NASA Report to the 15th Meetin of the GSICS Executive Panel

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Global Space-based Inter-Calibration Syste
15th Session of the Executive Panel
Hotel Landmark Canton
Guangzhou, China

May 16-17, 2014

Agenda

1. MOderate Resolution Imaging Spectroradiometer (MODIS) Terra & Aqua Status

2. Atmospheric InfraRed Sounder (AIRS) Status

3. Suomi National Polar-orbiting Partnership (SNPP), Joint Polar Satellite System-1 & 2 (JPSS-1, JPSS-2) Status

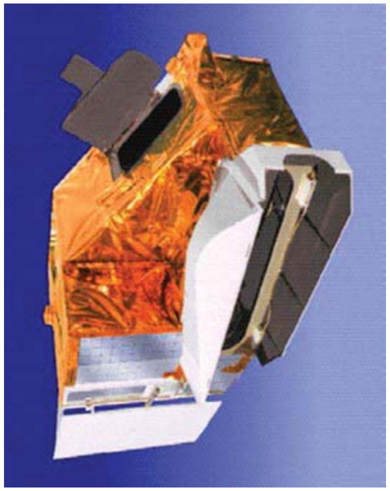
4. Climate Absolute Radiance and Refractivity Observatory (CLARREO) Status

5. NASA Satellite Calibration Inter-consistency Studies

6. Joint NOAA/NASA Airborne Field Campaign in Support of SNPP Calibration and Validation

1. MOderate Resolution Imaging Spectroradiometer (MODIS) Terra & Aqua Status

MODIS Terra and Aqua Instrument Status



MODIS

Terra launch: 12/18/1999

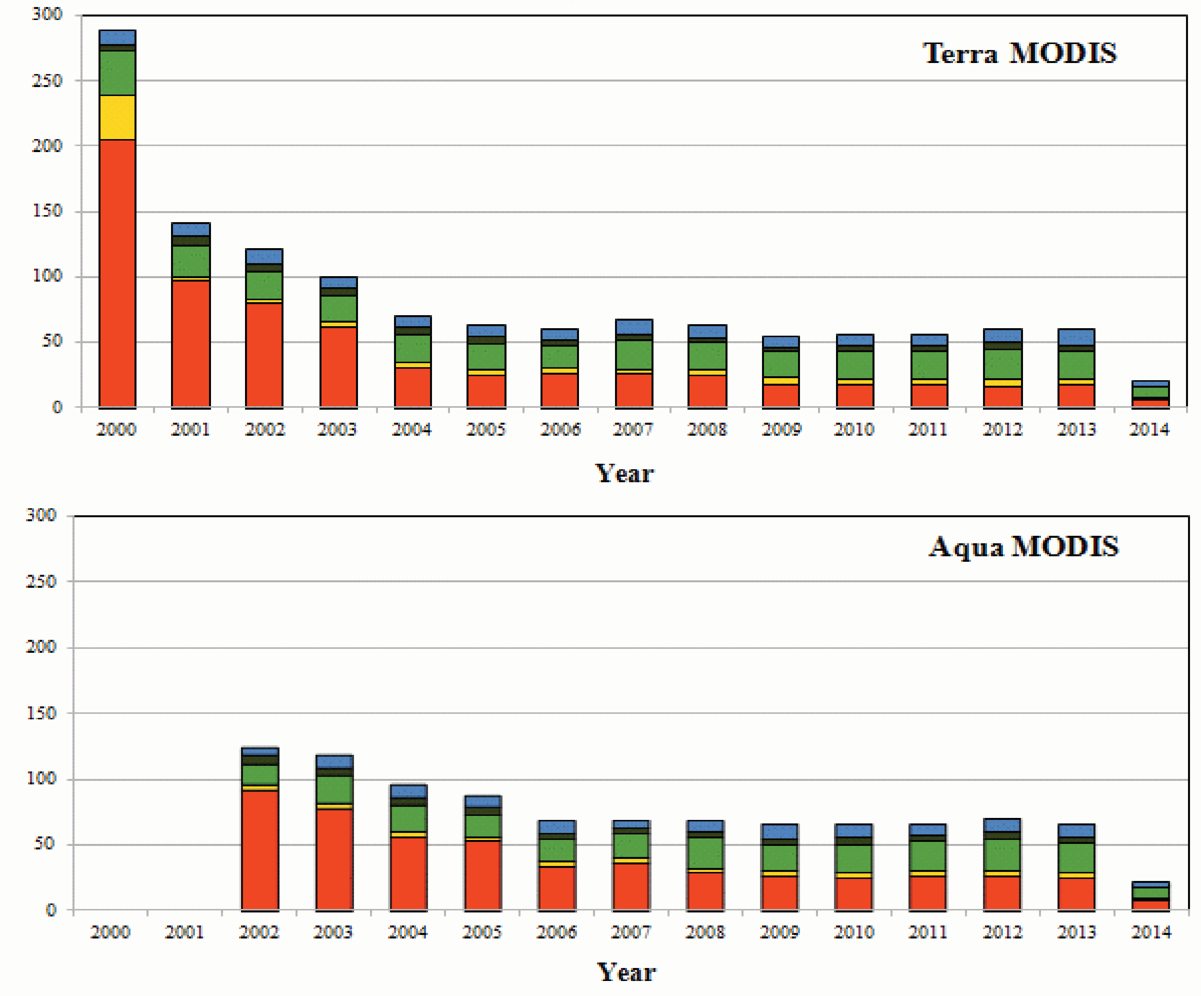
Aqua Launch: 5/4/2002

- Both MODIS Terra and Aqua continue to operate and function normally
  - -No configuration changes in recent years
  - -Only 3 noisy detectors have appeared over the last 5 years (MODIS Terra D4, D7 in Band 30 & MODIS Aqua D6 in Band 29)
- Level 1B data processing
  - -C6 L1B processing completed in 2012 and data released to public
  - -Calibration updates include: C6 new response versus scan angle approach applied to more VNIR bands
  - -Updates to several MODIS Terra and Aqua look up tables

To date, over 7400 technical articles and over 10,000 technical/proceedings articles have used and/or cited MODIS and its data

MODIS Comprehensive Calibration Effort Continues to Produce High Quality Level 1 Data

Number of calibrations



	Terra	Aqua
🟦 Lunar Roll	136	116
⬛ PV Ecal	84	64
🟩 SRCA	396	271
🟨 BB	89	52
🟥 SD/SDSM	674	520

•BB T cals: 270 - 315K

•SRCA cals: radiometric, spatial, spectral cals

•Additional cals:
Maneuvers
Ground Targets
Inter-comparisons
Nighttime day mode ops

Acronyms: PV-photovoltaic; Ecal-electronic cal; SRCA-Spectral Radiometric Calibration Assembly; BB-Blackbody; SD/SDSM-Solar Diffuser/Solar Diffuser Stability Monitor

MODIS Terra and Aqua: Future Work

- **Future work to address existing and new challenging issues includes:**
  - Changes in VNIR response versus scan angle
    - Band (detector) and mirror side dependent
  - SD degradation at short wavelengths
    - Potential increase in cal uncertainty from correction
    - SD degradation at SWIR wavelengths not directly tracked
  - Changes in MODIS Terra VNIR polarization sensitivity
    - Band (detector), mirror side and angle of incidence dependent
    - No noticeable changes in MODIS Aqua so far
  - Aging instruments
    - Gradual increase in MODIS Aqua cold focal plane temps
    - Calibration impacts due to potential satellite MLT drift

MODIS dedicated calibration and characterization effort and close interaction and communication with the science and data user community will continue

2. Atmospheric InfraRed Sounder (AIRS) Status

AIRS on Aqua uses Hyperspectral IR to Measure Atmospheric Greenhouse Gases

Atmospheric Infrared Sounder (AIRS)

<u>AIRS Characteristics</u>

Aqua Spacecraft

Launched: May 4, 2002

Orbit: 705 km, 1:30pm

IFOV : 13.5 km

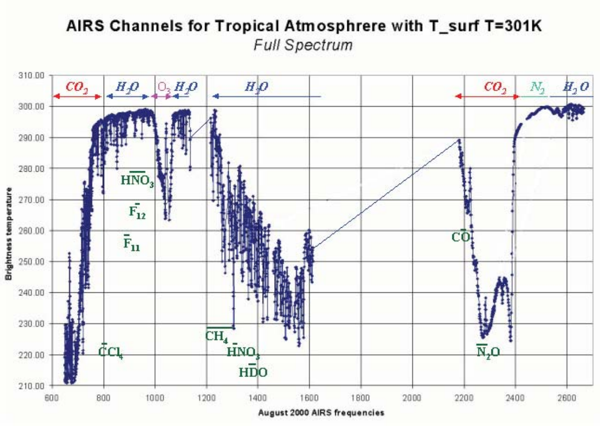
Global Daily Coverage

Spectral Range: 3.5-15.4 µm

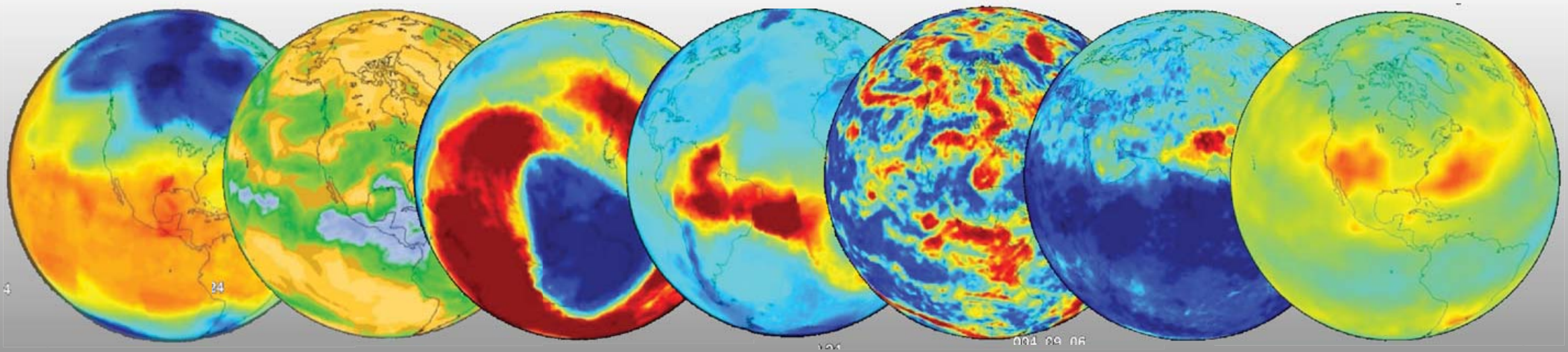
No. Channels: 2378

Climate Quality Accuracy and Stability

AIRS Hyperspectral Infrared Spectrum



AIRS Measures Key Greenhouse Gases with Global Daily Coverage



Temperature

Water Vapor

Ozone

Carbon Monoxide

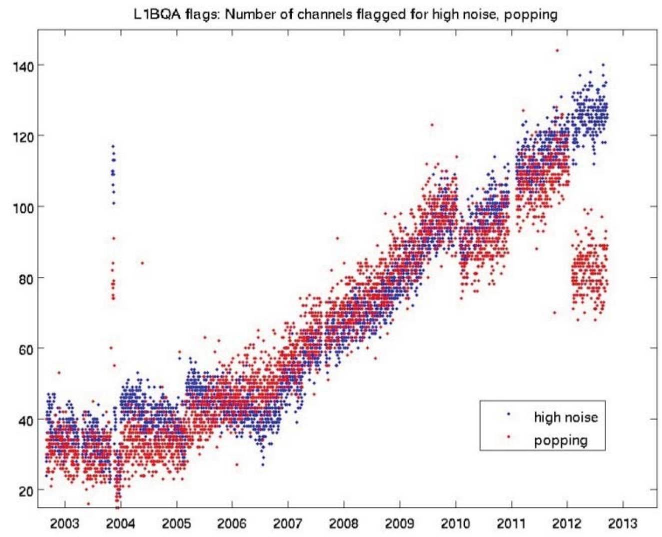
Cloud Properties

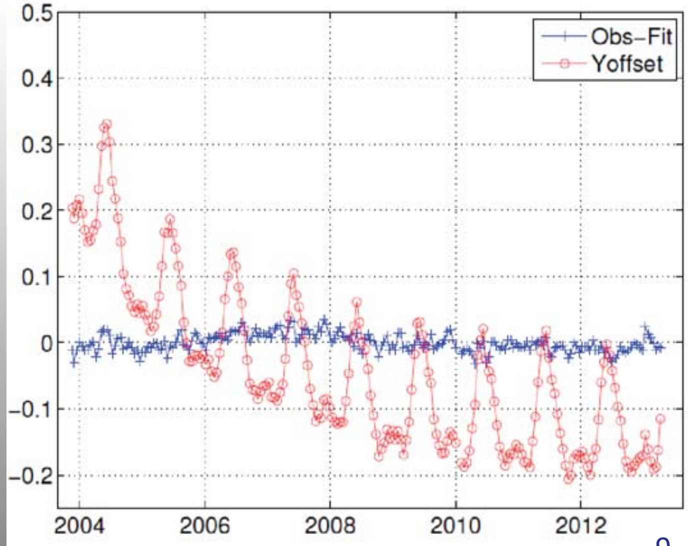
Methane

Carbon Dioxide

AIRS Instrument Status

- AIRS in excellent health.
  - Expect to operate beyond the year 2022 when S/C fuel exhausted
- No significant trends in engineering parameters
  - Coolers running with high margin for life of AIRS
- Noise:
  - Radiation dosage causes some detectors to suffer increased noise
  - Channels with non-Gaussian noise, or “popping” swapped to redundant detector where possible
  - High Gaussian-noise detectors not changed to preserve spectral response for long-term climate studies
- Spectral Response:
  - Small changes in spectrometer temperature cause small spectral shifts
  - Shifts on the order of ~3 ppm over course of mission. Drift Stabilized
  - Knowledge to better than 0.2 ppm
- These changes are minor and have virtually no impact on retrieved products, T(p), Q(p)
- Knowledge of these changes is very good and important for climate studies





3. Suomi National Polar-orbiting Partnership (SNPP), Joint Polar Satellite System-1 & 2 (JPSS-1, JPSS-2) Status

Suomi NPP, JPSS-1, & JPSS-2 Status

Mission	Instrument(s)	Status	Pre-ship Review	Instrument S/C Integration	Launch Date
SNPP	ATMS, CERES, CrIS, OMPS-N&L, VIIRS	On-orbit and all instruments fully operating			10/28/2011
JPSS-1	ATMS	Post-T/V Performance Testing	7/2014	1/2015	12/2016
	CERES	Completed Testing & In Storage	4/2014	12/2014	
	CrIS	T/V Testing	10/2014	3/2015	
	OMPS-N	Post-T/V Performance Closeout	6/2014	2/2015	
	VIIRS	Pre-T/V Testing	12/2014	4/2015	
JPSS-2	ATMS, RBI, CrIS, OMPS-N&L, VIIRS	Instrument sub-system/system level procurement , assembly, & testing			11/2021

Instruments: ATMS-Advanced Technology Microwave Sounder; CERES-Clouds and the Earth's Radiant Energy System; CrIS-Crosstrack Infrared Sounder; OMPS-Ozone Mapping and Profiler Suite; VIIRS-Visible InfraRed Imaging Radiometer Suite; RBI-Radiation Budget Instrument

4. Climate Absolute Radiance and Refractivity Observatory (CLARREO) Status

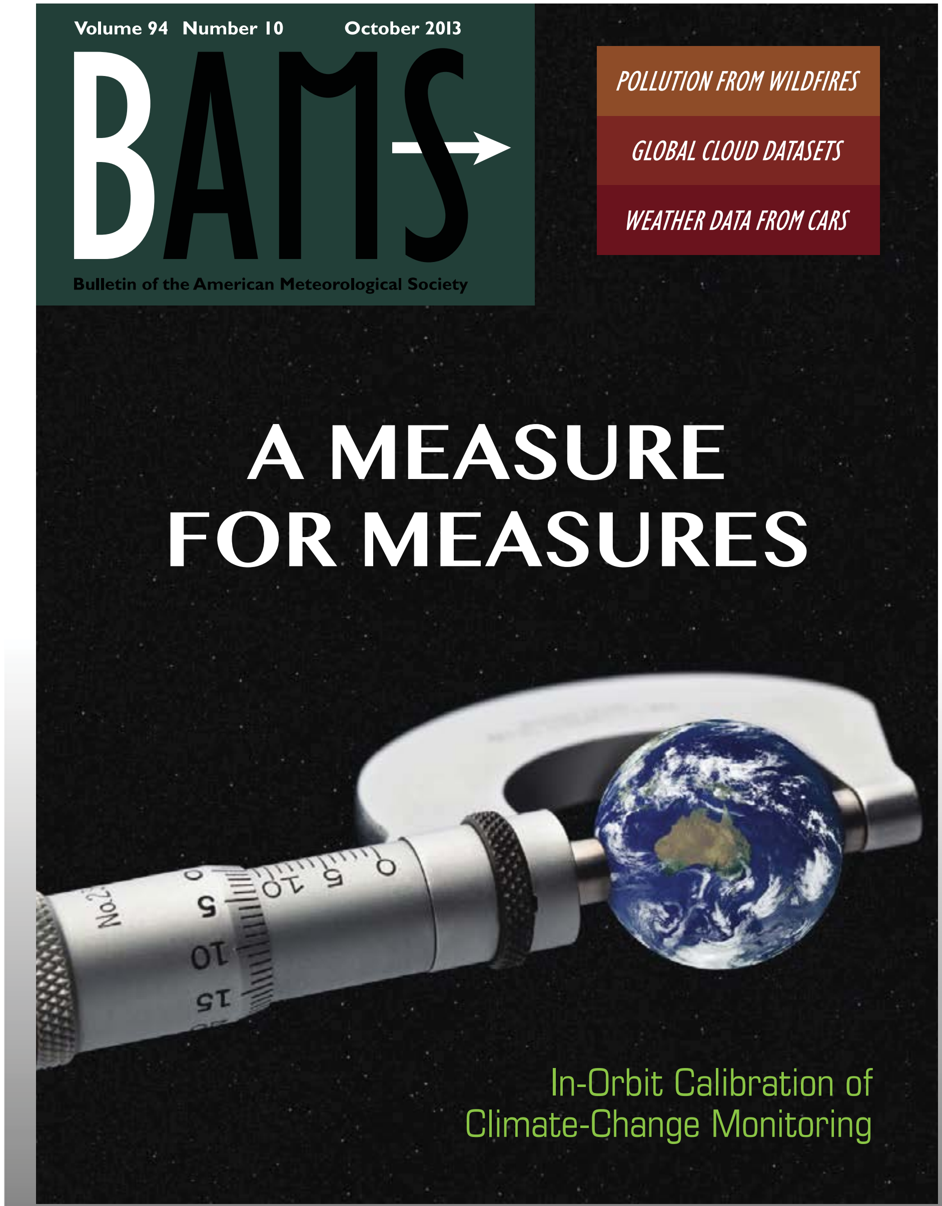
CLARREO Mission Status

- Passed Mission Concept Review Nov 2010
- Science Definition Team selected Jan 2011
- CLARREO remains in pre-phase A studies with a current launch date not earlier than 2022
- 2 Reflected solar and 2 Infrared instrument cal demonstration systems underway:
  - CU LASP successful high altitude balloon flight other their prototype RS spectrometer
  - GSFC participated in Landsat ground calibration campaign with prototype RS spectrometer and held successful NIST peer review.
  - UW demonstrated successful space environmental testing on the prototype IR interferometer
  - LaRC cal demonstration system within a factor of 2 of IR requirements as established thru NIST peer review
- Continue work on climate model OSSEs and intercalibration simulation studies
- Alternate less costly mission studies: ISS best option to date
- International collaborations with UK and Italy in study
- The lack of an on-orbit climate observing system remains a large challenge for the climate science community

2013 CLARREO Progress: Journals

- 26 journal papers published/in press in 2013
- 15 papers submitted/in review
- 42 papers in preparation
- 13 journal papers were published in 2012

CLARREO Mission BAMS Cover Paper: October 2013



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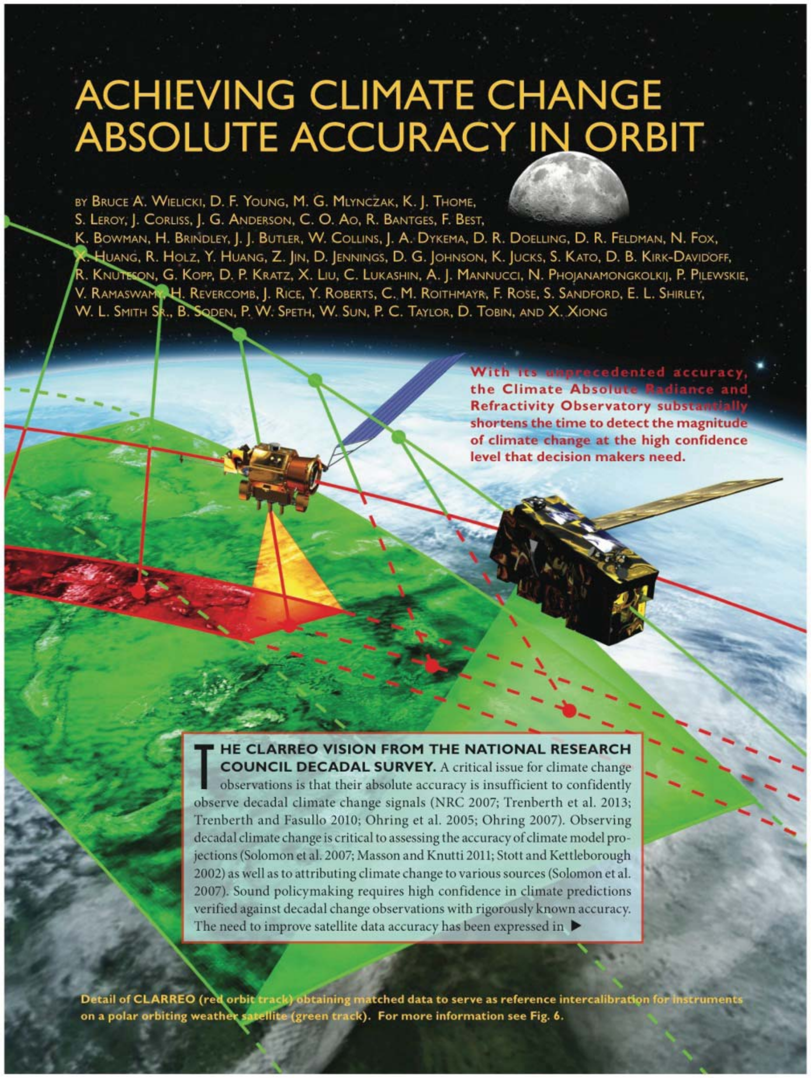
POLLUTION FROM WILDFIRES

GLOBAL CLOUD DATASETS

WEATHER DATA FROM CARS

A MEASURE FOR MEASURES

In-Orbit Calibration of Climate-Change Monitoring



ACHIEVING CLIMATE CHANGE ABSOLUTE ACCURACY IN ORBIT

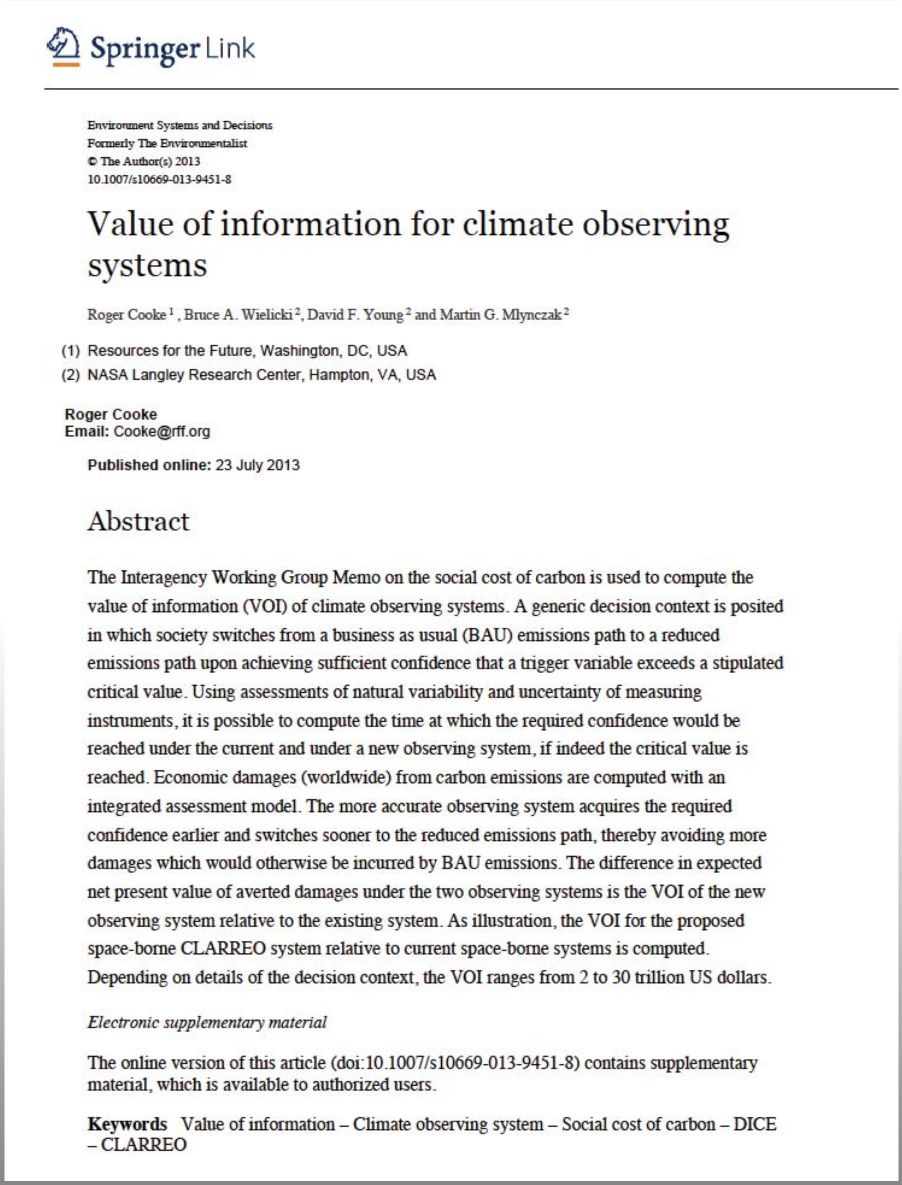
by Bruce A. Wielicki, D. F. Young, M. G. Mlynczak, K. J. Thome, S. Leroy, J. Corliss, J. G. Anderson, C. O. Ao, R. Bantges, F. Best, K. Bowman, H. Brindley, J. J. Butler, W. Collins, J. A. Dykema, D. R. Doelling, D. R. Feldman, N. Fox, X. Huang, R. Holz, Y. Huang, Z. Jin, D. Jennings, D. G. Johnson, K. Jucks, S. Kato, D. B. Kirk-Davidoff, R. Knuteson, G. Kopp, D. P. Kratz, X. Liu, C. Lukashin, A. J. Mannucci, N. Phojanamongkolkij, P. Pilewskie, V. Ramaswamy, H. Revercomb, J. Rice, Y. Roberts, C. M. Roithmayr, F. Rose, S. Sandford, E. L. Shirley, W. L. Smith Sr., B. Soden, P. W. Speth, W. Sun, P. C. Taylor, D. Tobin, and X. Xiong

With its unprecedented accuracy, the Climate Absolute Radiance and Refractivity Observatory substantially shortens the time to detect the magnitude of climate change at the high confidence level that decision makers need.

THE CLARREO VISION FROM THE NATIONAL RESEARCH COUNCIL DECADAL SURVEY. A critical issue for climate change observations is that their absolute accuracy is insufficient to confidently observe decadal climate change signals (NRC 2007; Trenberth et al. 2013; Trenberth and Fasullo 2010; Ohring et al. 2005; Ohring 2007). Observing decadal climate change is critical to assessing the accuracy of climate model projections (Solomon et al. 2007; Masson and Knutti 2011; Stott and Kettleborough 2002) as well as to attributing climate change to various sources (Solomon et al. 2007). Sound policymaking requires high confidence in climate predictions verified against decadal change observations with rigorously known accuracy. The need to improve satellite data accuracy has been expressed in ▶

Detail of CLARREO (red orbit track) obtaining matched data to serve as reference intercalibration for instruments on a polar orbiting weather satellite (green track). For more information see Fig. 6.

Economic Value of Climate Observations



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Value of information for climate observing systems

Roger Cooke[1], Bruce A. Wielicki[2], David F. Young[2] and Martin G. Mlynczak[2]

(1) Resources for the Future, Washington, DC, USA
(2) NASA Langley Research Center, Hampton, VA, USA

Roger Cooke
Email: Cooke@rff.org

Abstract

The Interagency Working Group Memo on the social cost of carbon is used to compute the value of information (VOI) of climate observing systems. A generic decision context is posited in which society switches from a business as usual (BAU) emissions path to a reduced emissions path upon achieving sufficient confidence that a trigger variable exceeds a stipulated critical value. Using assessments of natural variability and uncertainty of measuring instruments, it is possible to compute the time at which the required confidence would be reached under the current and under a new observing system, if indeed the critical value is reached. Economic damages (worldwide) from carbon emissions are computed with an integrated assessment model. The more accurate observing system acquires the required confidence earlier and switches sooner to the reduced emissions path, thereby avoiding more damages which would otherwise be incurred by BAU emissions. The difference in expected net present value of averted damages under the two observing systems is the VOI of the new observing system relative to the existing system. As illustration, the VOI for the proposed space-borne CLARREO system relative to current space-borne systems is computed. Depending on details of the decision context, the VOI ranges from 2 to 30 trillion US dollars.

Electronic supplementary material

The online version of this article (doi:10.1007/s10669-013-9451-8) contains supplementary material, which is available to authorized users.

Keywords Value of information – Climate observing system – Social cost of carbon – DICE – CLARREO

Journal of Environment, Systems, and Decisions

Cooke et al., 2013

-Available free and open access online @ http://link.springer.com /article/10.1007%2Fs10669-013-9451-8

-Phase 2 VOI study underway with June 2014 publication submission date

Conclusion

- GCICS remains a key focus of the CLARREO mission
- The intercalibration software tools development presented at the last GSICS meeting (Costy Lukashin & Chris Currey) continue in development with deployment at NOAA NCDC planned.

5. NASA Satellite Calibration Inter-consistency Studies

Aqua-AIRS and NOAA-HIRS Pixel- to Global Scale Radiance Comparisons for Improved Long-Term Cloud-Type Trends

Brian H. Kahn, Mathias Schreier, Eric Fetzer, Evan Fishbein, NASA Jet Propulsion Laboratory; Andrew Heidinger, NOAA/Cooperative Institute for Meteorological Satellite Studies/Space Science and Engineering Center; Hai-Tien Lee, University of Maryland-College Park; Paul W. Staten, California Institute of Technology

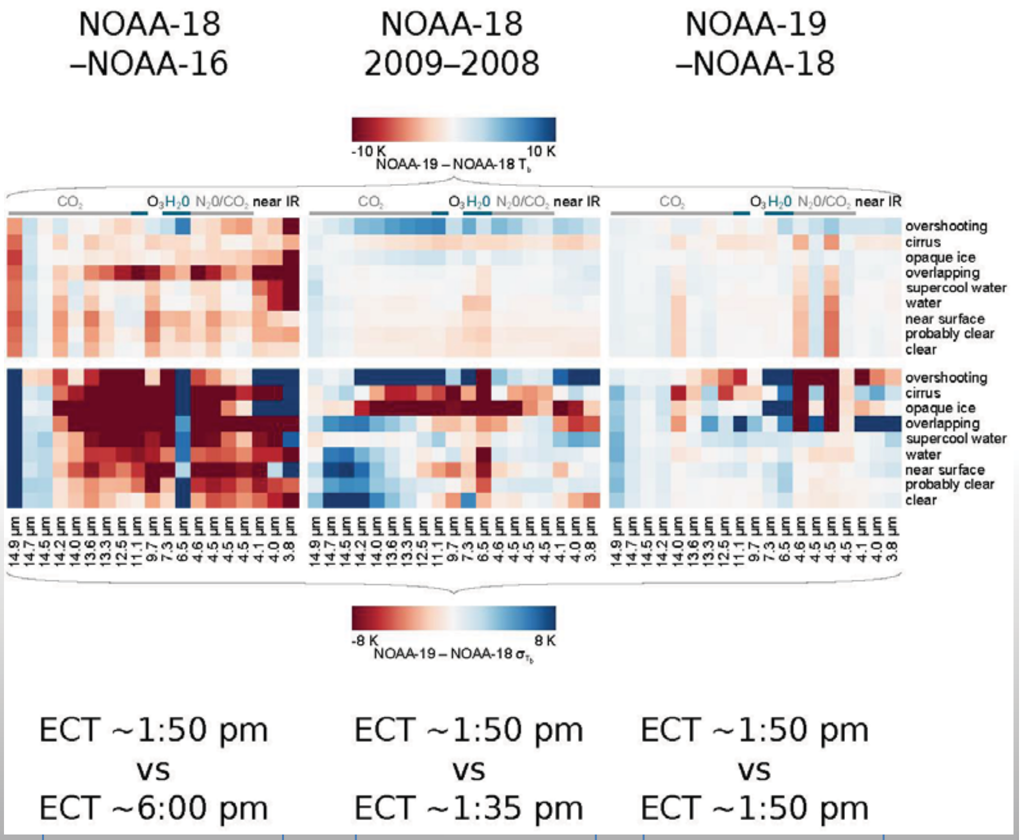
Primary research objectives:

Construct a consistent, cross-platform data set of NOAA HIRS radiances building on the high calibration accuracy and stability of NASA AIRS using a unique approach

1) Use MODIS and AVHRR high spatial resolution imagery and Simultaneous Nadir Overpasses (SNOs) to uncouple pixel-scale NOAA-19 HIRS and NASA AIRS radiance variability and trends caused by cloudiness and instrument calibration

2) Use NOAA-19 HIRS/NASA AIRS comparison as a benchmark to extend technique backwards through the NOAA HIRS observational record

3) Resulting HIRS radiances sorted by cloud conditions are better suited to inter-annual and trend analyses than simple space-time averages



NOAA-18 minus NOAA-16 HIRS brightness temperature differences showing diurnal cycle effects as a function of cloud type

NOAA-18 HIRS brightness temperature differences for two the years 2008 and 2009

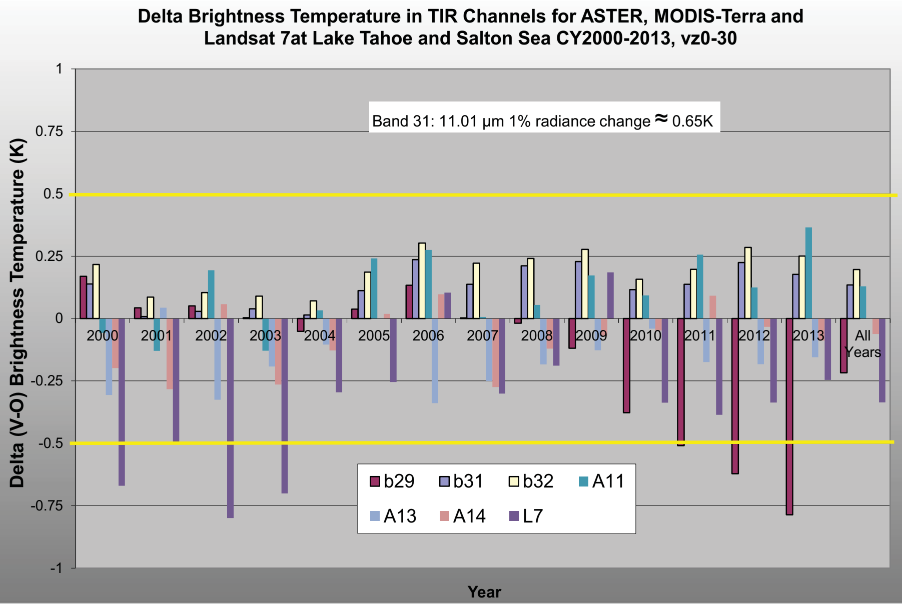
NOAA-19 minus NOAA-18 HIRS brightness temperature differences

Cross Calibration and Interconsistency of Satellite Mid and Thermal Infrared At-Sensor Products for Earth Science

Simon J. Hook (PI – JPL), A. Ignatov (Co-I – NOAA) G. Corlett (Co-I –Leicester University)

Primary research objectives:

1) Cross calibrate and validate the mid and thermal infrared at-sensor data products from AATSR, ASTER, AVHRR, Landsat and MODIS at the Lake Tahoe and Salton Sea sites for the period 1999 to present using brightness temperature measurements made by permanently instrumented buoys
2) Employ the NOAA inter-satellite calibration facility, MICROS, to check for consistencies between AATSR, AVHRR and MODIS
3) Document the calibration and consistency of data from the aforementioned sensors and make the information available to the instrument teams and scientific community to enable NASA to provide well calibrated multi-year, multi-satellite data and product series.



Delta Brightness Temperature in TIR Channels for ASTER, MODIS-Terra and Landsat 7at Lake Tahoe and Salton Sea CY2000-2013, vz0-30

Difference between the predicted and ASTER, MODIS-Terra and Landsat 7 thermal infrared On-Board Calibrator (OBC) derived brightness temperatures for 2000 through 2013 using the Lake Tahoe and Salton Sea validation sites.

-MODIS bands: b29 (8.40- 8.70µm), b31 (10.78-11.28 µm), and b32 (11.77-12.27µm)

ASTER bands: A11(8.475-8.825µm) and A13(10.25-10.95 µm).

Landsat band, L7, is from 10.4-12.5µm.

MODIS absolute calibration spec for thermal infrared bands: ± 0.5% (i.e. ~0.34K) radiance level.

Intercalibration of Satellites at NASA LaRC for Climate and Weather Applications

Patrick Minnis, David R. Doelling, NASA Langley Research Center

Utilize a number of comparison techniques to create reliable, long term data sets with small uncertainties for several operational LEO and GEO satellite instruments as seen in the figures below for the AVHRR 0.63µm channel on NOAA-18 and -9

-Aqua Ray Matching (RM): Reference (i.e. Aqua MODIS (0.65µm channel))and target imager (i.e. NOAA-18 AVHRR (0.63µm channel)) view the same area within specified time and viewing angle windows

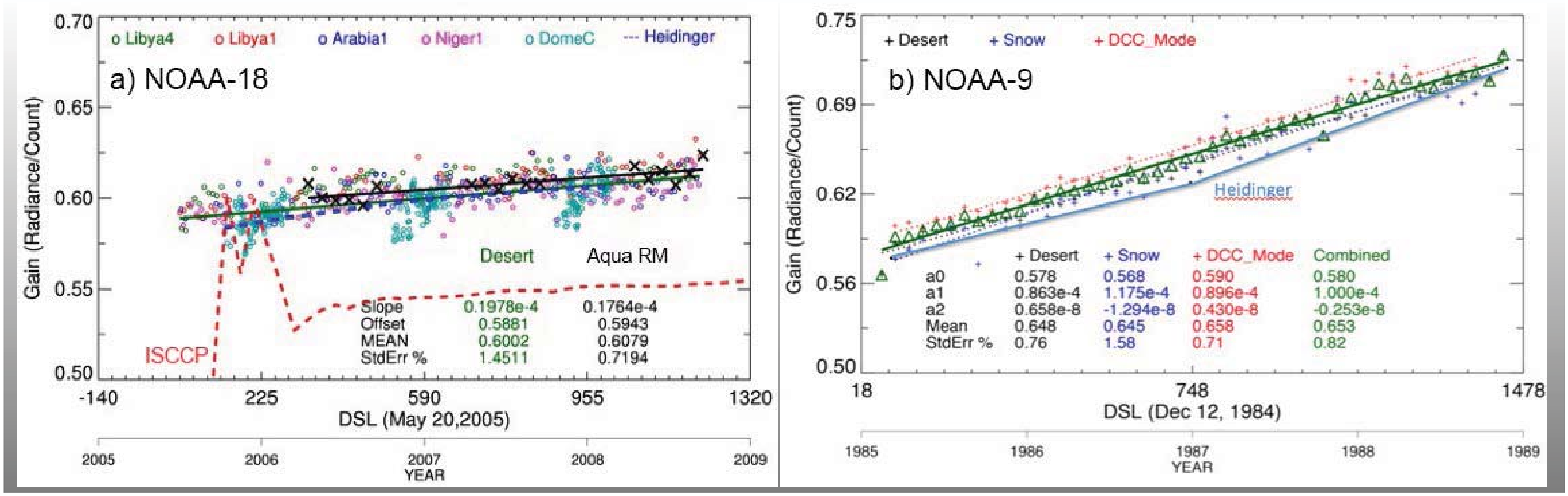
-Libya 4, Libya 1, Arabia 1, Niger 1, Desert, Snow: Daily exo-atmospheric models built using a reference GEOsat (e.g. Meteosat-9) intercalibrated with Aqua MODIS. The models are then used to predict the target AVHRR gain

-DCC: Deep convective cloud (DCC) reflectance means or modes determined using Aqua MODIS for a given area and time period assumed invariant over time

Also shown in the figures

-Heidinger, et al., 2010: Deriving an inter-sensor consistent calibration for the AVHRR solar reflectance record, *Intl. J. Remote Sens*, **31**, 6493 – 6517

-ISCCP calibration

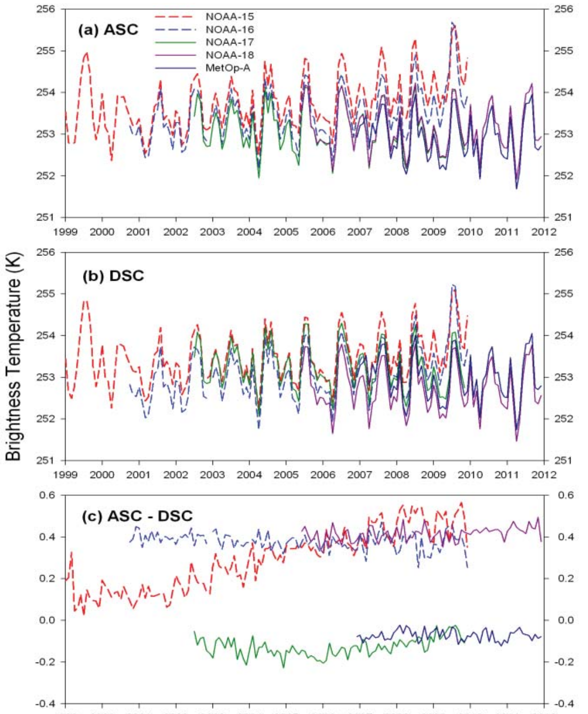


Monitoring Long-term Variations in Upper and Mid-tropospheric Water Vapor from Microwave Satellite Observations

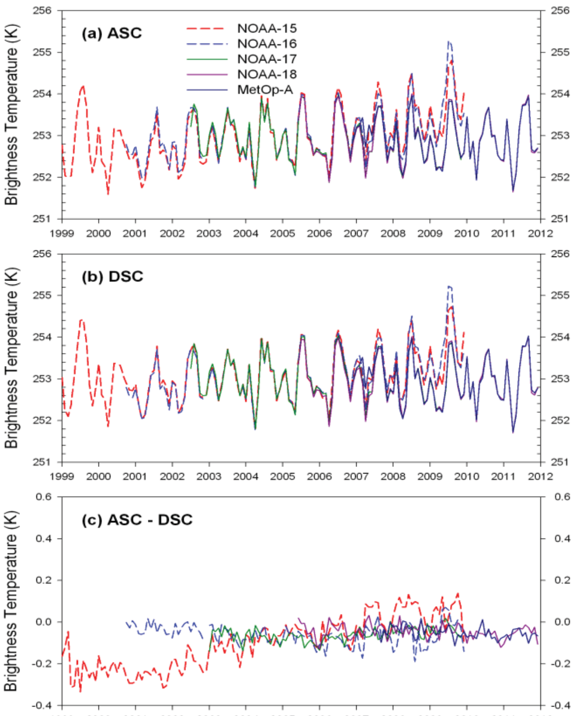
Eui-Seok Chung, Brian J. Soden, Rosenstiel School of Marine and Atmospheric Science, University of Miami; and Viju O. John, Met Office Hadley Centre, UK

Produce an accurate, continuous observational record of upper tropospheric water vapor to better understand water vapor feedback and to assess fidelity of climate models

Use archive of 183 GHz water vapor measurements from AMSU-B and MHS on-board polar orbiting satellites, cloud-filtered, limb-corrected for view angle and observation time differences



Time series of the tropical-mean 183.31±1 GHz brightness temperature for polar orbiting satellites with microwave humidity sounder AMSU (NOAA-15,-16, and -17) and MHS (NOAA-18 and MetOP-A): (top) ascending node, (middle) descending node, and (bottom) difference between ascending and descending nodes.

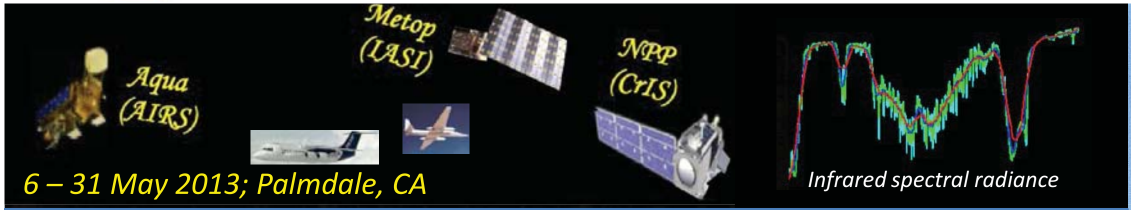


Time series of the diurnal sampling, bias-corrected inter-satellite calibrated, monthly tropical mean 183.31±1 GHz brightness temperature.

6. Joint NOAA/NASA Airborne Field Campaign in Support of SNPP Calibration and Validation

Joint NOAA / NASA Airborne Field Campaign in Support of Suomi NPP (SNPP) Cal/Val

Allen M. Larar, NASA Langley Research Center



6 – 31 May 2013; Palmdale, CA

Infrared spectral radiance

Purpose:

- *Cal/Val for SNPP sensors (CrIS, ATMS, VIIRS), algorithms, and data products (SDRs & EDRs)*
- Inter-platform comparisons between SNPP sensors and legacy systems on MetOp and Aqua (e.g. CrIS vs IASI vs AIRS)
- Advanced sounder science studies (e.g. convective tendencies, surface characterization, retrievals and radiative transfer modeling)

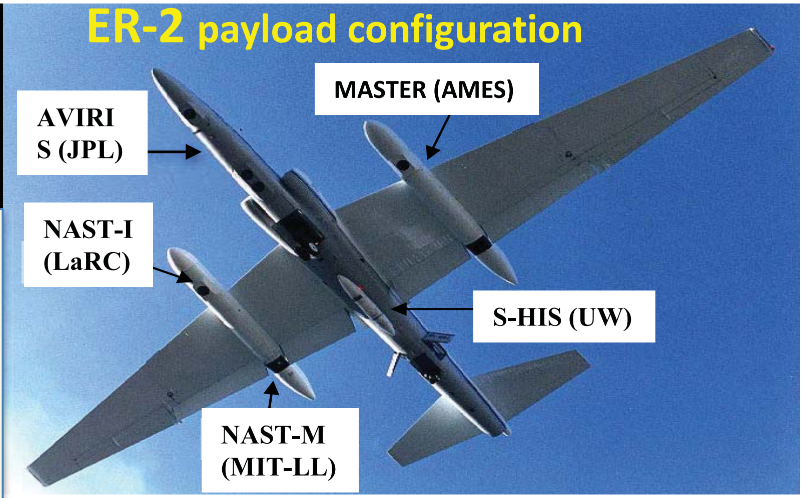
Approach:

- ER-2 aircraft under-flights of SNPP, Aqua, MetOP-A, and MetOP-B satellites
- Over-flight of several instrumented calibration ground sites (i.e. Salton Sea water site, DOE mobile site in Yuma, AZ; DOE CART site in Lamont, OK; NOAA, DOE, NGA measurements at the CarbonTracker tower in Moody, TX) including ground-based FTIR and radiosonde measurements
- Joint sorties with UK Met Office BAe146 aircraft based out of Tucson, AZ (fully instrumented with remote / in-situ sensors and dropsondes)

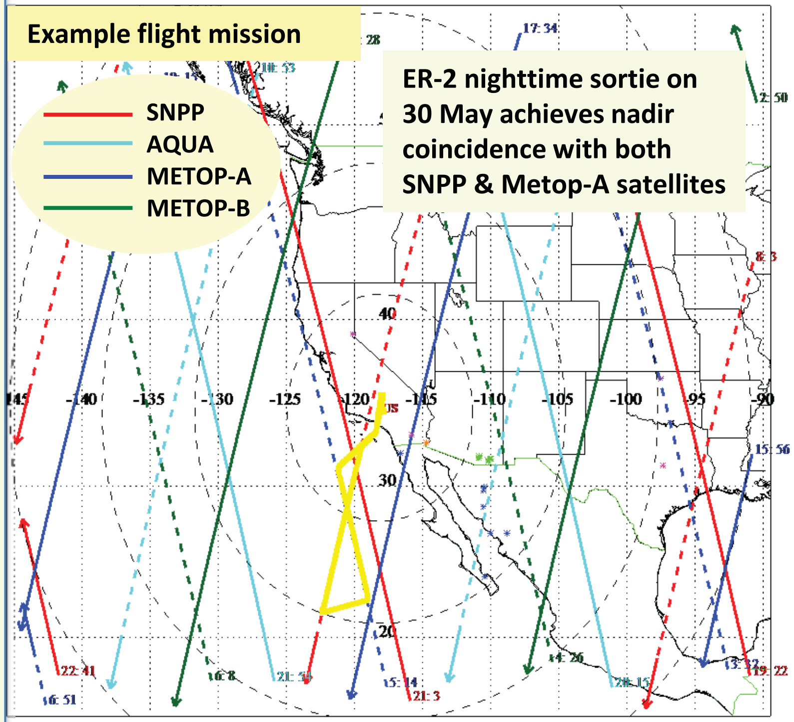
Summary:

- Implemented 11 science flights, ~ 70 flight hours, over varying surfaces and meteorological scenes (i.e. water, land, clear, cloudy,…)
- All flights achieved satellite coincidence (8 at s/c nadir); 9 days had coincidence with multiple s/c in single flight; 3 night flights implemented
- Diplomatic clearance enabled flights over Mexican airspace (i.e. Gulf of California and Baja California)
- Convective stability tendency flight captured Moore, OK tornado on 20 May

ER-2 payload configuration



SNPP cal/val campaign sub-satellite tracks & ground sites: 5 / 30 (Thu)



Example flight mission

ER-2 nighttime sortie on 30 May achieves nadir coincidence with both SNPP & Metop-A satellites

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  - Jack Xiong-NASA Goddard Space Flight Center
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  - Brian Kahn-NASA Jet Propulsion Laboratory
  - Simon Hook-NASA Jet Propulsion Laboratory
  - Pat Minnis-NASA Langley Research Center
  - Brian Soden-University of Miami
  - Allen Larar-NASA Langley Research Center