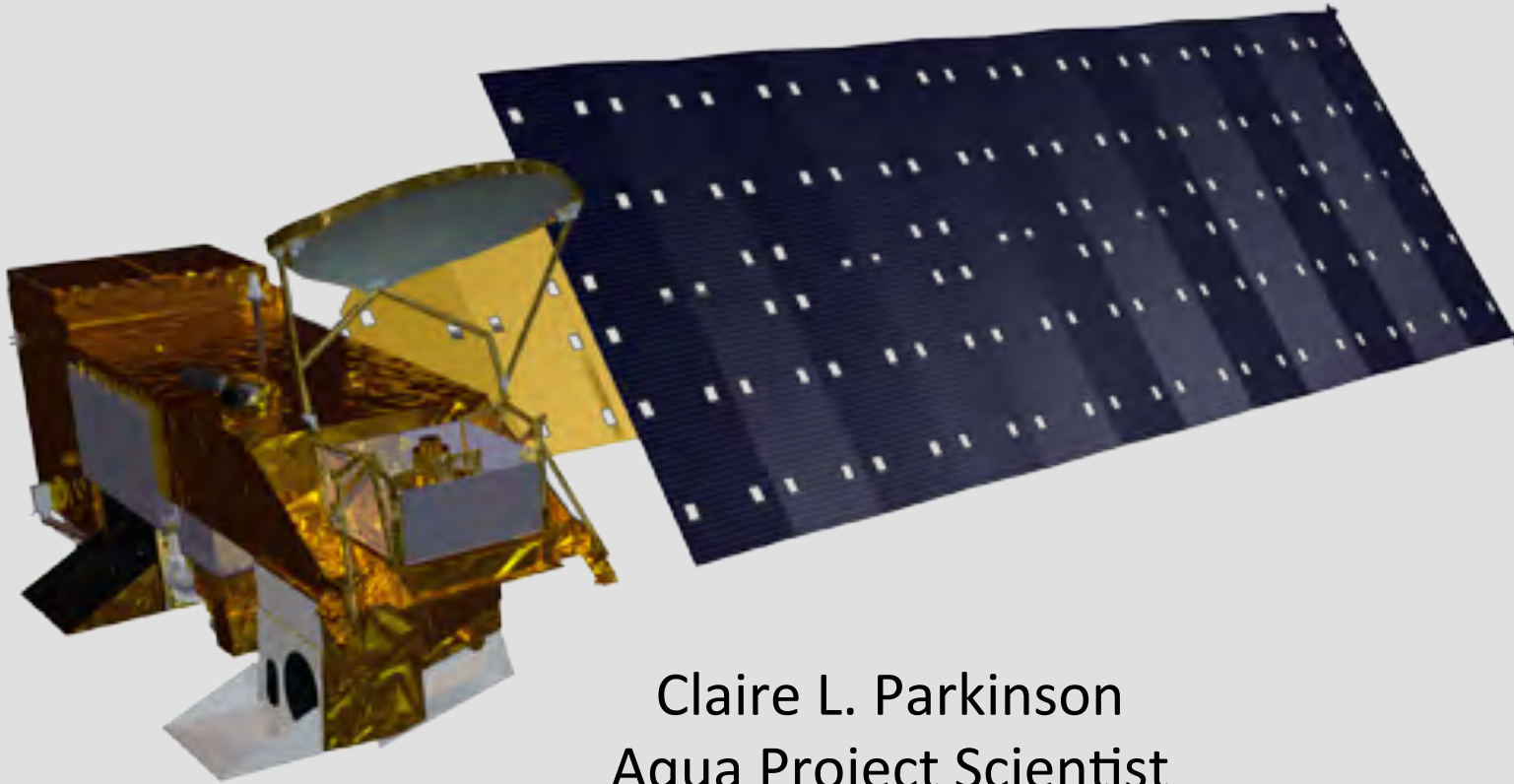


## Aqua Update



Claire L. Parkinson  
Aqua Project Scientist  
NASA Goddard Space Flight Center

Presented at the NASA Sounder Science Team Meeting,  
Greenbelt Marriott Hotel, Greenbelt, Maryland, October 13, 2015



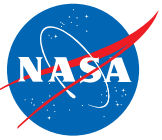
## Aqua Overview

- Aqua was launched on May 4, 2002, and has been in orbit around the Earth at an altitude of 705 km since then.
- Thousands of scientific publications have used Aqua data.
- Aqua data have also provided wide-ranging practical benefits.
- Mission success depends on many people.
- Enough fuel remains on board for Aqua operations at least through 2021.

(photo by Bill Ingalls)

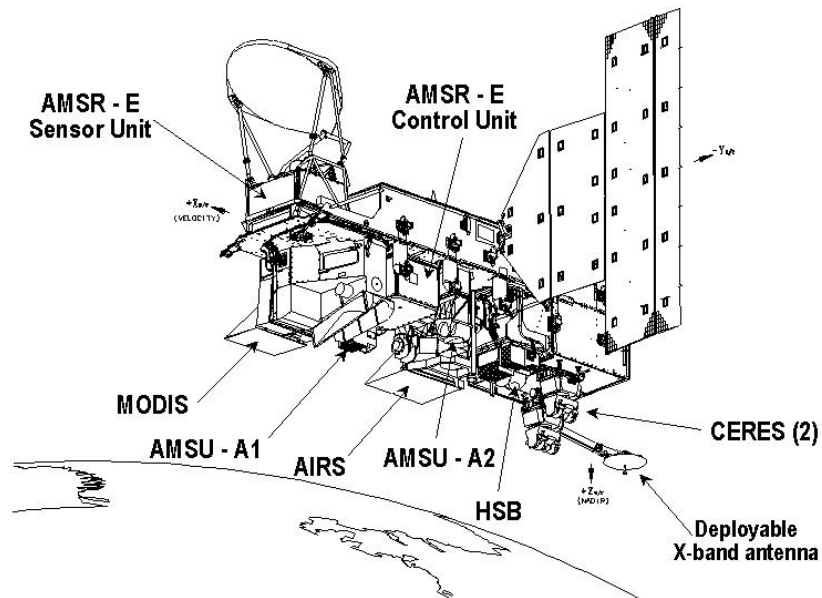


Aqua launch May 4, 2002



## Aqua's Instrument Suite

- AIRS: Atmospheric Infrared Sounder
- AMSU: Advanced Microwave Sounding Unit
- HSB: Humidity Sounder for Brazil
- CERES: Clouds and the Earth's Radiant Energy System
- MODIS: Moderate Resolution Imaging Spectroradiometer
- AMSR-E: Advanced Microwave Scanning Radiometer for the Earth Observing System



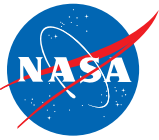
Aqua pre-launch (courtesy of Northrop Grumman)



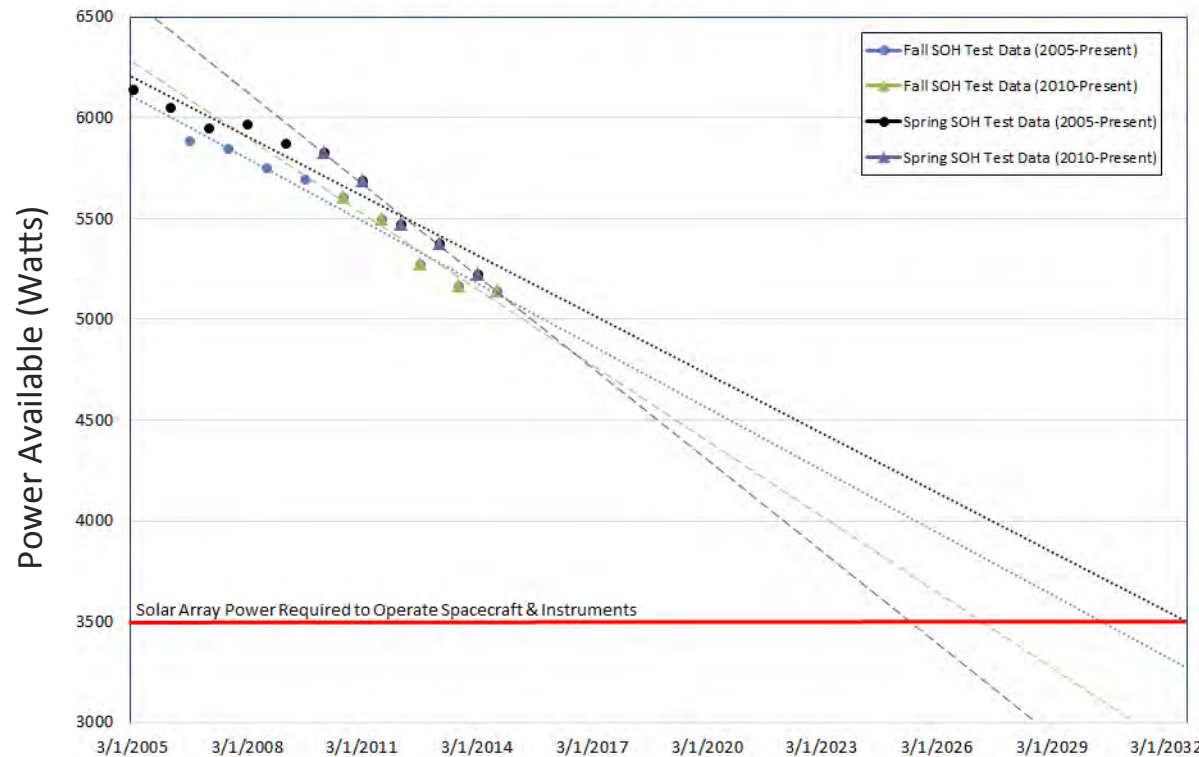
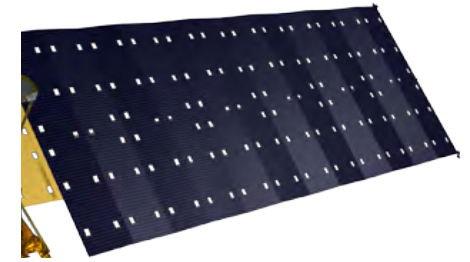


# Status of Aqua and Its Earth-Observing Instruments

- **Spacecraft Bus & Solar Array – Excellent health**
  - All components remain on primary hardware.
  - 121 of the 132 strings of solar cells continue to operate (11 have failed).
- **AIRS – Excellent health**
  - Only ~ 200 of 2378 infrared channels are degraded (due to radiation).
  - Cooler A telemetry has been frozen since 3/28/2014 but with no impact on science.
- **AMSU – Good health**
  - 12 of 15 channels continue to perform well (Channels 4, 5, and 7 are degraded and have been removed from Level 2 processing).
- **HSB (provided by Brazil) – Non-operational** since February 2003
- **CERES FM-3 – Excellent health**
  - All channels operational, with both cross-track and biaxial models fully functioning.
- **CERES FM-4 – Good-to-Marginal health**
  - Shortwave channel failed on 3/30/2005; the two other channels remain operational.
- **MODIS – Excellent health**
  - All components remain on primary hardware.
  - Two of four 10 W lamps used for calibration have failed.
- **AMSR-E (provided by Japan) – Poor health**
  - Operating at a reduced rotation rate (2 rpm versus 40 rpm), primarily for cross-calibration with AMSR2.
  - Plan to spin down to 0 rpm and turn off at the end of October 2015.

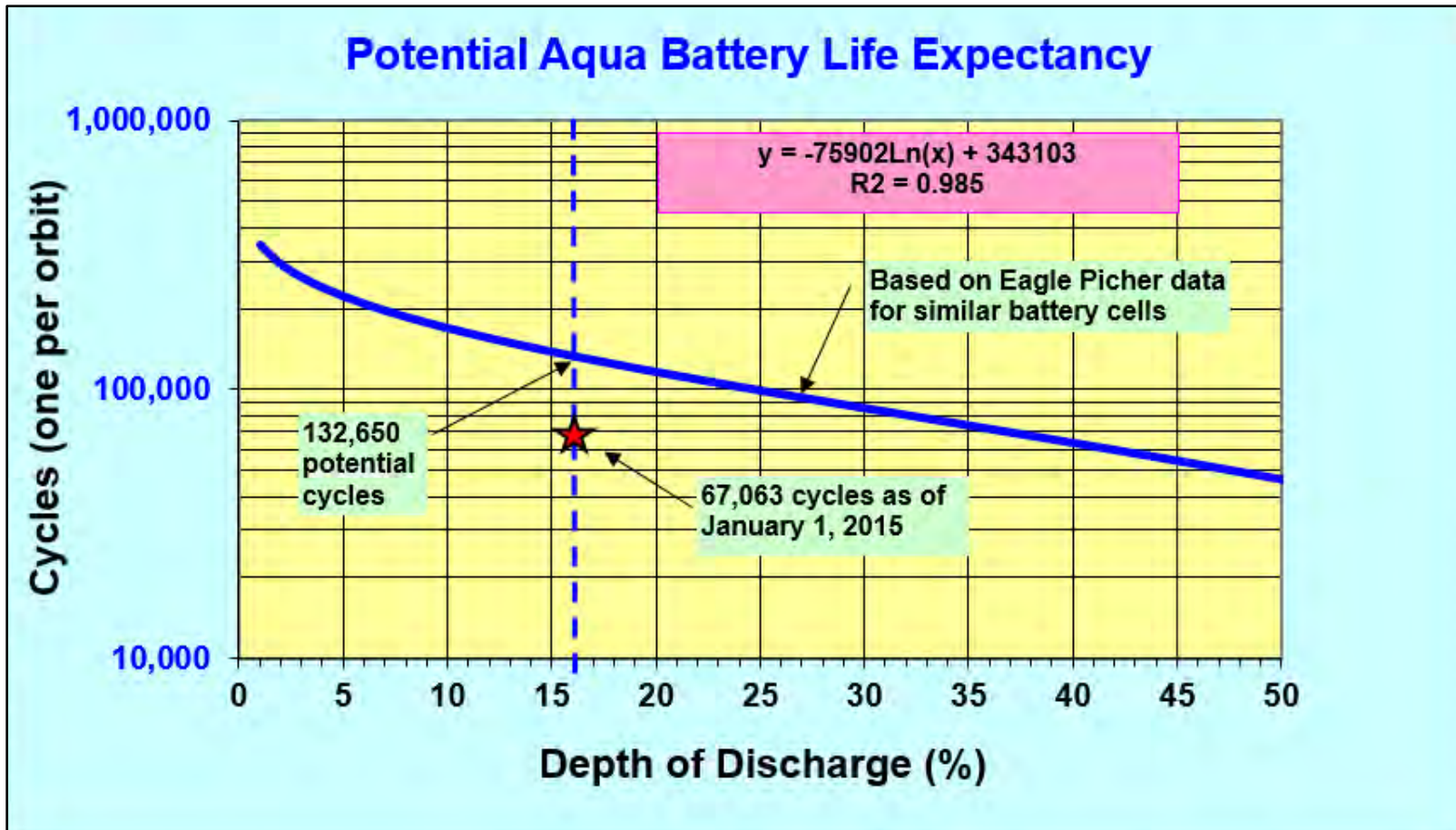


## Past and Projected Output of the Aqua Solar Array, based on spring and fall state-of-health (SOH) tests



- The Aqua solar array has 132 strings of solar cells, 121 of which continue to perform nominally.
- The solar array has experienced an anticipated normal slow degradation.
- All projections indicate that the solar array will continue to generate enough power to support all spacecraft and instrument operations at least to 2025.

(plot from the 2015 Aqua Senior Review proposal)

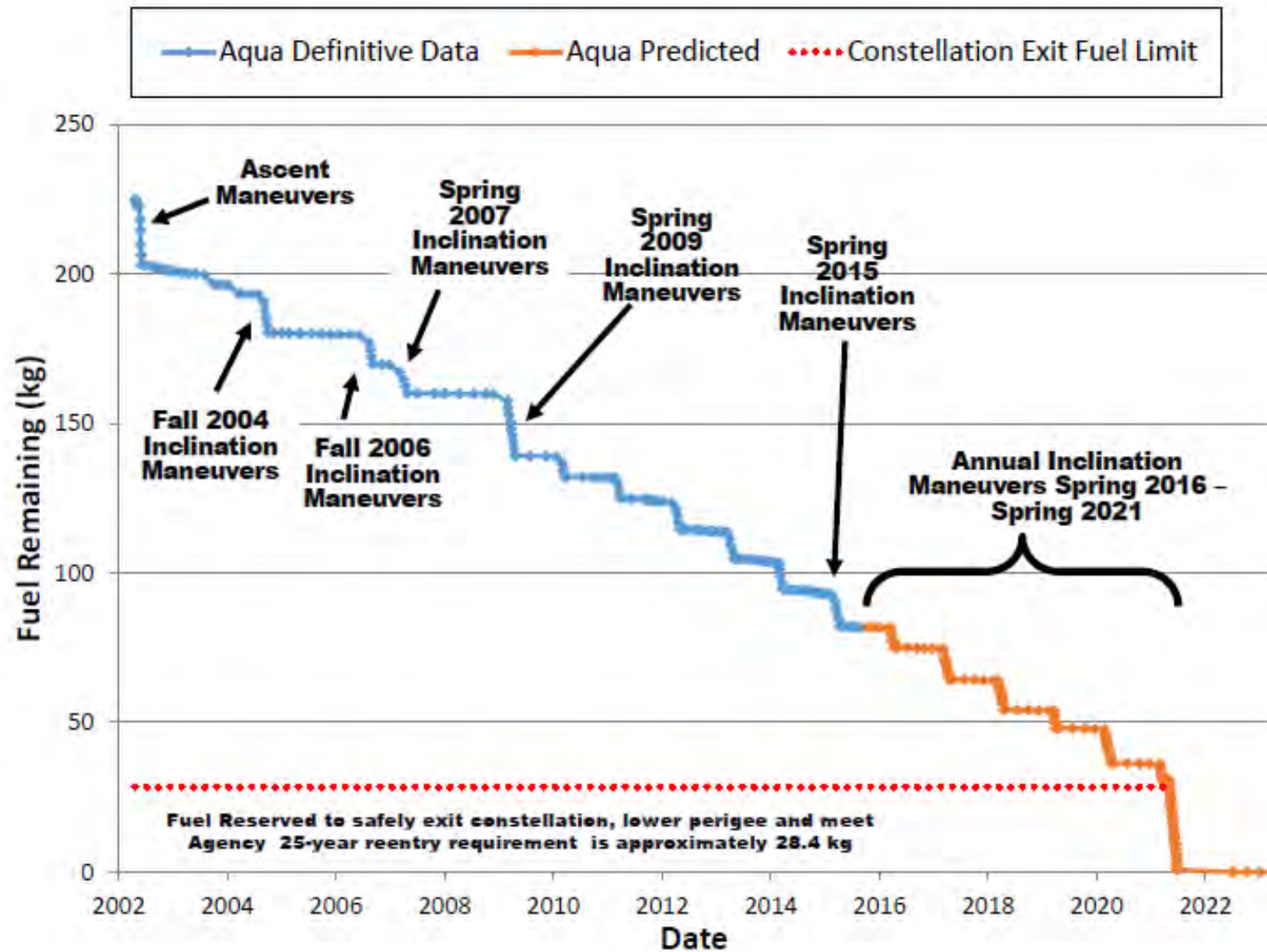


- The Aqua battery's typical depth of discharge is 15-16% (dashed blue line).
- With 16% depth of discharge, we can expect the battery to last for 132,650 orbits around the Earth based on the manufacturer Eagle Picher's data (solid blue curve).
- Aqua would reach 132,650 orbits in April 2027.

(plot from the 2015 Aqua Senior Review proposal)

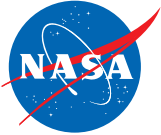


## Fuel Usage: Actual and Predicted



(plot from NASA Earth Science Mission Operations [ESMO])

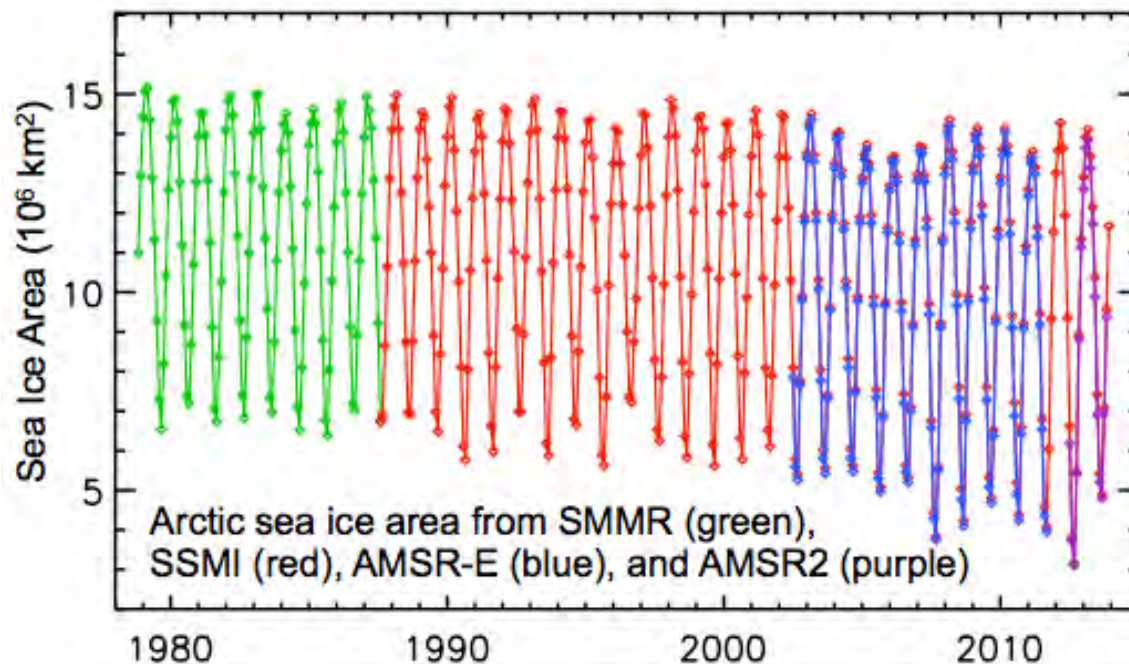




## AMSR-E



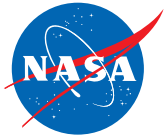
- The Japan Aerospace Exploration Agency (JAXA) plans to have NASA turn off AMSR-E by the end of October 2015.
- Most members of the U.S. AMSR-E Science Team are also members of the U.S. science team for AMSR2, launched into the A-Train on JAXA's Global Change Observation Mission - Water (GCOM-W) satellite in May 2012.
- The U.S. AMSR2 team is extending most of the Aqua AMSR-E data records with AMSR2 data (see sample plot below, for Arctic sea ice area), the main exception being the omission of the sea surface temperature (SST) product.



SMMR = Scanning Multichannel  
Microwave Radiometer  
SSMI = Special Sensor Microwave  
Imager

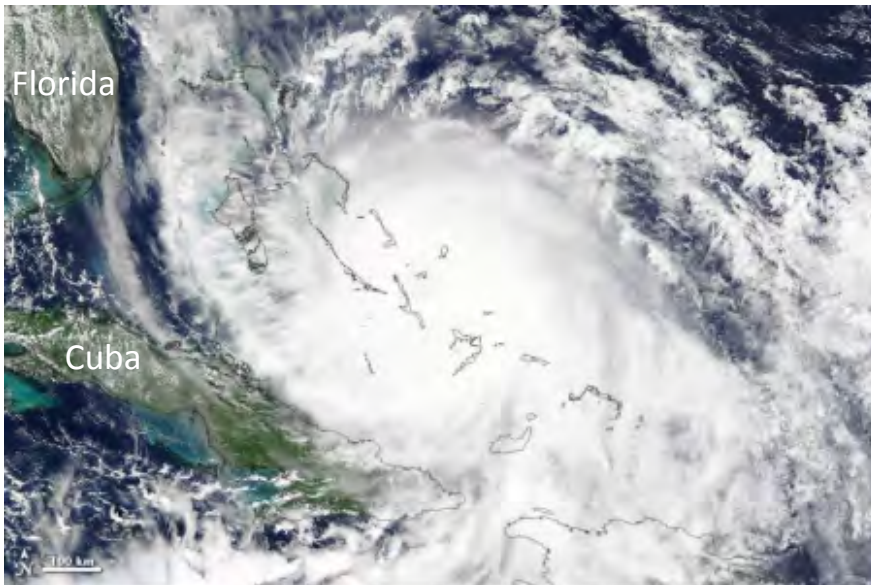
(plot from J. Comiso, 2015,  
with relabeling)



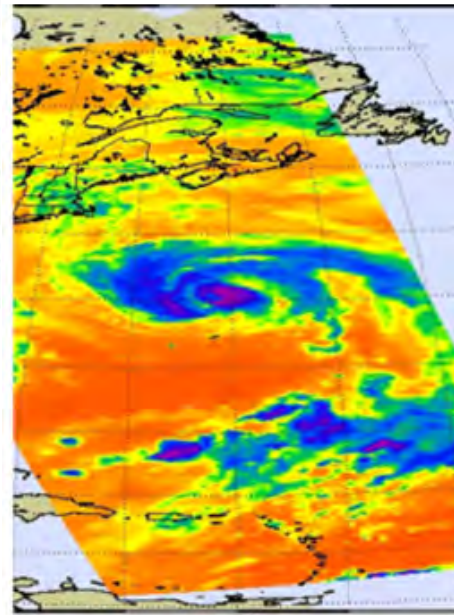


## Aqua Visible and Infrared Imagery of Hurricane Joaquin

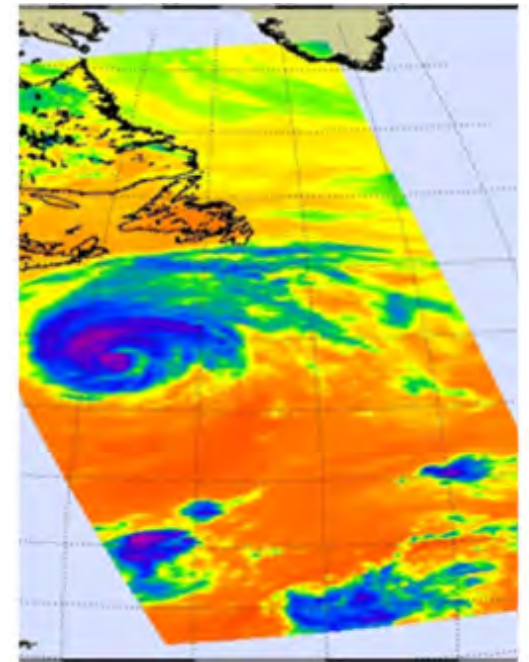
MODIS Visible Image, October 2, 2015



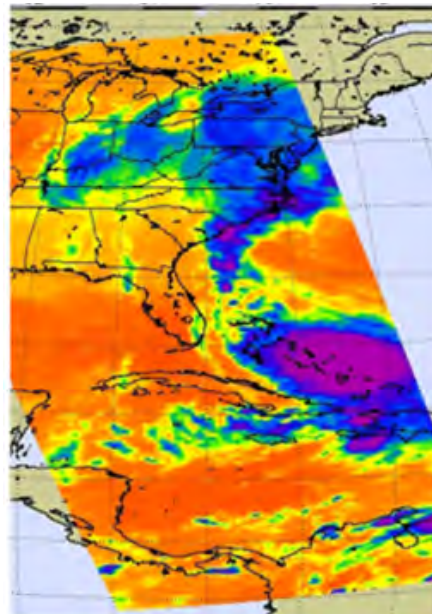
AIRS Infrared Images, October 2-6, 2015



October 5, 2015

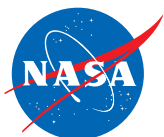


October 6, 2015



October 2, 2015

(AIRS images from Ed Olsen;  
MODIS image from [visibleearth.nasa.gov](http://visibleearth.nasa.gov))



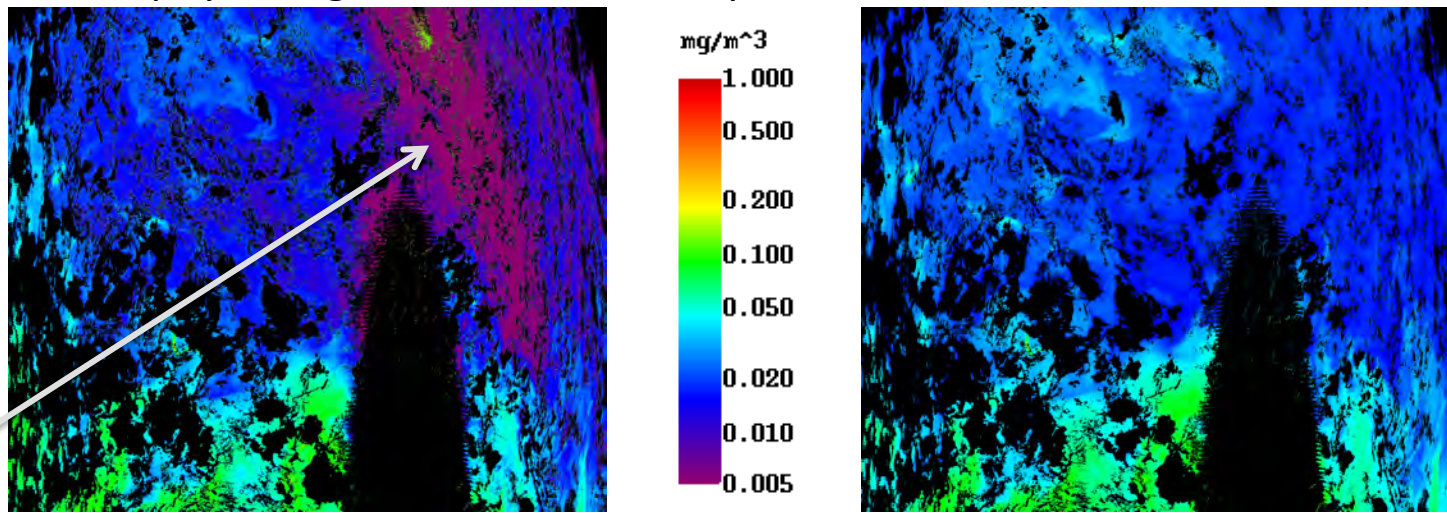
## Key Recent MODIS Ocean Color Enhancements

- An improved Chlorophyll  $a$  algorithm has been implemented.

Left: Sample Chlorophyll  $a$  image with old algorithm

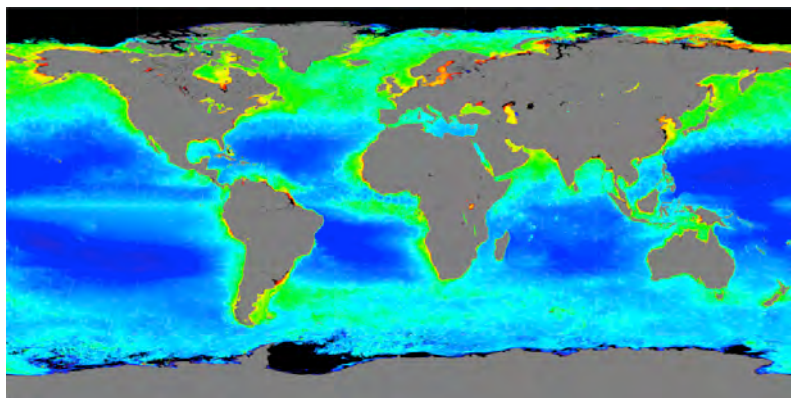
Right: Same image with new algorithm

uncorrected sun glint

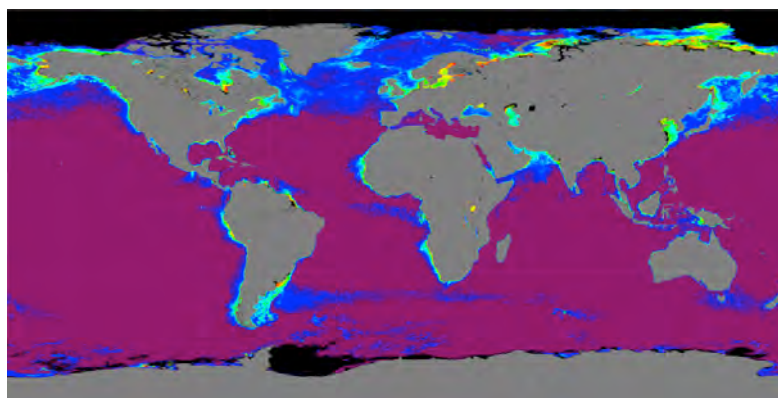
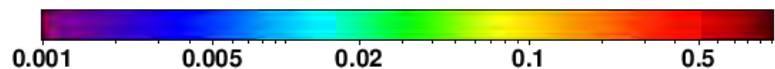


- A new suite of inherent optical property (IOP) products was added, each with root-mean-square uncertainty estimates for each pixel (see sample below).

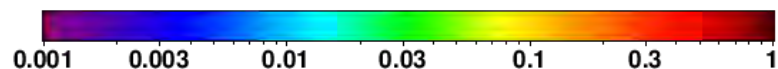
Sample New MODIS Ocean Color Product and Its Mapped Uncertainties



Absorption due to gelbstof and detritus at 443 nm ( $\text{m}^{-1}$ )

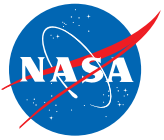


Uncertainty on absorption due to gelbstof and detritus at 443 nm ( $\text{m}^{-1}$ )



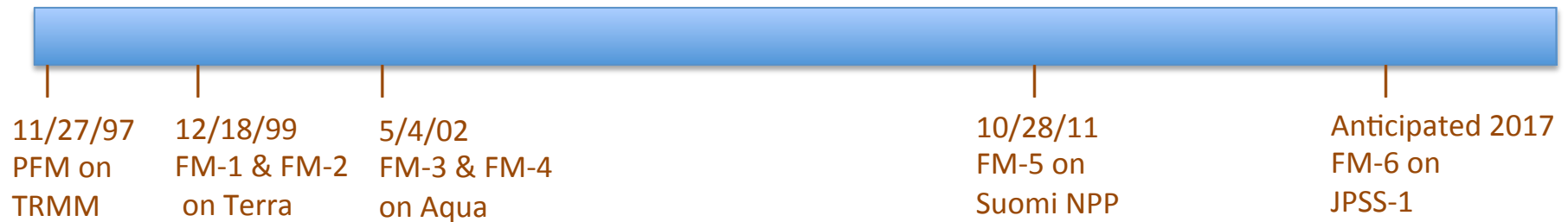
(maps from  
B. Franz,  
2015)



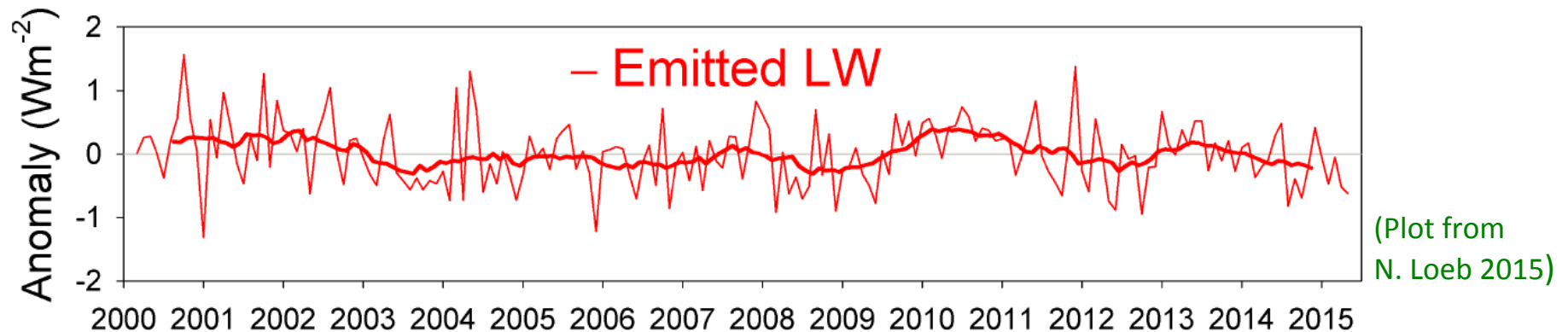


# CERES

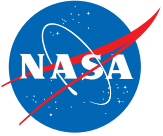
## Schematic timeline of CERES launches



- CERES instruments are currently in orbit on Terra, Aqua, and the Suomi National Polar-Orbiting Partnership (NPP).
- The CERES Science Team is using the CERES instruments in conjunction with other satellite instruments to determine, map, and plot absorbed solar radiation, emitted longwave radiation, and net radiation, and to examine these in the context of climate change.



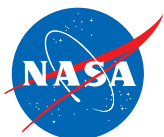
PFM = Protoflight Model; FM = Flight Model; JPSS = Joint Polar Satellite System



## 2015 Aqua Senior Review

- The Aqua Senior Review is a major proposal to secure funding for Aqua for at least the next two years; it was submitted on time to NASA Headquarters (HQ) on 3/3/2015.
- The Senior Review Panel submitted questions to the Aqua team on 4/13/15 and received responses in a presentation before the Panel on 4/29/2015.
- The Senior Review Panel's final report, dated June 22, 2015, reviewed 10 missions, scoring several very highly and ranking Aqua at the top.
- The official letter from NASA HQ was received on 9/23/2015 and contained praise for the Aqua mission and the Senior Review proposal and guidelines to continue the mission with the proposed baseline budget.
- A response is due to NASA HQ on 10/30/2015.



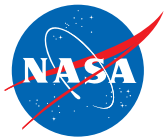


# Aqua Senior Review Title Page and Table of Contents



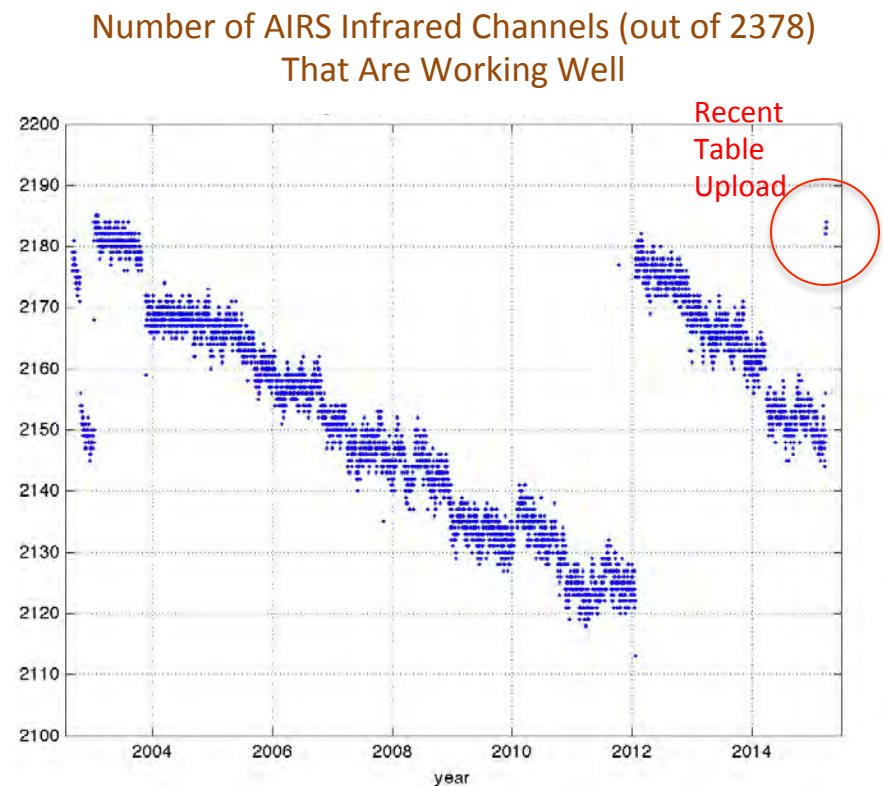
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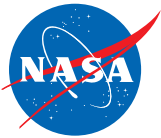


## AIRS Updates between the Submission of the Senior Review Proposal and the Presentation to the Senior Review Panel

- A new gain table was uploaded to the AIRS instrument, recovering about 30 channels whose noise had increased due to radiation effects in the detectors (see figure).
- The new AIRS Level 1C Product Generation Executable and User Documentation were delivered to the Goddard Earth Sciences Data and Information Services Center (GES/DISC).



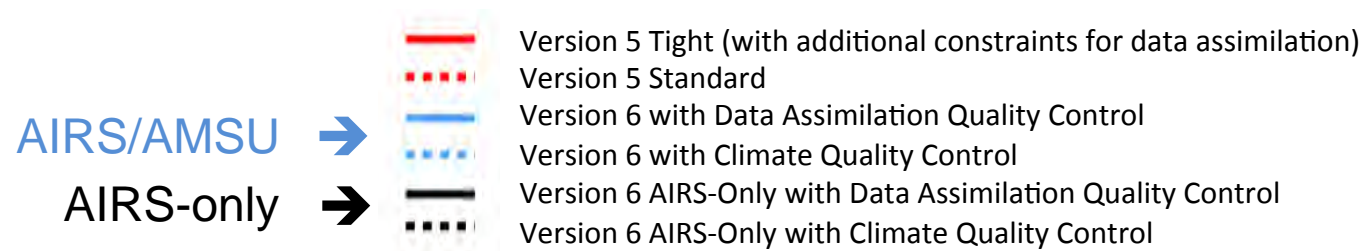
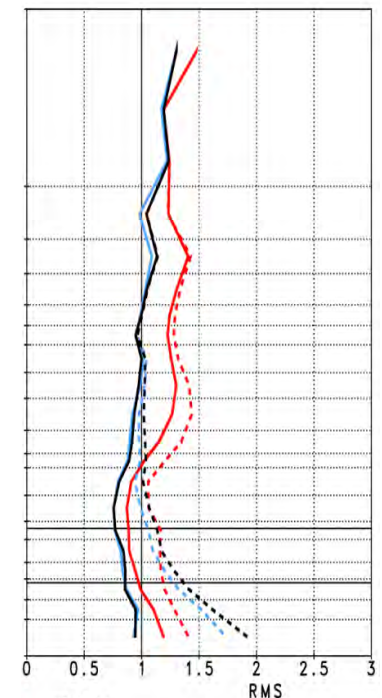
(plot from the AIRS Project, 2015)

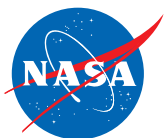


## Sole AIRS/AMSU Specific Request from the Senior Review Panel: Describe the science impact of the loss of the AMSU channels

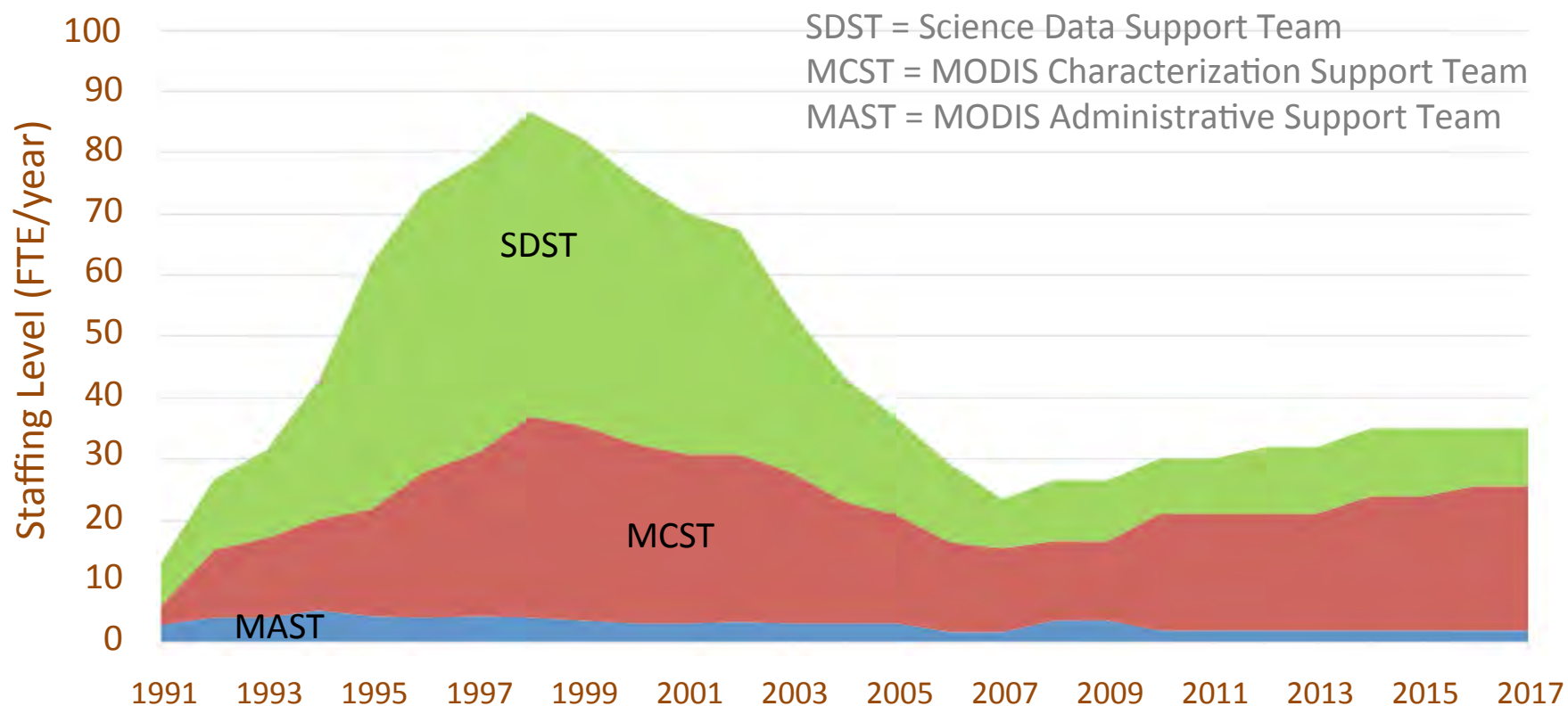
- Loss of AMSU channels 4, 5, and 7 causes slightly greater uncertainties in lower tropospheric temperatures, mitigated by an improved first guess in the Version 6 retrieval algorithm.
- The entire AIRS record is generated and made publicly available using an AIRS-only algorithm as well as the AIRS/AMSU algorithm. The AIRS-only algorithm has slightly reduced yield and increased uncertainties, especially in cloudier regions.

Layer Mean RMS (K)  
Differences from ECMWF



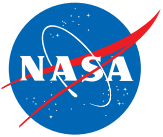


## MODIS Support Team Staffing Over Time



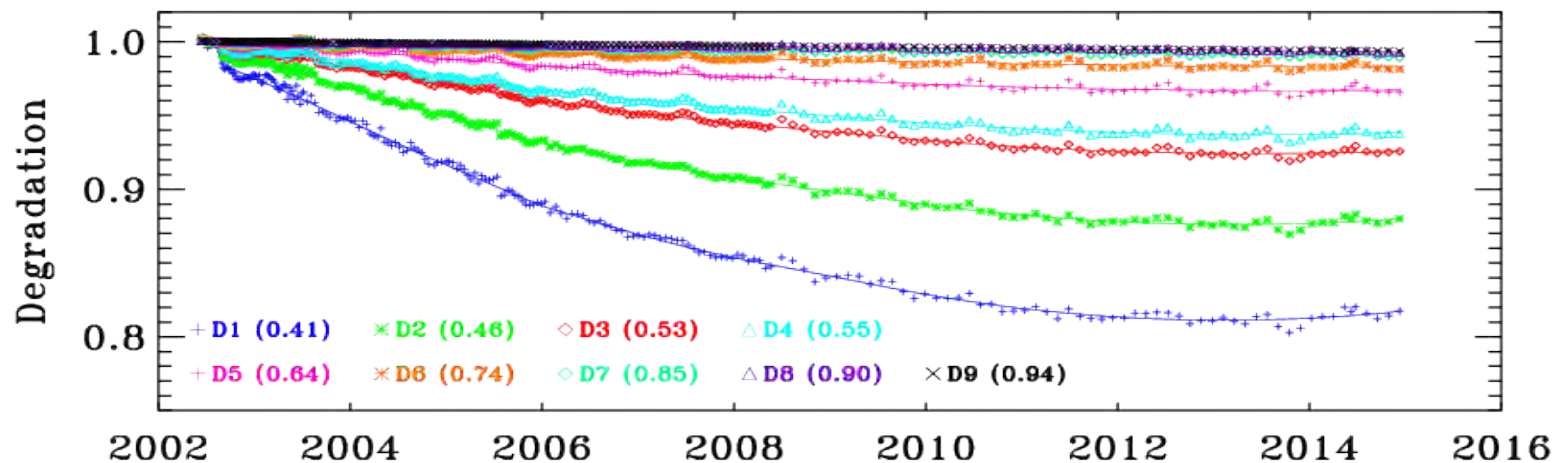
(data from E. Masuoka, 2015)





## Rationale for Increased Funding for the MODIS Characterization Support Team

- Solar Diffuser (SD) degradation (see plot) has reached the point where degradation can begin to be expected for wavelengths above 0.94  $\mu\text{m}$ , warranting new corrections. (Degradation at 0.94  $\mu\text{m}$  has reached 1%.)
- Frequent updates of calibration lookup tables are needed for both Collection 5 and Collection 6.
- The Terra MODIS has experienced on-orbit changes in sensor polarization sensitivity and associated large impacts on Earth view response trending. Such changes could start occurring with the Aqua MODIS as well.
- For accurate calibration, it is necessary to accurately track changes in sensor response versus the scan angle, or angle of incidence, for each of the 36 MODIS bands and each mirror side.



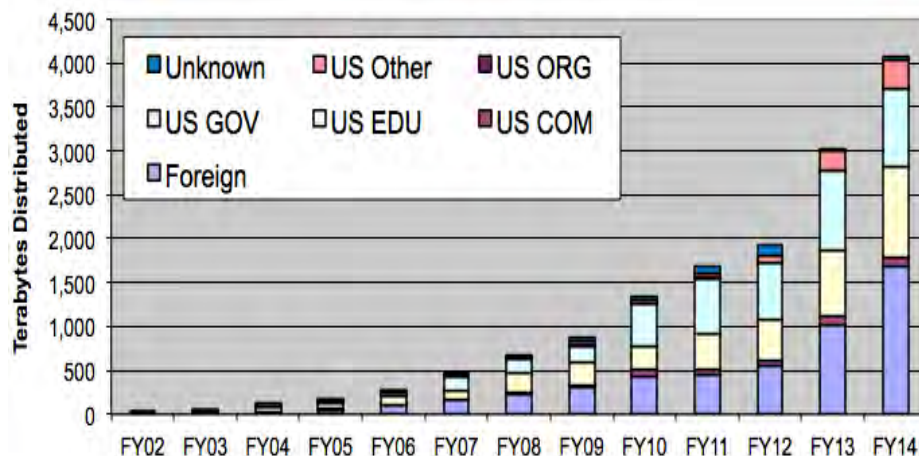
(plot from the 2015 Aqua Senior Review proposal)



## Summary

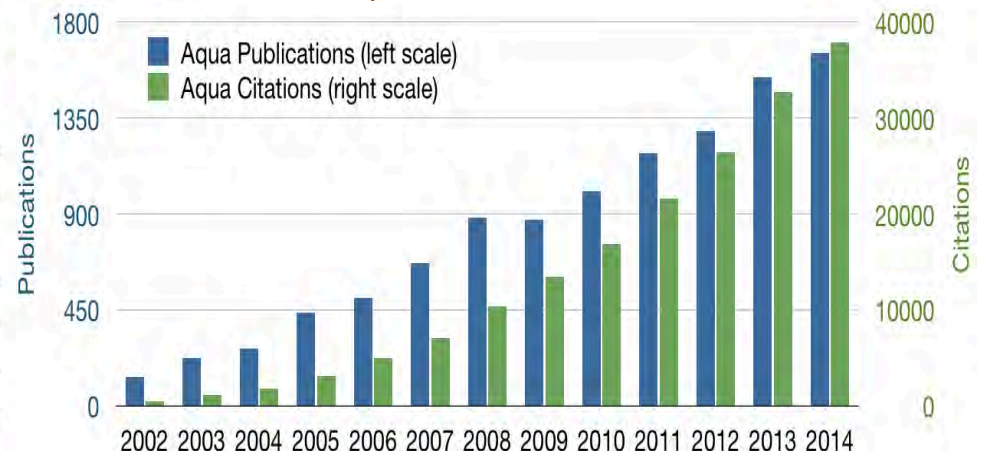
- Aqua is doing well, over 13 years after launch.
- AIRS/AMSU, CERES, and MODIS continue to transmit high-quality data.
- The mission could well continue through 2021 (with fuel the likely limiting factor).
- Users have downloaded well over 12 million gigabytes of Aqua data; and thousands of publications have incorporated Aqua data.
- The 2015 Aqua Senior Review proposal was very favorably reviewed, and NASA HQ has agreed to continue funding the mission for at least the next two years.

Terabytes of Aqua Data Distributed to Users



[ORG, GOV, EDU, and COM signify the internet addresses .org, .gov, .edu, and .com]

Number of Aqua Publications and Citations



[Publication data are from the Web of Science and include Terra CERES and MODIS data as well as Aqua data]

(plots from the 2015 Aqua Senior Review proposal)