Performance of the Atmospheric Infrared Sounder (AIRS) in the Radiation Environment of Low-Earth Orbit

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Earth Observing Systems X Conference
SPIE Annual Meeting, San Diego, CA
August 2, 2005

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Outline

- Introduction
- AIRS overview
- AIRS detector stability
- Anomalies attributed to radiation effects
- Conclusions

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Introduction

- **AIRS has been operational for nearly 3 years (since Sept. ’02)**
  - ***In sun-synchronous polar orbit – low-earth orbit (LEO) on Aqua***
  - ***Makes frequent passages through the South Atlantic Anomaly where it is subject to high radiation doses***
- **AIRS has shown excellent stability and operability throughout the mission**
  - ***Careful attention was paid to radiation effects during the design***
  - ***Smoothing of the calibration data eliminates most radiation effects; system of flags alerts user of remaining anomalies***
- **Some anomalies have been attributed to radiation effects**
  - ***Transients in the calibration data***
  - ***A few degraded channels and channels with increased noise***
  - ***Temporary operational anomalies***

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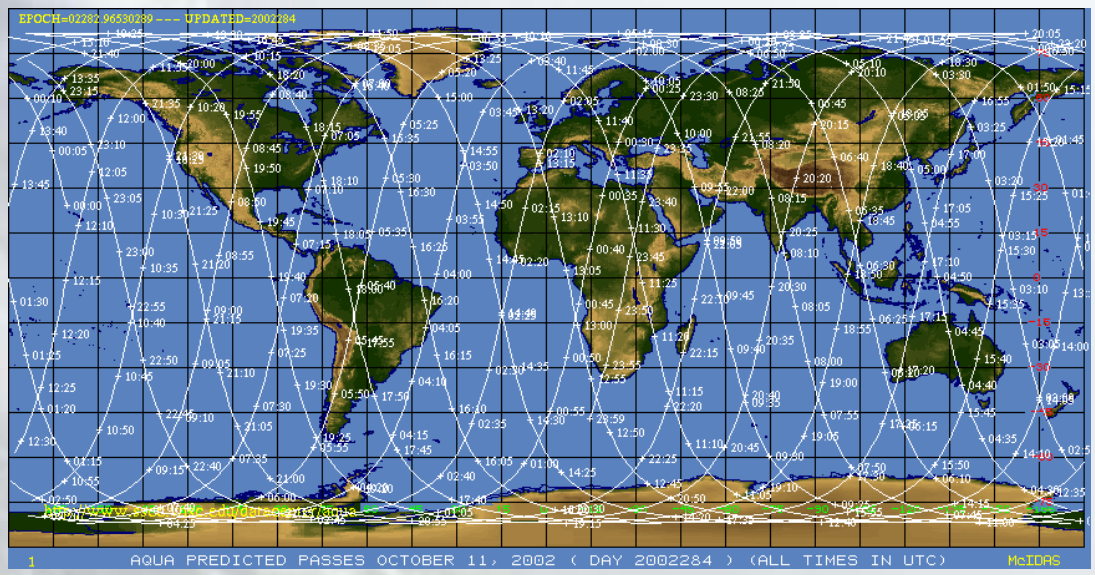
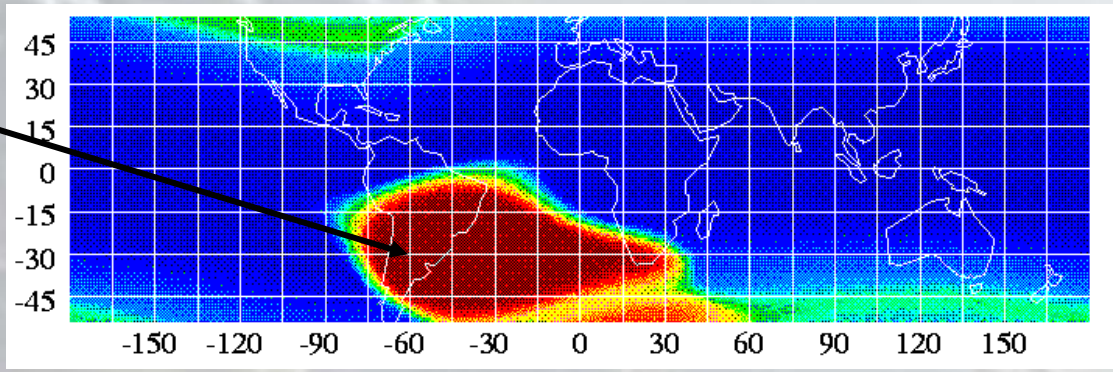
South Atlantic Anomaly

- **The Aqua satellite makes several passages per day through the South Atlantic Anomaly (SAA), where it is subjected to high radiation levels**





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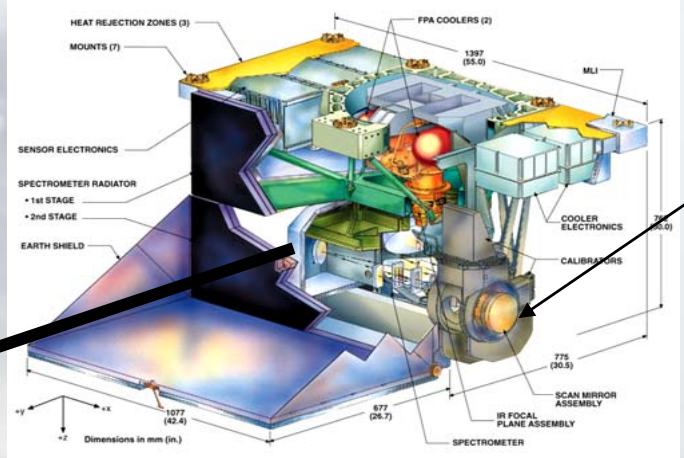
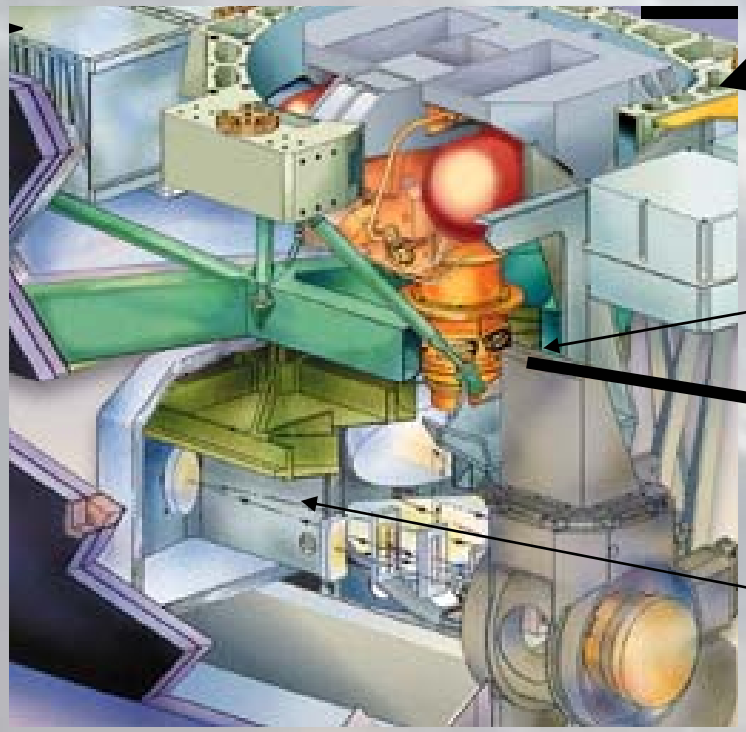
AIRS Configuration Details

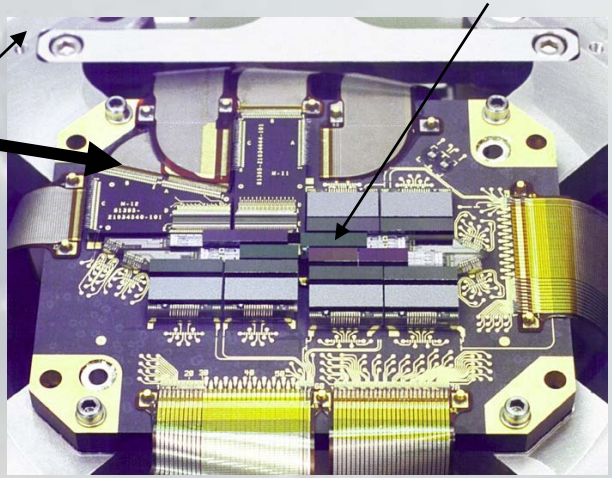


Scan Head Assembly



Detector / dewar (58K)

Focal Plane Array with 2378 IR Detector Channels (Most A/B redundant)



Grating Spectrometer (157K)

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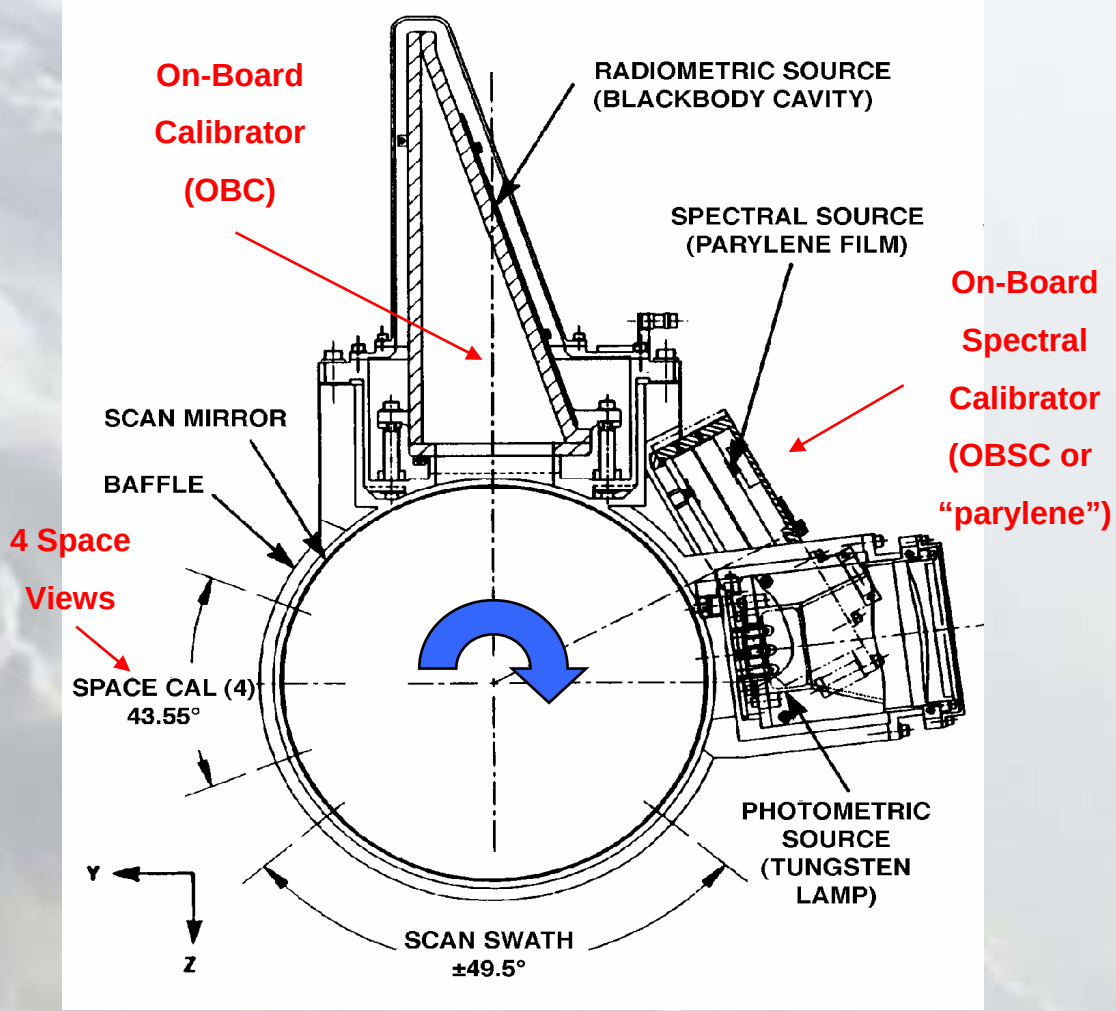
Scan Mirror and Calibrators

- **Most radiation effects have been detected during views of the calibration sources**
- **The space and OBC views are used to calculate the offset and the Noise-Equivalent Temperature Difference (NEdT)**
- **The offset-subtracted OBC response is used to calculate the gain**



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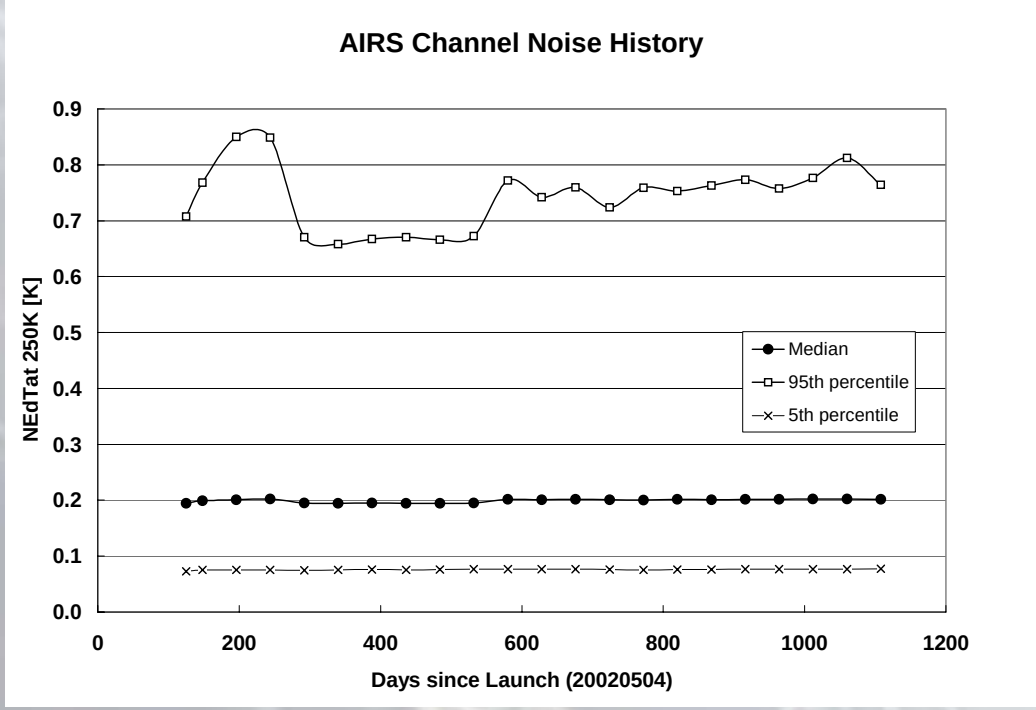
AIRS Channel Stability



- **The NEdT statistics illustrate the overall stability of the AIRS channels. Most of the variation in the 95th percentile NEdT can be attributed to small changes in the FPA temperature, primarily in the on-orbit activation and evaluation phase**

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Anomalies Attributed to Radiation Effects

- **Pops**
- **Spikes**
- **Radiation damage / total dose effects**
- **Operational anomalies**

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Pops

- **Pops are steps in the calibration data**
  - ***The L1B pop flag is set whenever all 6 calibration looks have a step between scans of greater than 7 times the standard deviation of the space look differences for the granule (6 minutes or 135 scans) and all 6 steps are in the same direction***
- **The name comes from the similarity to rapid telegraph signal or popcorn noise**

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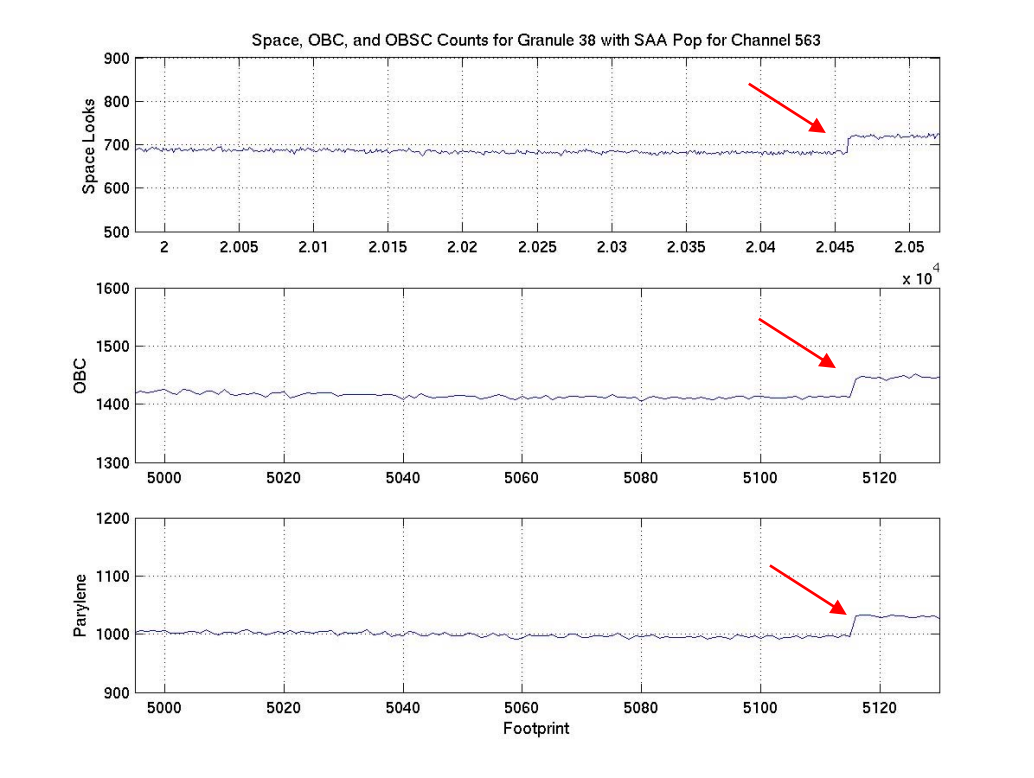
Example of a Pop



- **The footprint numbers are counted from the beginning of the day, and there are 4 space looks, one OBC look and one parylene (OBSC) look per scan, and 135 scans per granule (6 minutes of data)**

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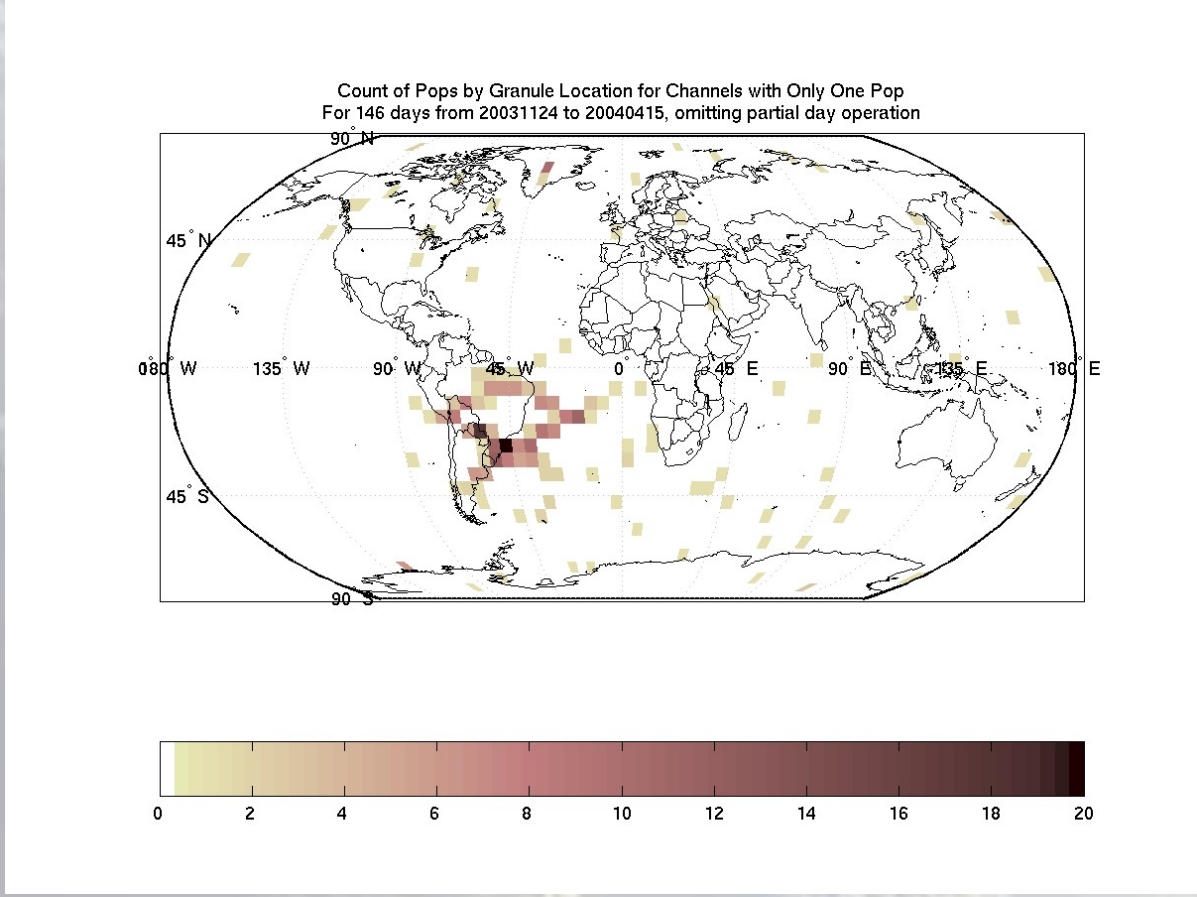
Pops Occur Mostly in the SAA



- **The grid is a sampling artifact of using granule centers**

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Pops Are Attributed to Radiation

- **The vast majority of pops occur when AIRS is in the SAA, where radiation levels are high**
- **They occur only for modules for which DC restore is implemented**
  - ***This is the periodic resetting of the read-out integrated circuit (ROIC) output voltage level, needed to compensate for drift***
  - ***These are modules M3 – M10 (6.20 – 13.75 μm)***
- **The pops are probably the result of radiation-induced charge in the large DC restore capacitor**
- **These are very rare events (337 for 1590 channels in one 146-day period)**
  - ***It is still important to monitor the flags to avoid anomalous data***

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Spikes

- **Spikes occur in the AIRS channel data due to radiation effects in the detector material**
  - ***Such effects were anticipated, and the signal processing system was designed to suppress them***
  - ***Each AIRS footprint consists of 8 or 16 subsamples. When circumvention is engaged, peaks in the 2nd differences between subsamples are removed from the subsample average***
- **Because of anomalous effects in some modules, circumvention was engaged only for the short-wavelength modules (M1 – M4, 3.73 – 4.61 μm) where radiation-induced spikes were significant**
- **Infrequent spikes have been detected in the calibration data for the other modules**

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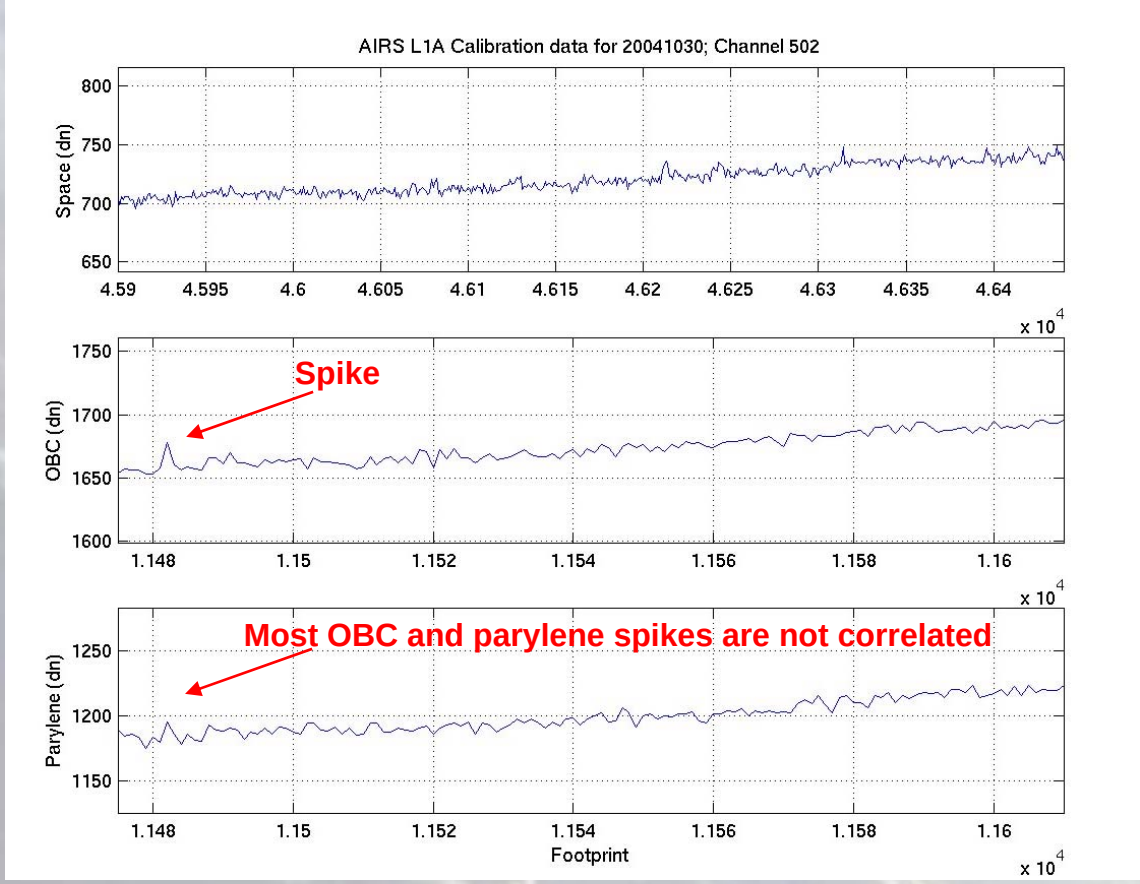
Example of a Spike



- **Spikes were detected by finding large values of the second difference between calibration looks in successive scans**

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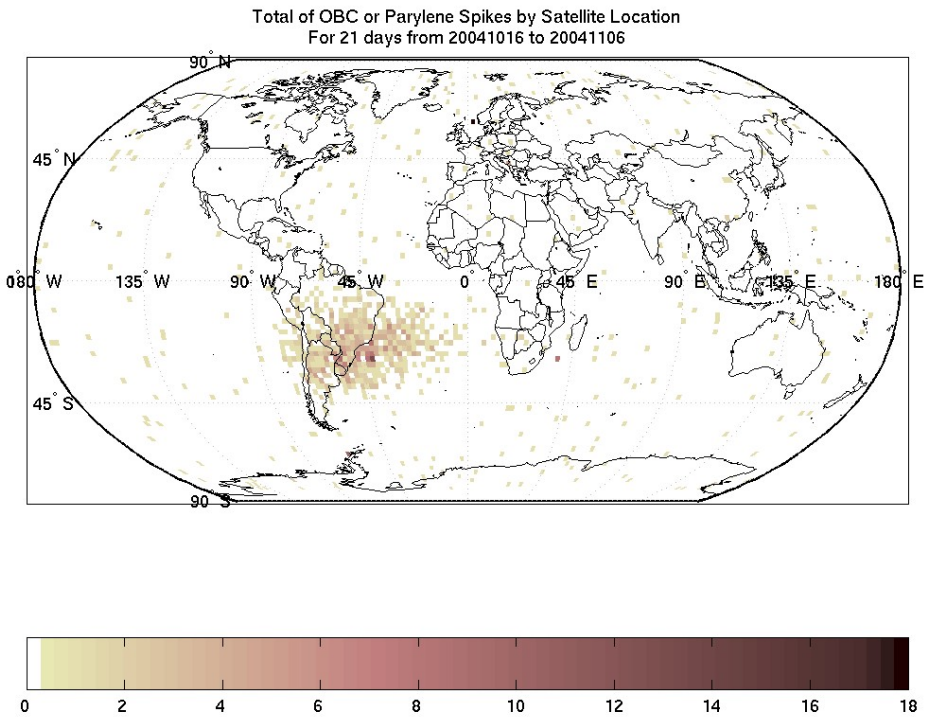
Most Spikes are Also in the SAA



Statistical estimate:

- **5 SAA granules/day**
- **135x90 earth scene footprints/granule**
- **For each M5 – M10 channel there is a 50% probability of one earth scene footprint with a spike**

- **Location of nadir footprint is plotted here, avoiding sampling artifacts**

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Radiation Damage

- **A total of 22 channels in 32 months of operation showed large increases in noise following an apparent charge injection event, almost always in the SAA although there were a few near the poles, where radiation levels are also high for the Aqua orbit**
- **One channel recovered after a few granules**
- **If the FPA is warmed to about 200K trapping states can change and radiation effects anneal**
- **The channels that degraded before the last FPA thermal cycle were found to have fully recovered when the FPA was restarted**

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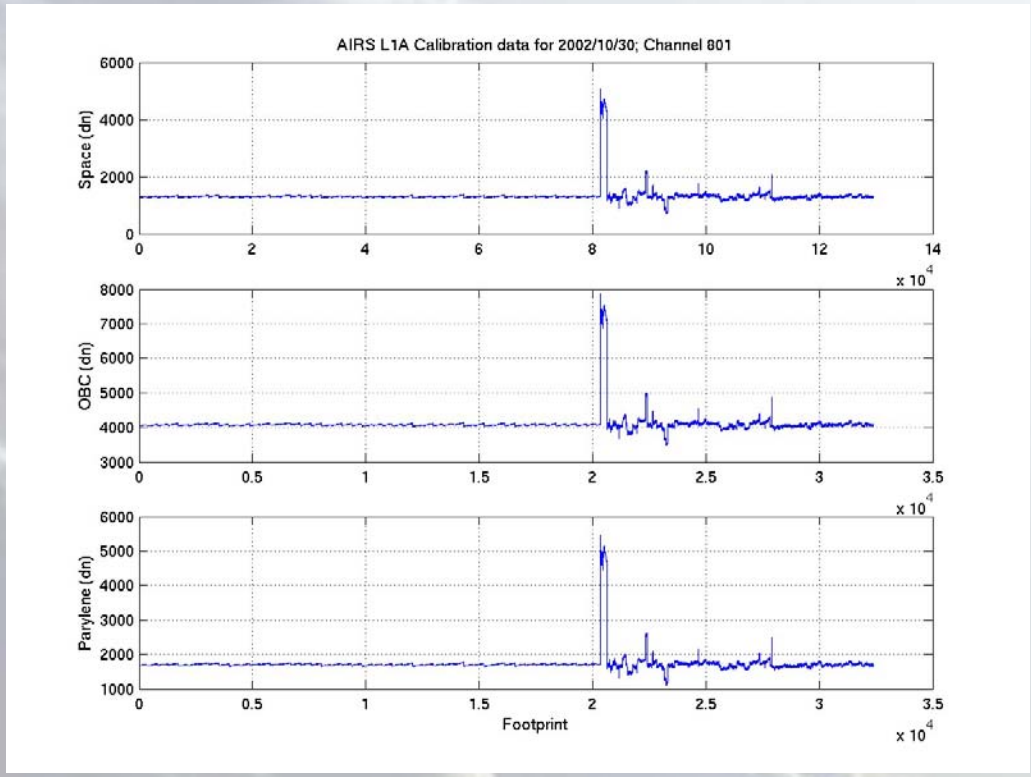
Example of a Radiation Hit



- **This is a plot of the calibration data for an entire day**
- **The channel was very noisy after the event, but still had optical response**

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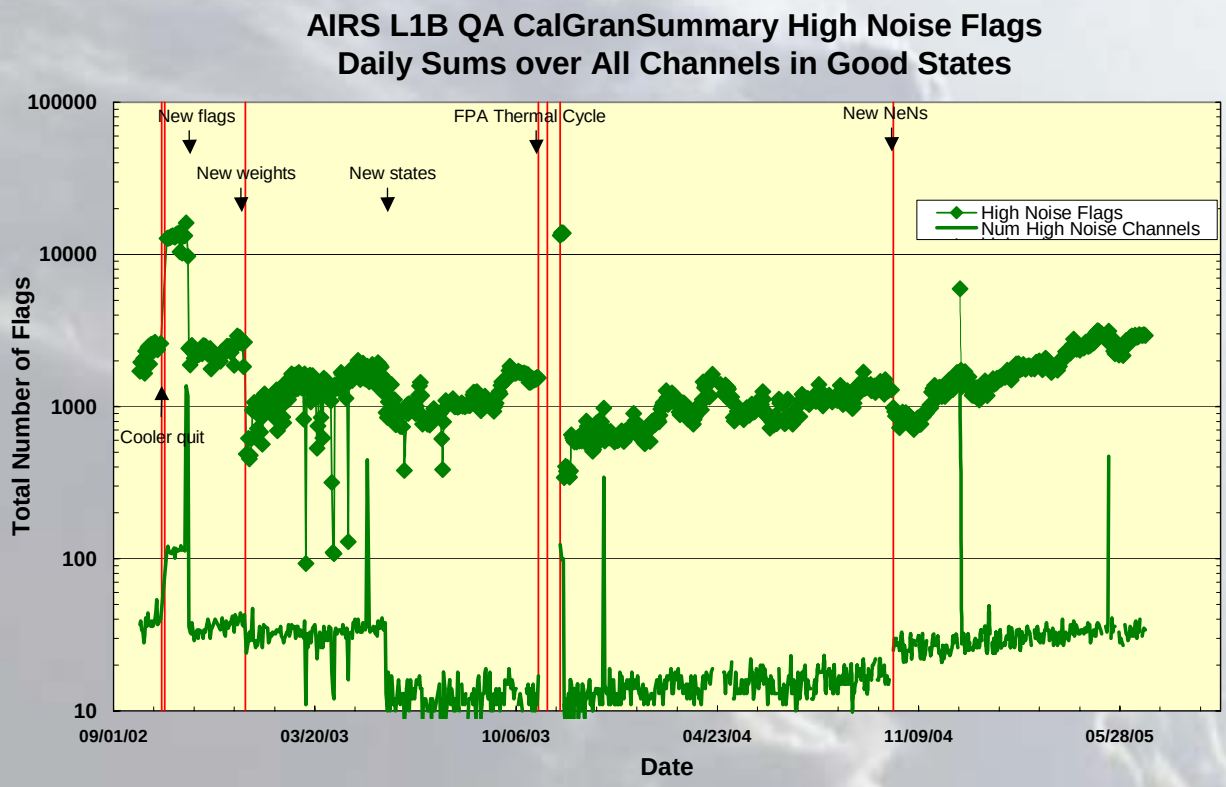
Suspected Total Dose Effect: Slow Rise in High Noise Flags and High Noise Channel Counts



- Changes have been made in the details of the flag limits, which have affected the counts ("weight" refers to the redundant detector selection, "state" a characterization of the noise as good or poor following the special calibration tests after each thermal cycle)

- A high noise flag is set for any granule for a channel with high levels of noise, as determined by comparing the Noise Equivalent Spectral Radiance (NeN) for that granule with a benchmark value

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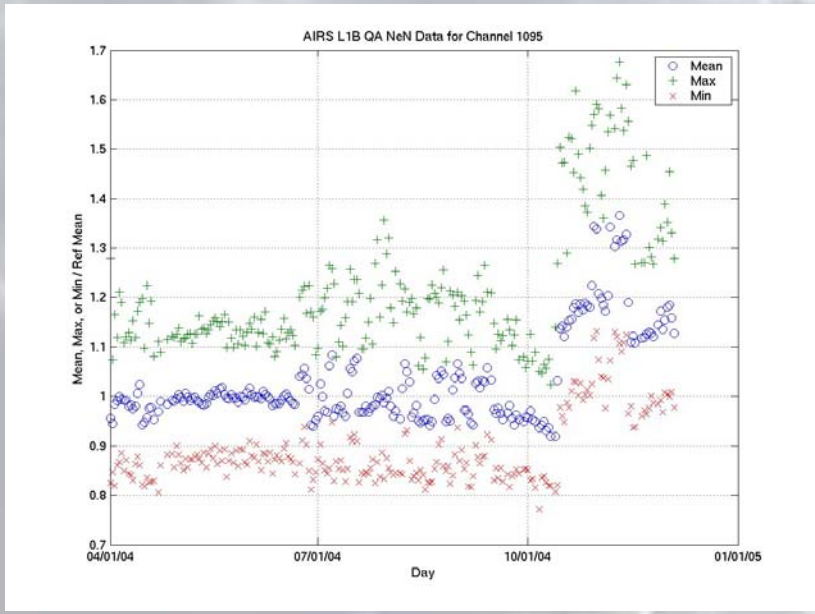
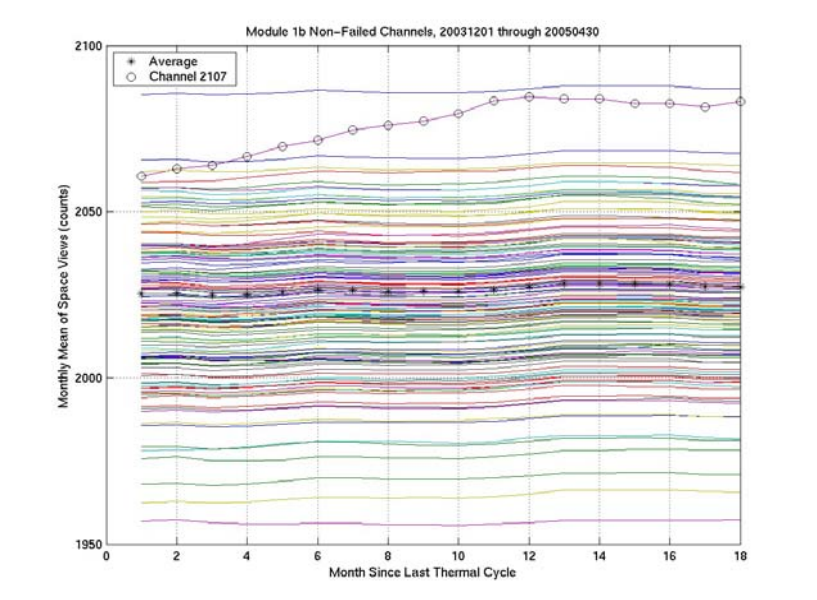
A Few Channels Have Shown Anomalous Increases in NEN or Output Level





- **The cause may be a small local increase in total dose (stored radiation-induced charge) which affects the bias level**
  - ***The CdTe-passivated HgCdTe detectors are radiation-hard but the read-out integrated circuit (ROIC) is radiation-tolerant***

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Operational Anomalies

- **There have been a few operational anomalies attributed to Single Event Upsets (SEUs)**
- **Cessation of cooler operation 10/19/03 (as well as a pre-operational cessation 8/22/02)**
  - ***The resulting thermal cycle required re-calibration of the detectors***
- **Uncommanded parking of the scanner 11/7/04**
  - ***Control register bit flipped, changing the mode from normal to idle***
  - ***Only consequence was short-term data loss***
- **AIRS was put into survival mode in late October, 2004, in anticipation of the solar coronal emission event**
  - ***This was the most recent thermal cycle; no more are anticipated***

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Summary

- **The attention to radiation hardness implemented in the design of the AIRS instrument, and the system of data reduction and flags, has ensured excellent stability and operability throughout the mission**
- **In particular, the channel noise distribution has been remarkably stable**
- **It is important to use the flags to ensure high quality data, and to be aware of possible data spikes in the SAA for modules M4 – M10**
- **Because of the possibility of isolated channel degradation, it is advisable in using AIRS data to take advantage the many channels available in a given spectral region**