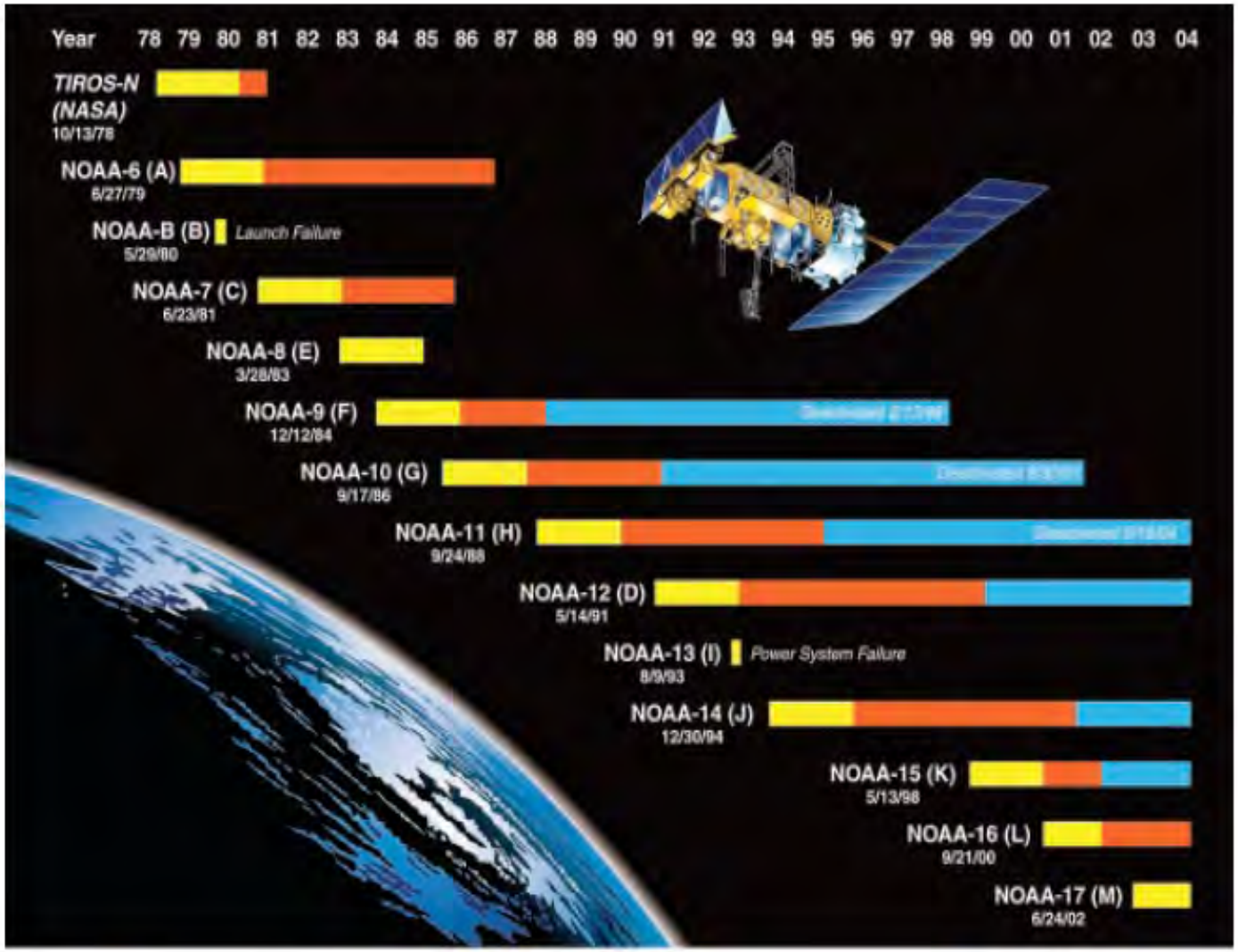
# Why Now?

- **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.

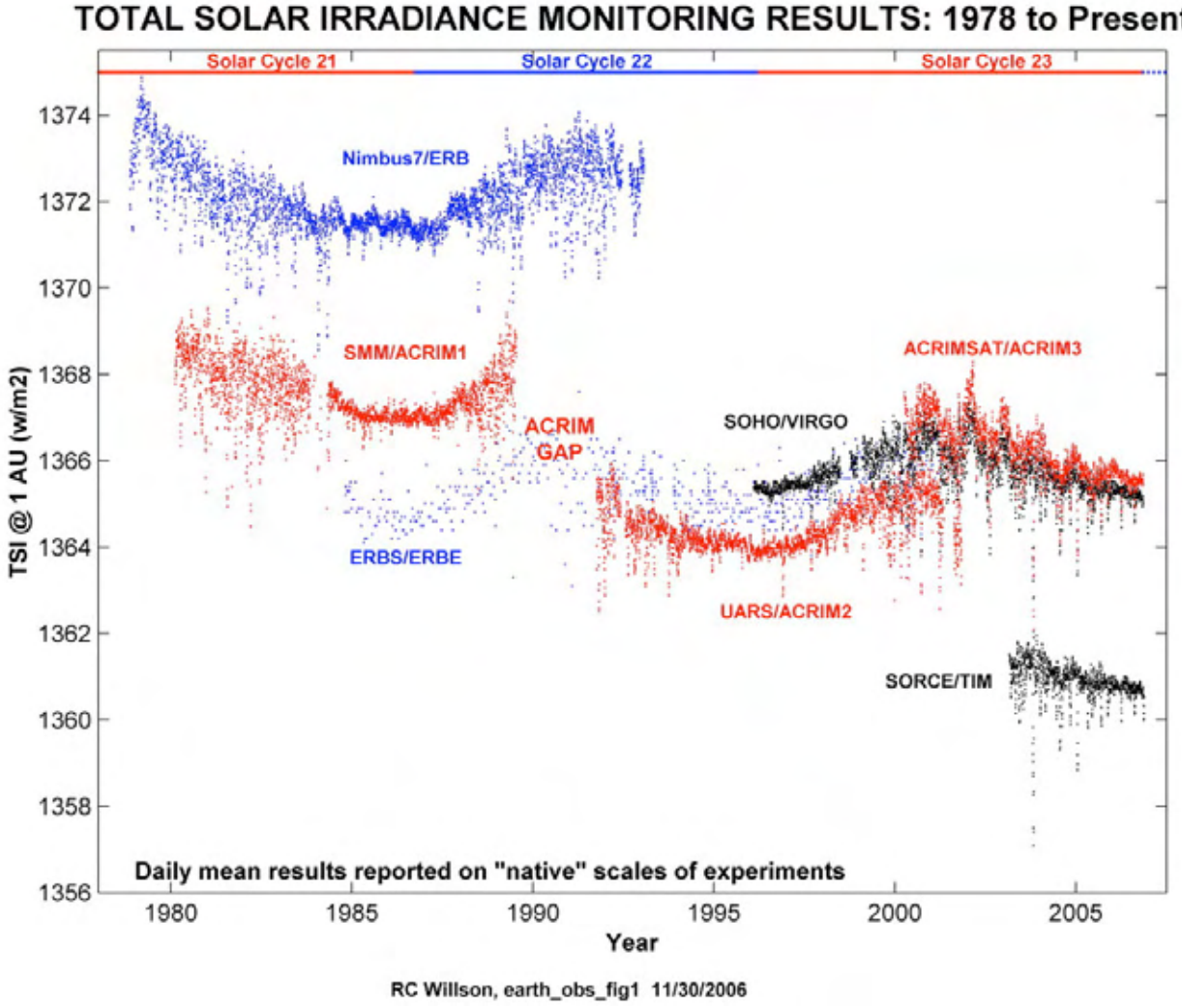
# The Problem

- 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



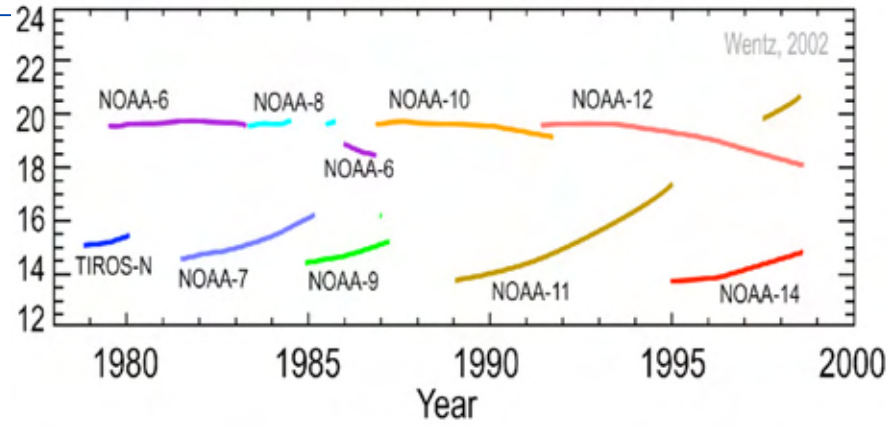
# Monitoring Solar Irradiance

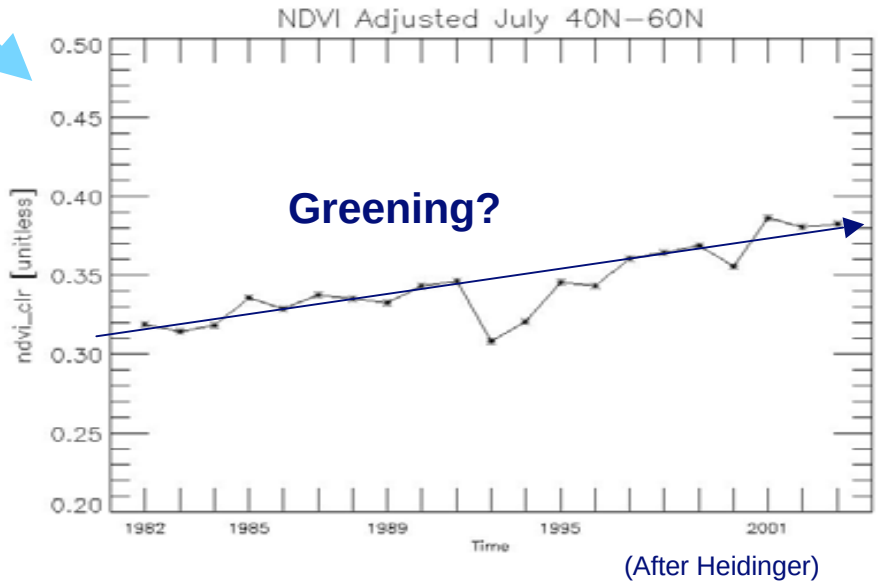



**We don't know the absolute solar forcing to better than 5 W/m$^2$!**

# 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)

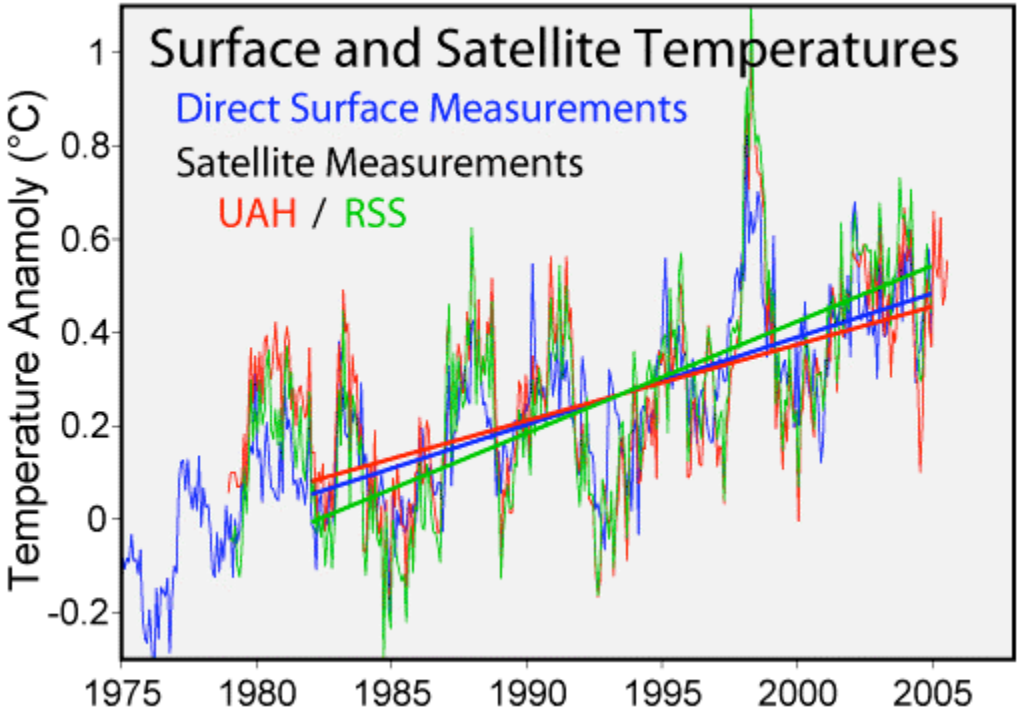
# ASIC$^3$ Overarching Recommendations

## 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**

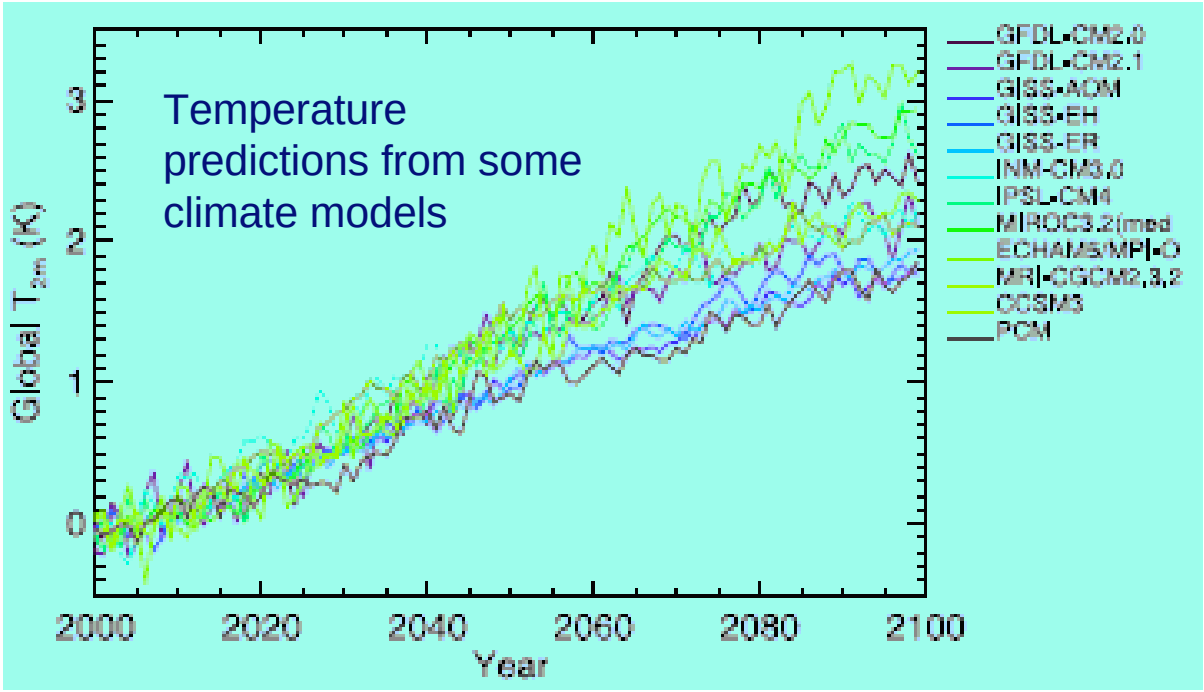



Benchmark instruments will provide reliable records of climate change

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



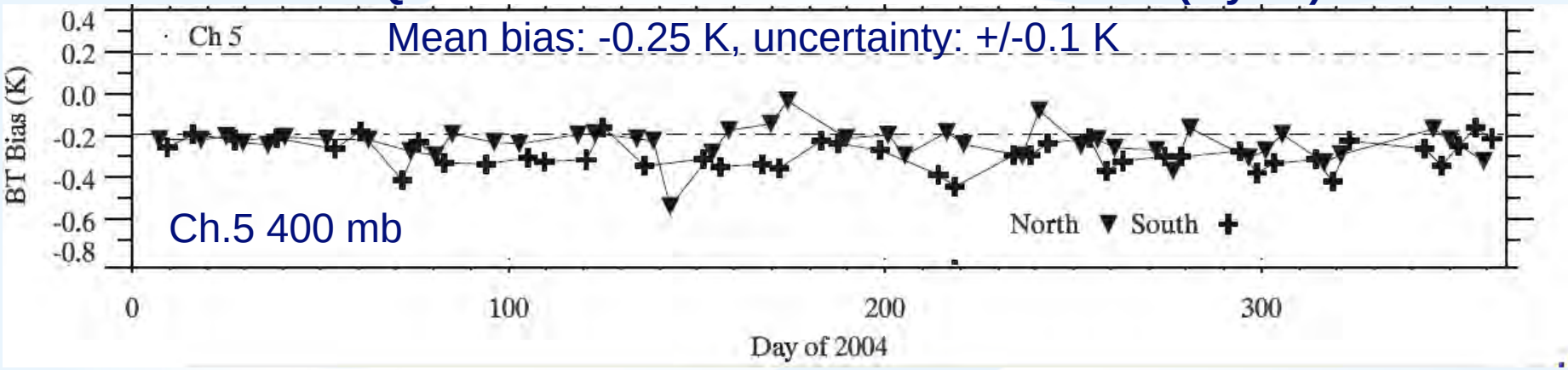

(After Leroy et al., 2006)

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

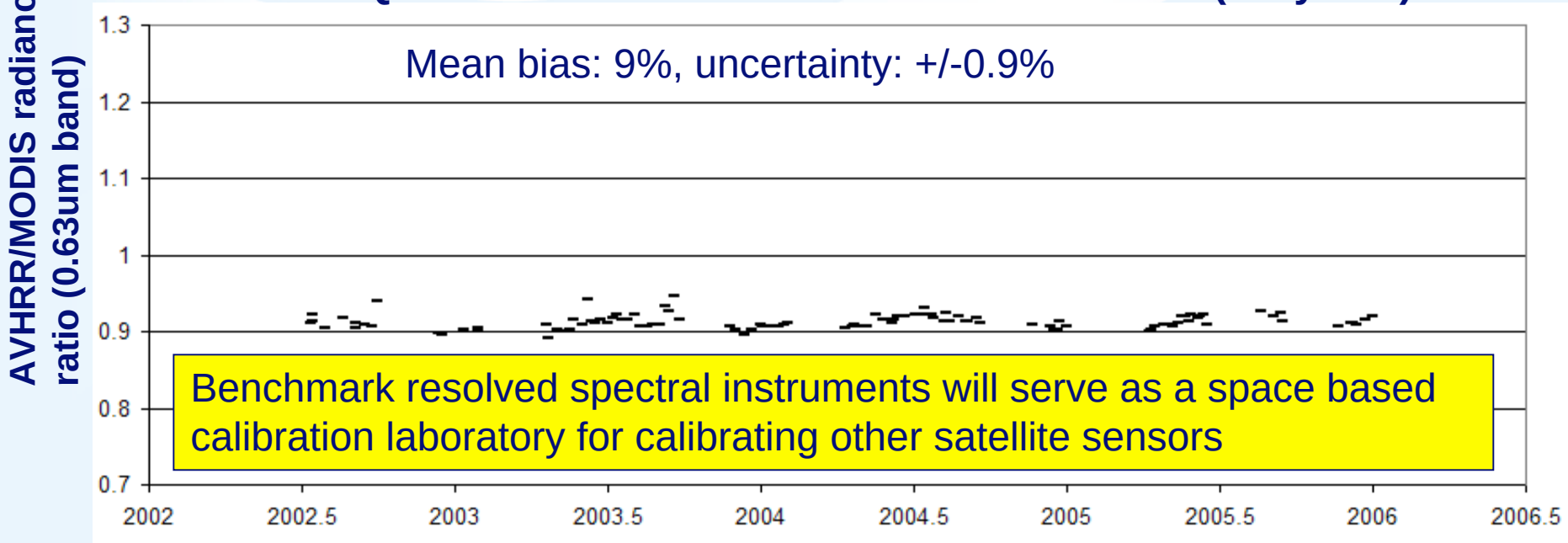
# Illustration: Use of a Benchmark Instrument to Calibrate Other Sensors

(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)



# ASIC$^3$ Overarching Recommendations (cont.)

## 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**

# ASIC$^3$ 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 $\sigma_v$, timescale $\tau_v$, and measurement uncertainty ($\sigma_m$ and $\tau_m$).
- With a time series of length $T$, the uncertainty ($\delta m$) 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 HadCM$_3$)

| **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