Early Calibration Results from the Atmospheric Infrared Sounder (AIRS) on Aqua

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SPIE 4891-09
Remote Sensing of the Atmosphere, Ocean, Environment, and Space
Hangzhou, China
10/25/02

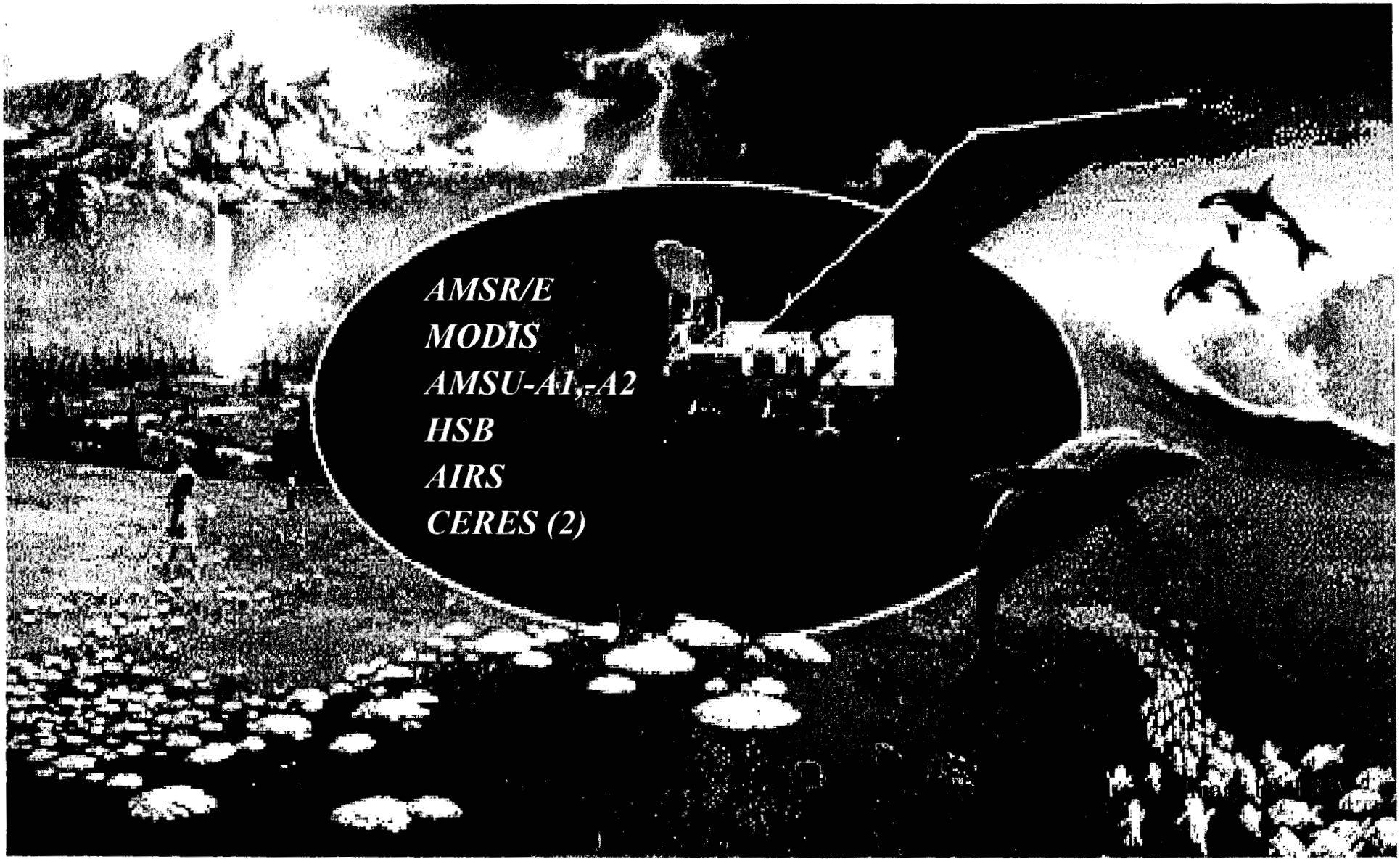
AIRS-AMSU-HSB

Atmospheric Infrared Sounder

Advanced Microwave Sounding Unit

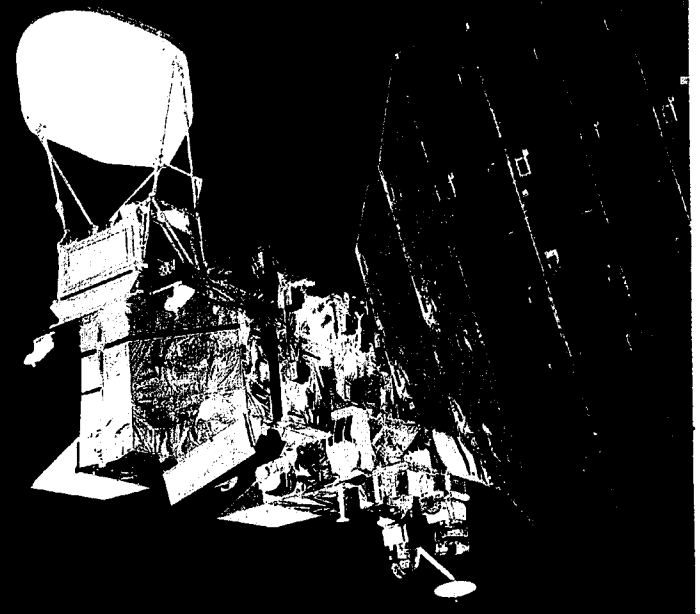
Humidity Sounder for Brazil

AQUA MEASURES EARTHS WATER CYCLE, ENERGY FLUXES, VEGETATION, AND TEMPERATURES



AIRS

Monitoring Earth's Atmosphere



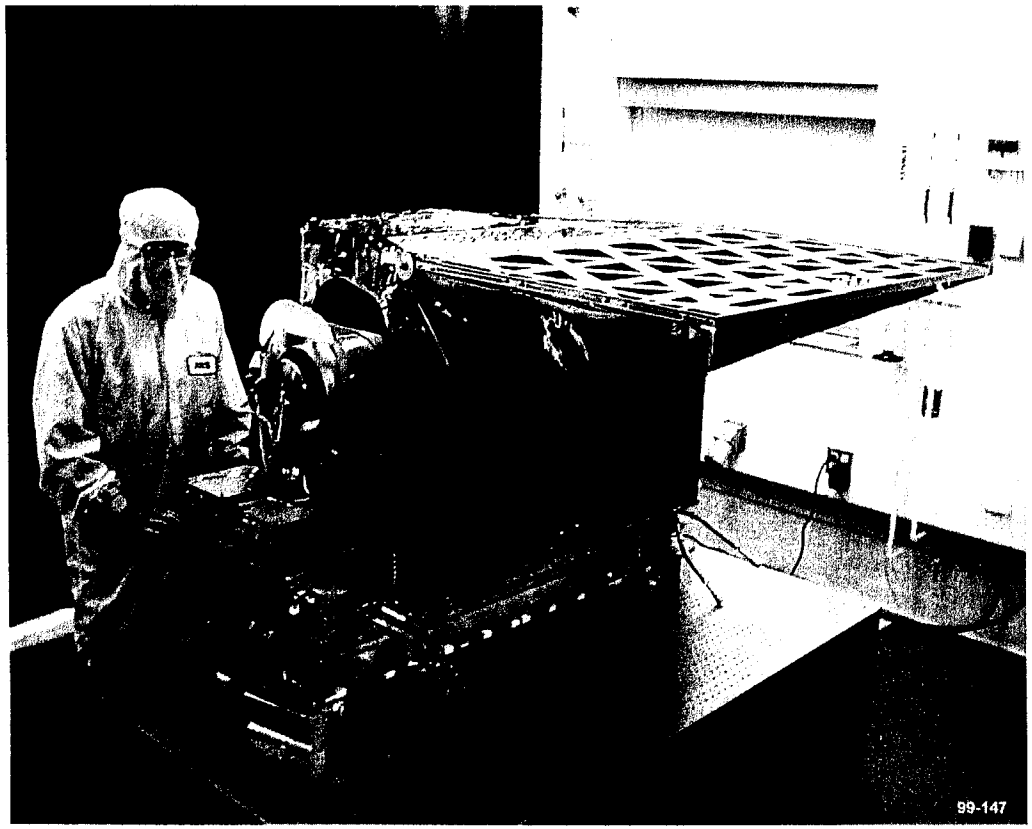
The AIRS/AMSU/HSB data will be used to address several climate questions

1. The global water and energy cycle: Is the cycle of evaporation and precipitation on Earth accelerating?
2. Determine the distribution and variations of water vapor - Earth's primary greenhouse gas
3. Climate weather connection: Are current weather anomalies (hurricanes, droughts) connected to climate change and how?
4. Improving weather prediction: NOAA is a user together with 6 other weather prediction centers in Europe, America, Australia and Japan
5. Trace Gasses: Will provide the first satellite global map of the distribution of atmospheric concentration of CO_2

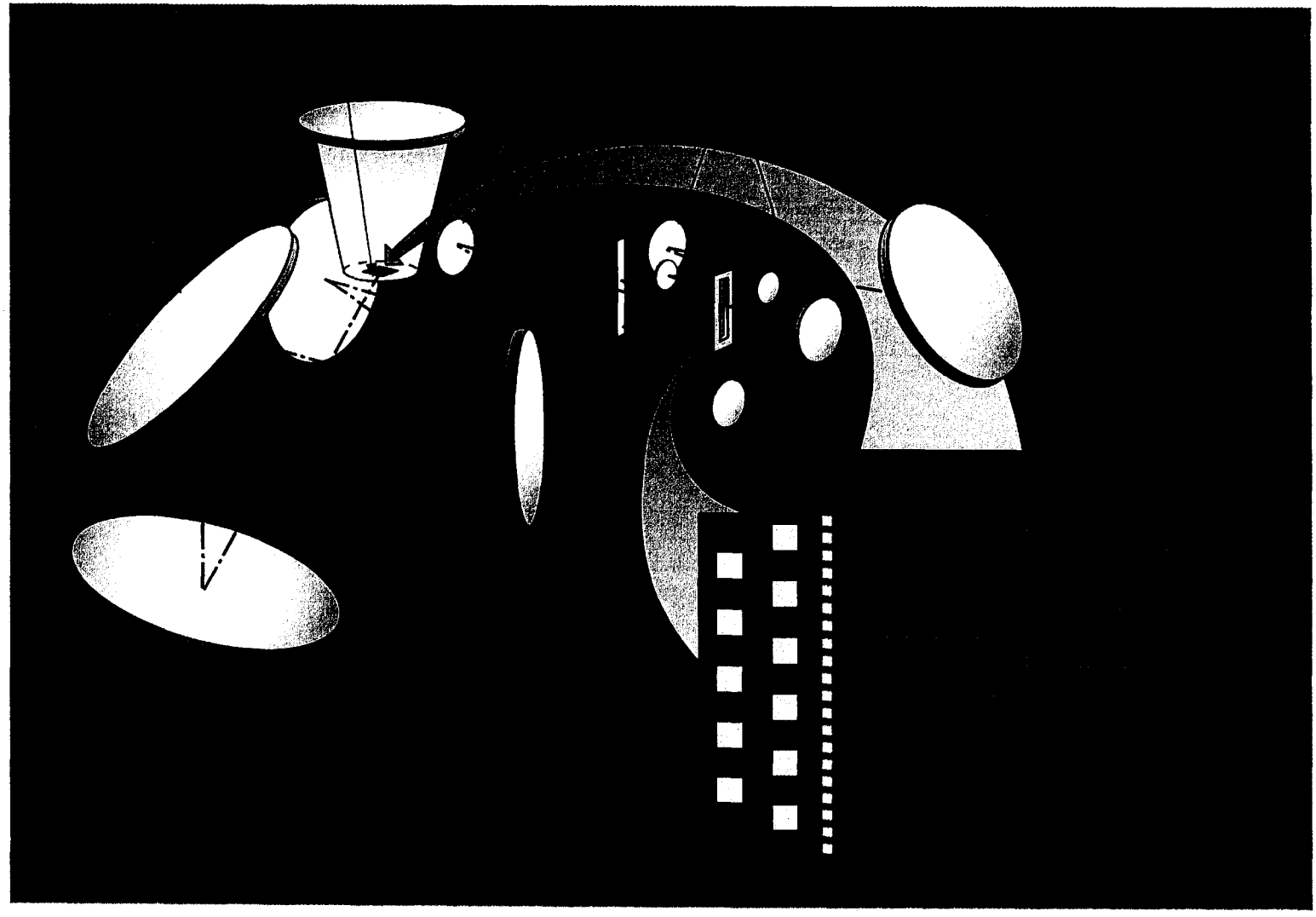
AIRS WAS DEVELOPED BY BAE SYSTEMS AND JPL AND DELIVERED IN NOVEMBER 1999

AIRS Requirements

- IFOV : 1.1° x 0.6° (13.5 km x 7.4 km)
- Scan Range: ±49.5°
- IR Spectral Range: 3.74-4.61 μm, 6.2-8.22 μm, 8.8-15.4 μm
- IR Spectral Resolution: ≈ 1200 ($\lambda/\Delta\lambda$)
- No. IR Channels: 2378 IR
- VIS Channels: 4 (0.41-0.44 μm,0.58-0.68 μm, 0.71-0.92 μm,0.49-0.94 μm)
- VIS IFOV: 0.14° (1.7 km)
- Mass: 177Kg, Power: 256 Watts, Life: 5 years (7 years goal)

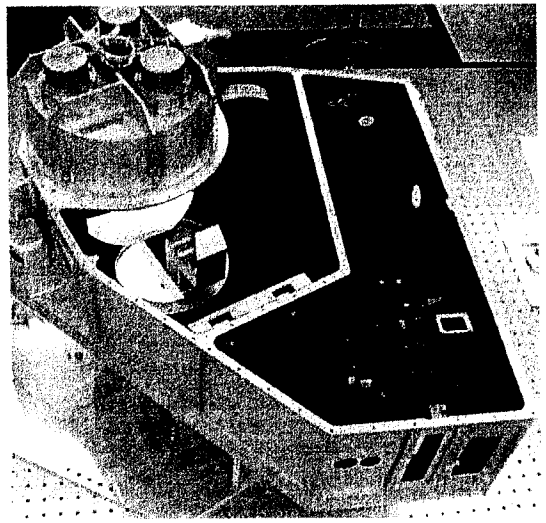


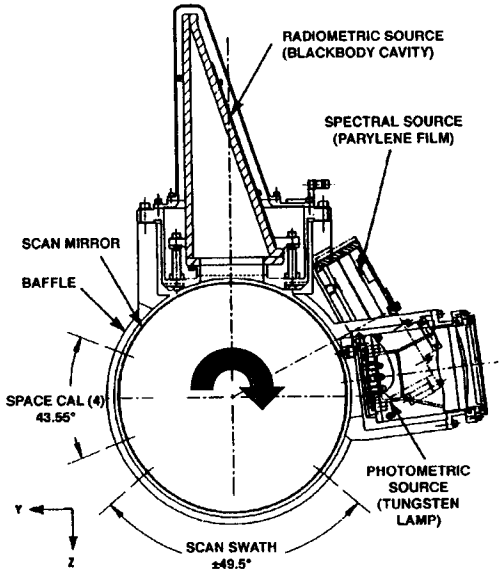
AIRS OPTICAL APPROACH IS BASED ON DEMANINDING PERFORMANCE REQUIREMENTS

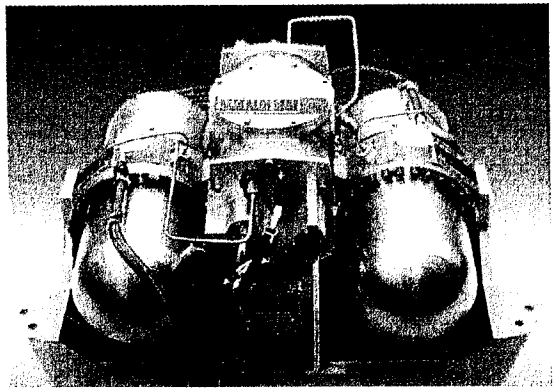


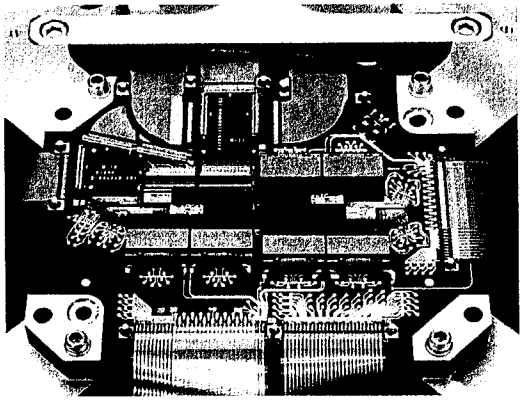
AIRS TECHNOLOGY

- IR Spectrometer: Multi-Aperture Array Grating Spectrometer
- Spectrometer Cooling to 155K with Two-Stage Passive Radiator
- Focal Plane Cooling using Single Stage Stirling Pulse Tube, Redundant
- FPAs: PV HgCdTe to 13.7 µm, PC HgCdTe to 15.4 µm
- On-Board Calibration Views: Space, Blackbody, Parylene (Spectral), 3 VIS/NIR Lamps
- Electronics Architecture:
  - *Dual Redundant/µ-processor controlled*
  - *On-board radiation circumvention signal processing*



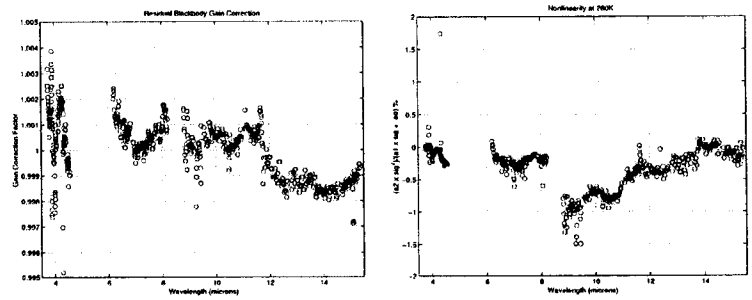




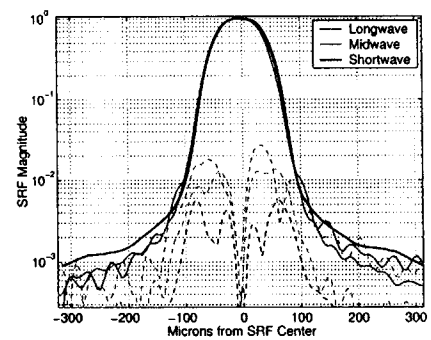


ABSOLUTE CALIBRATION AND CHARACTERIZATION PERFORMED PRIOR TO SPACECRAFT DELIVERY

- **Radiometric Response**
  - ***Emissivity, Nonlinearity (Less than 1.5%)***
  - ***Stray Light***
  - ***Polarization Sensitivity***
  - ***Scan Angle Dependence (Less than 2%)***



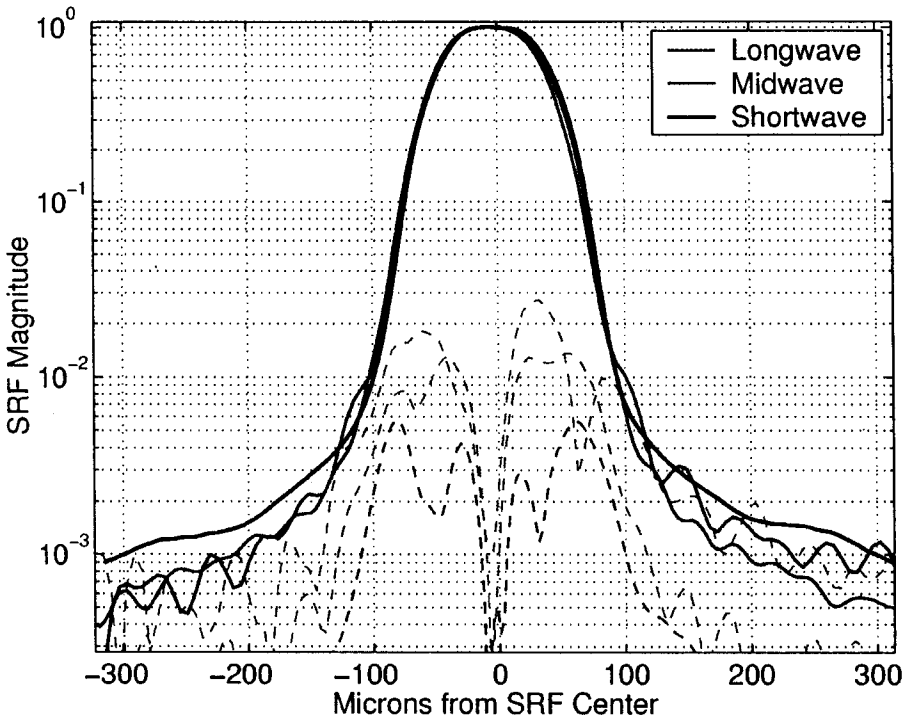
- **Spectral Response**
  - ***SRF Characterization (Less than 0.5% $\Delta\lambda$)***
  - ***Channel Spectral Modeling Demonstrated***



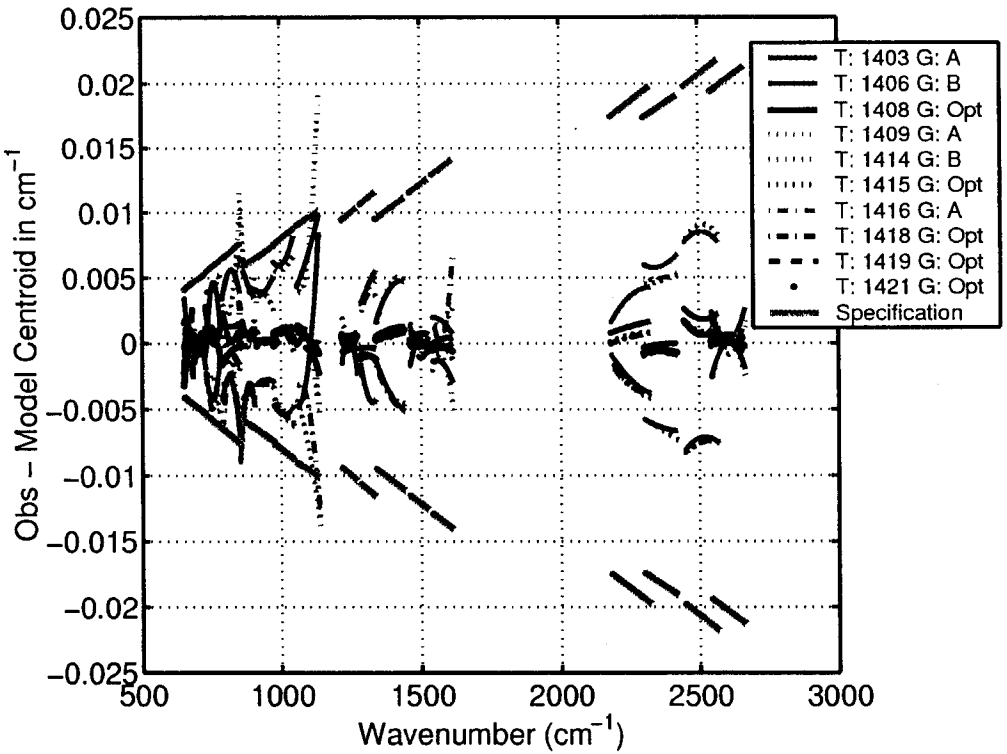
- **Spatial Response**
  - ***Spatial Co-Registration (Less than 10%)***
  - ***Stray Light Excellent***
  - ***Far Field Response Excellent***
- **All performance requirements met or approved by the AIRS Science Team as acceptable to meet the science requirements of the mission.**
- **Exceptional Performance Achieved**

PREFLIGHT SPECTRAL CAL SHOWS EXCELLENT SPECTRAL SHAPE AND STABILITY

SRF Shape Well Characterized to <10^{-3}



Knowledge of Centroids Within Spec Limits



Temperature Dependence Well Behaved

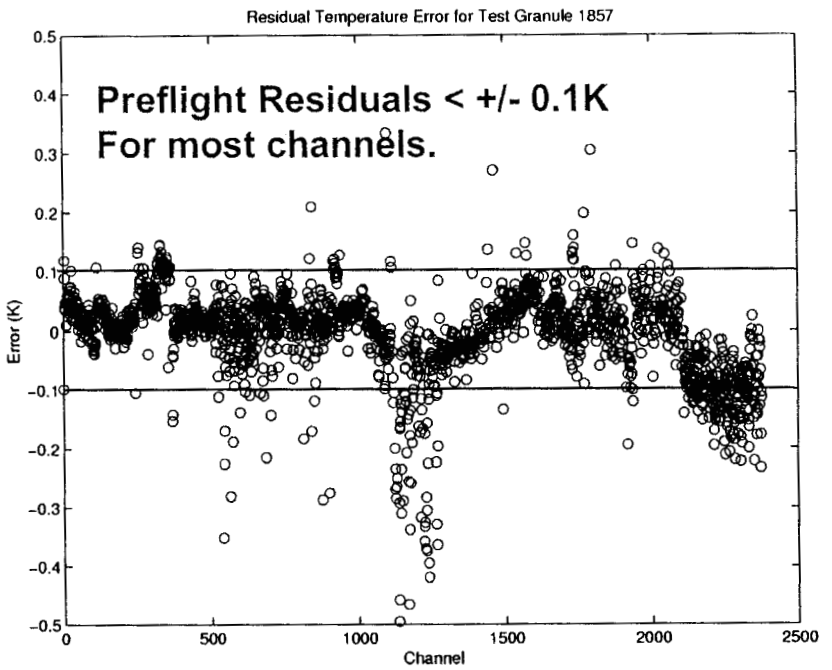
SIMPLE RADIOMETRIC TRANSFER EQUATIONS LEAD TO EXCEPTIONAL ACCURACY

$$N_{sc,i,j} = \frac{a_o(\theta_j) + a_{1,i}(dn_{i,j} - dn_{sv,i}) + a_2(dn_{i,j} - dn_{sv,i})^2}{1 + p_r p_t \cos 2(\theta_j - \delta)}$$

$$a_o(\theta_j) = P_{sm}\, p_r p_t [\cos 2(\theta_j - \delta) + \cos 2\delta]$$

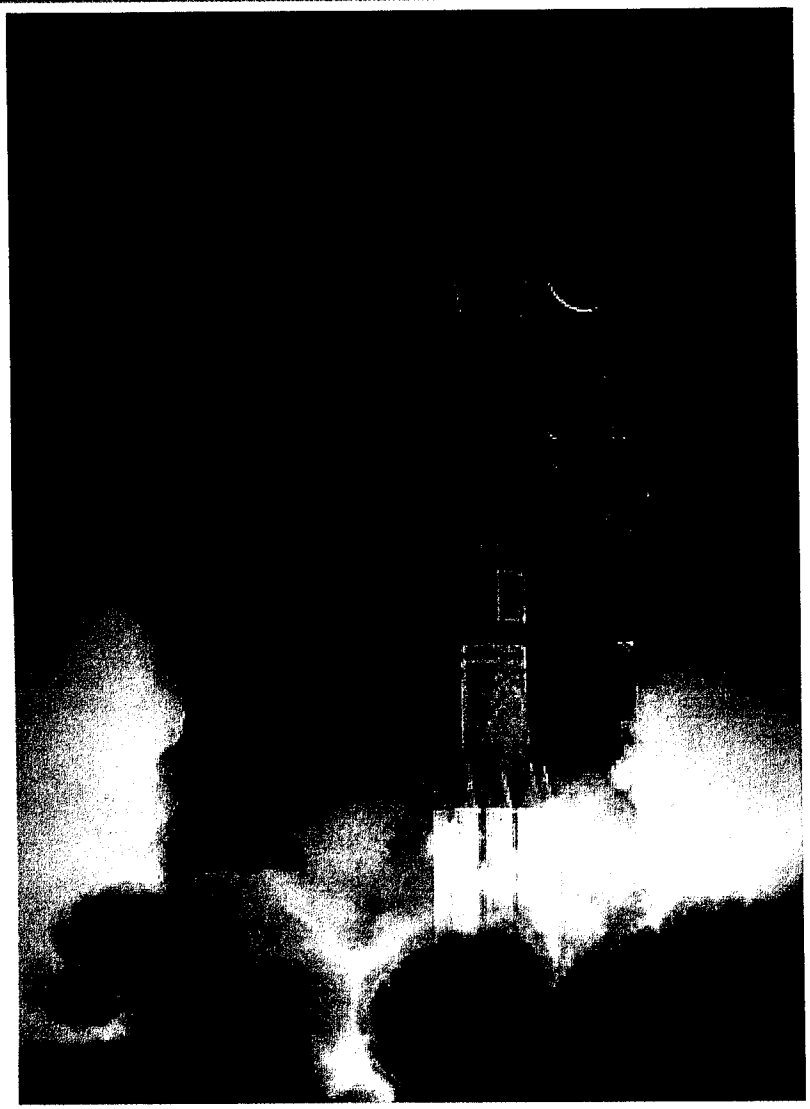
$$a_{1,i} = \frac{N_{OBC,i}(1 + p_r p_t \cos 2\delta) - a_o(\theta_{OBC}) - a_2(dn_{obc,i} - dn_{sv,i})^2}{(dn_{obc,i} - dn_{sv,i})}$$

$N_{sc,i,j}$ = Scene Radiance (mW/m^2-sr-cm^{-1})
Psm = Plank radiation function
$N_{OBC,i}$ = Radiance of the On-Board Calibrator
i = Scan Index, j = Footprint Index
q = Scan Angle. q = 0 is nadir.
$dn_{i,j}$ = Raw Digital Number in the Earth View
$dn_{sv,i}$ = Space view counts offset.
a_o = Radiometric offset. $a_{1,i}$ = Radiometric gain.
a_2 = Nonlinearity
$p_r p_t$ = Polarization Factor Product
d = Phase of the polarization



AQUA WAS LAUNCHED ON MAY 4, 2002

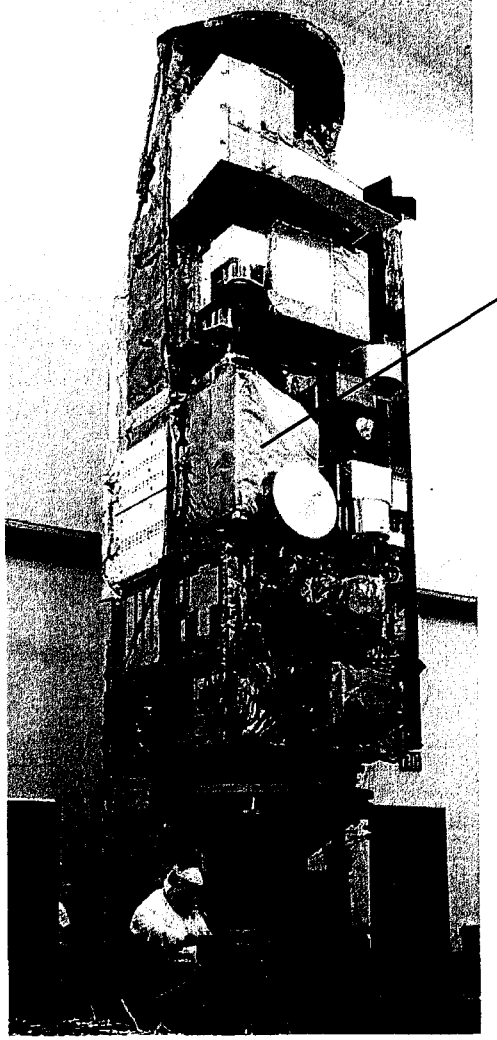
- Delta 2 Launch Vehicle
- 6 Strap On Boosters
- Extended Fairing
- 2:55 AM
- Vandenburg Air Force Base, California
- 705.3 km Orbit
- Polar Sun Synchronous
- 1:30 PM Equatorial Crossing
- Ascending Daytime



ELEVEN SPECIAL CALIBRATION TESTS USED TO TREND PRE-FLIGHT TO ON-ORBIT PERFORMANCE

Test ID	Name
AIRS-C1	Normal Mode / Special Events
AIRS-C2	Guard Test
AIRS-C3	Channel Spectra Phase
AIRS-C4	AMA Adjust
AIRS-C5	OBC Cooldown
AIRS-C6	Variable Integration Time
AIRS-C7	Space View Noise
AIRS-C8	Radiation Circumvention
AIRS-C9	Scan Profile
AIRS-C10	Lamp Operations
AIRS-C11	Warm Functional

EOS AQUA SPACECRAFT

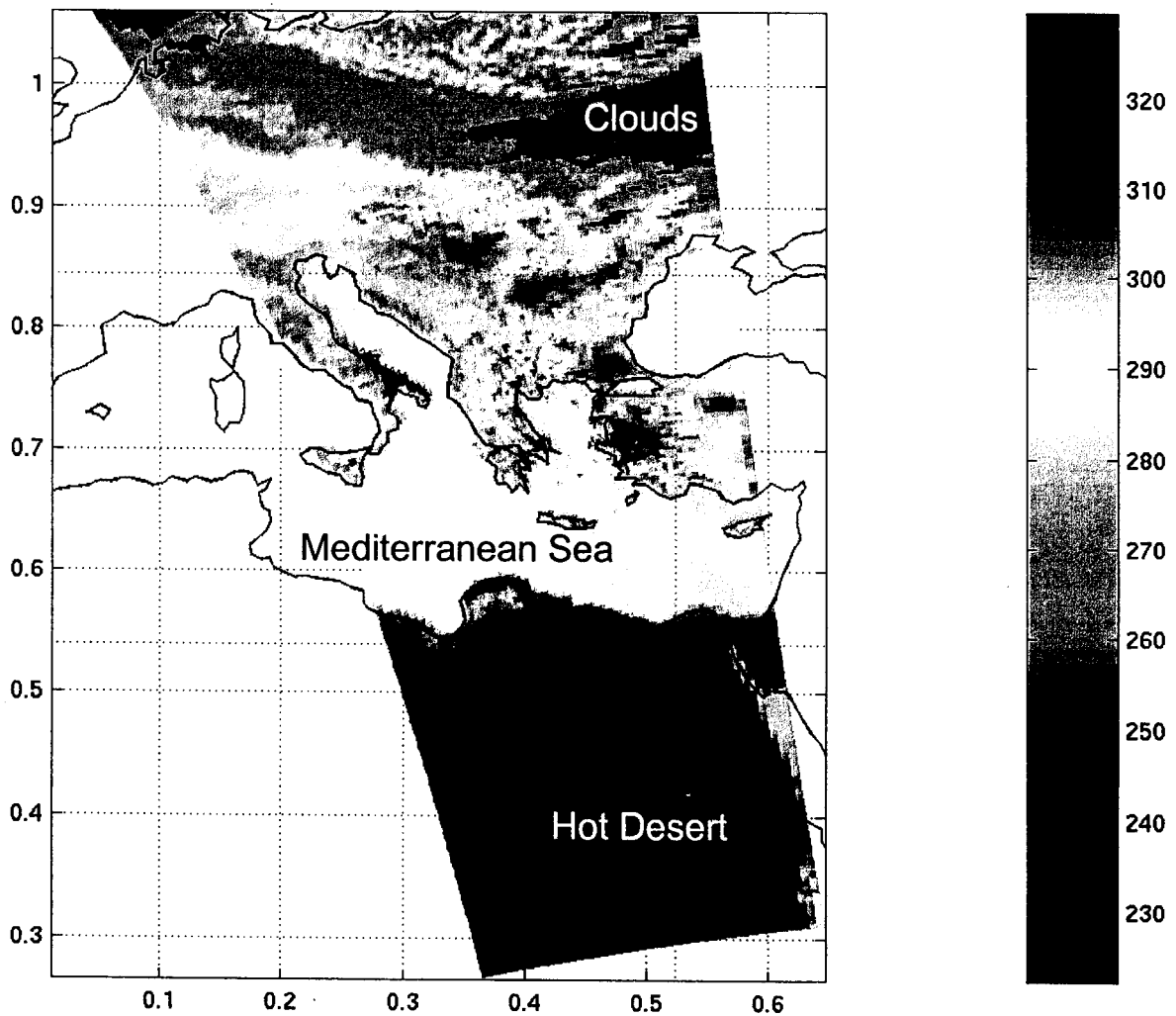


AIRS 900 cm^{-1} SUPERWINDOW CHANNEL DIRECTLY MEASURES SKIN TEMPERATURE

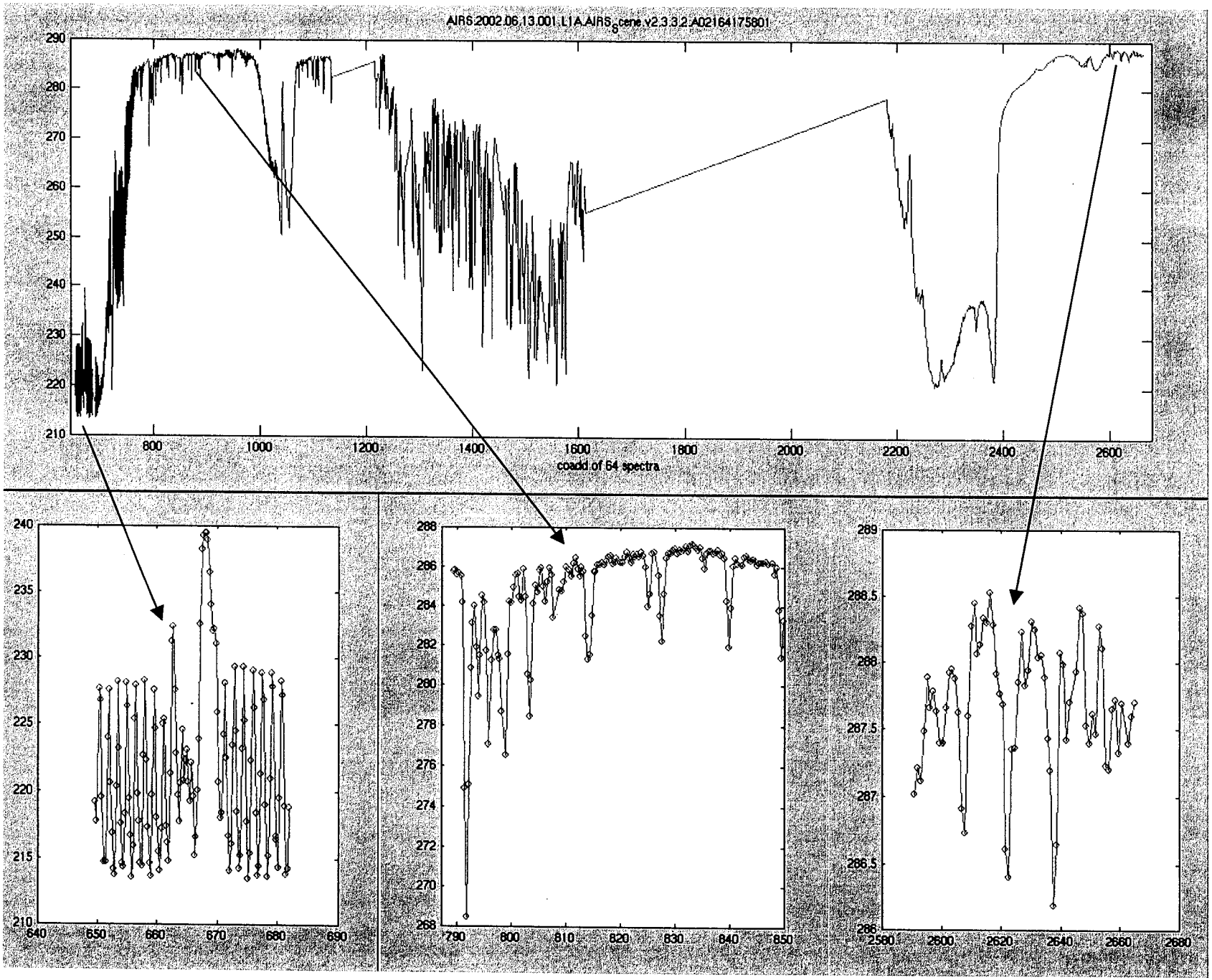
- **First Vis/NIR Image May 26, 2002**
- **AIRS first light IR June 13, 2002**

AIRS Vis/NIR IMAGE

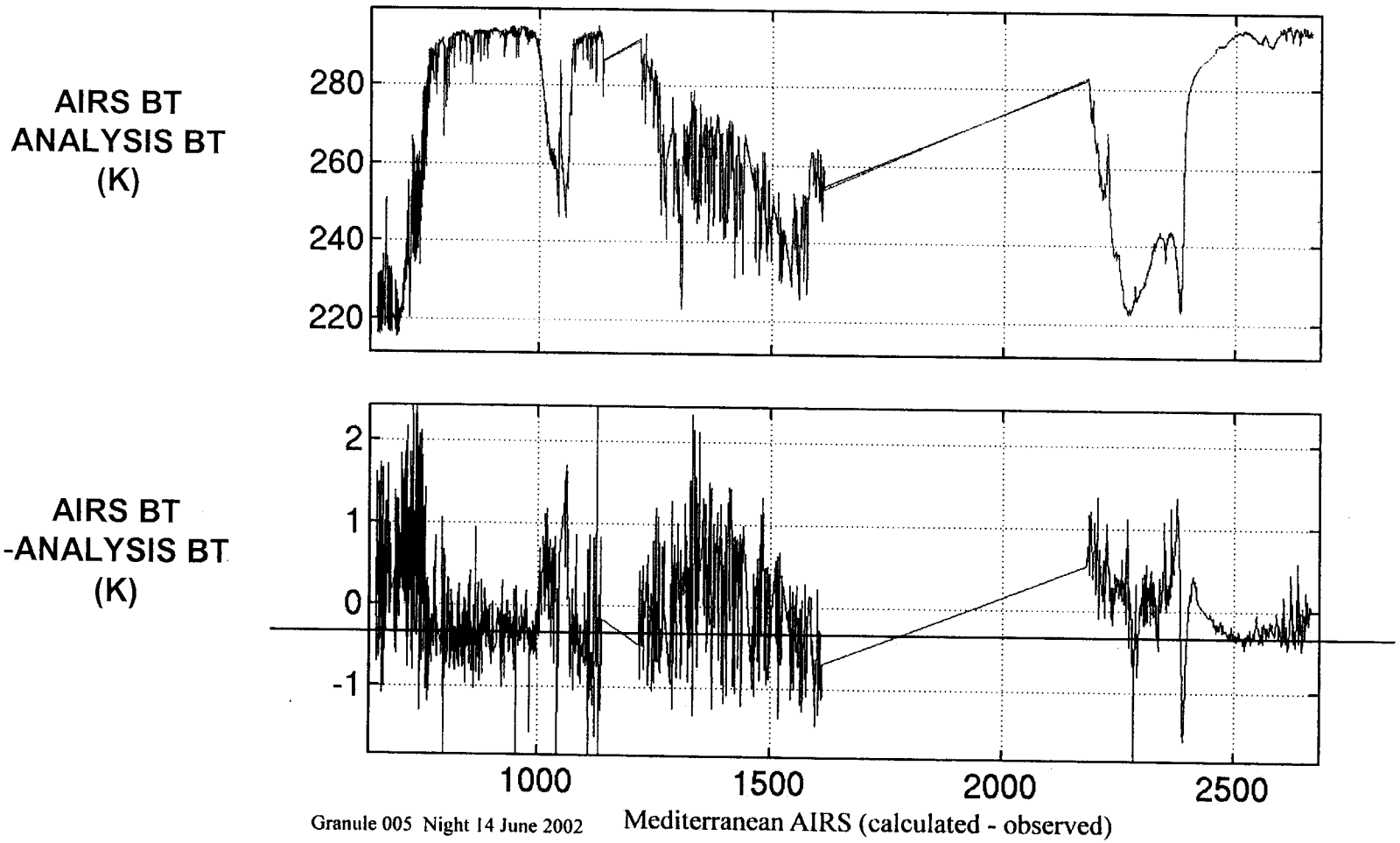
AIRS.2002.06.14.116.L1B.AIRS$_R$ad.v2.3.3.2.A02165215116



btemp at 900cm−1 window channel. Day pass. Ocean cooler than land!

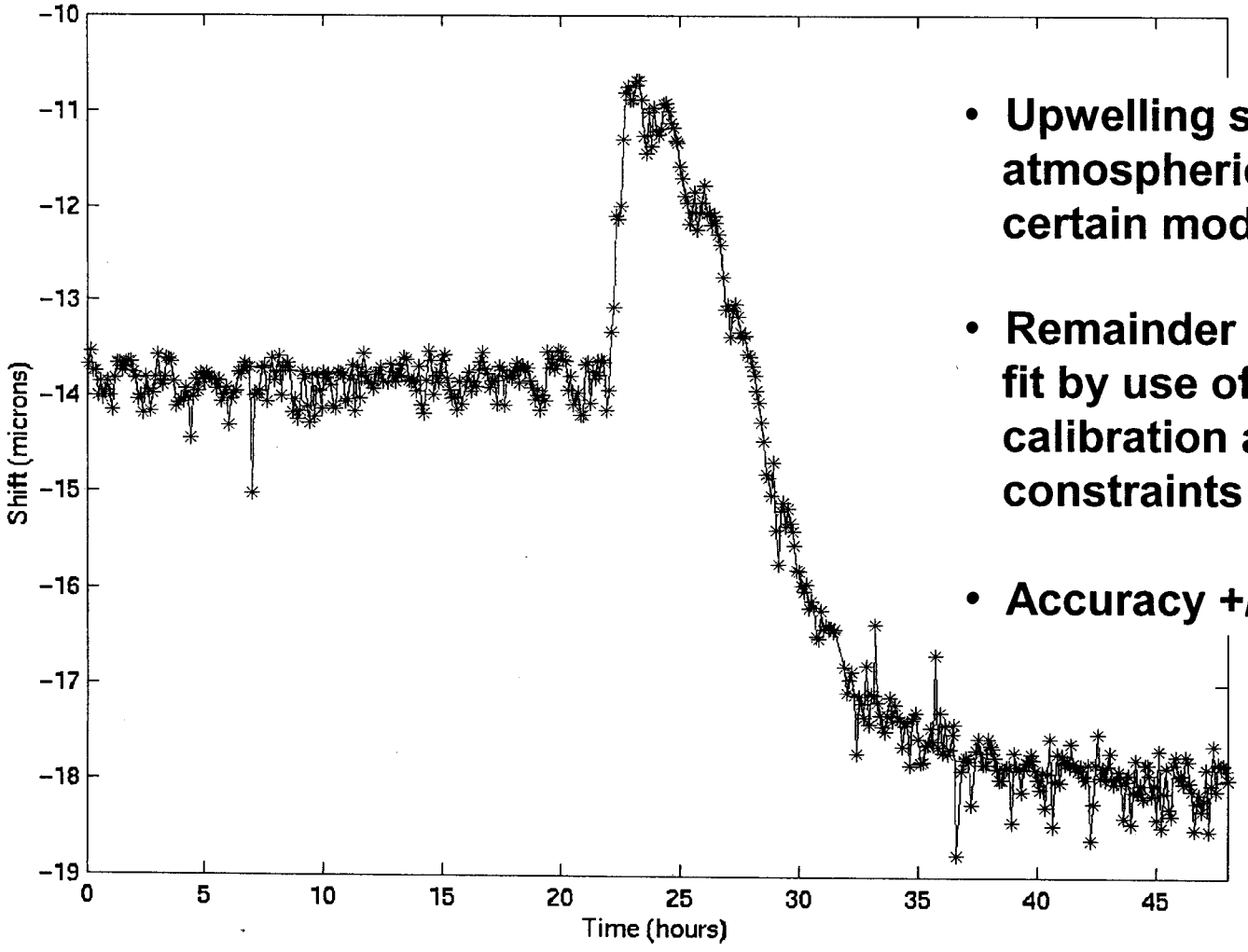

AIRS.2002.06.13.001.L1A.AIRS_scene.v2.3.3.2.A02164175801
coadd of 64 spectra

AIRS RADIOMETRIC ACCURACY BETTER THAN 0.5K AT MOST FREQUENCIES



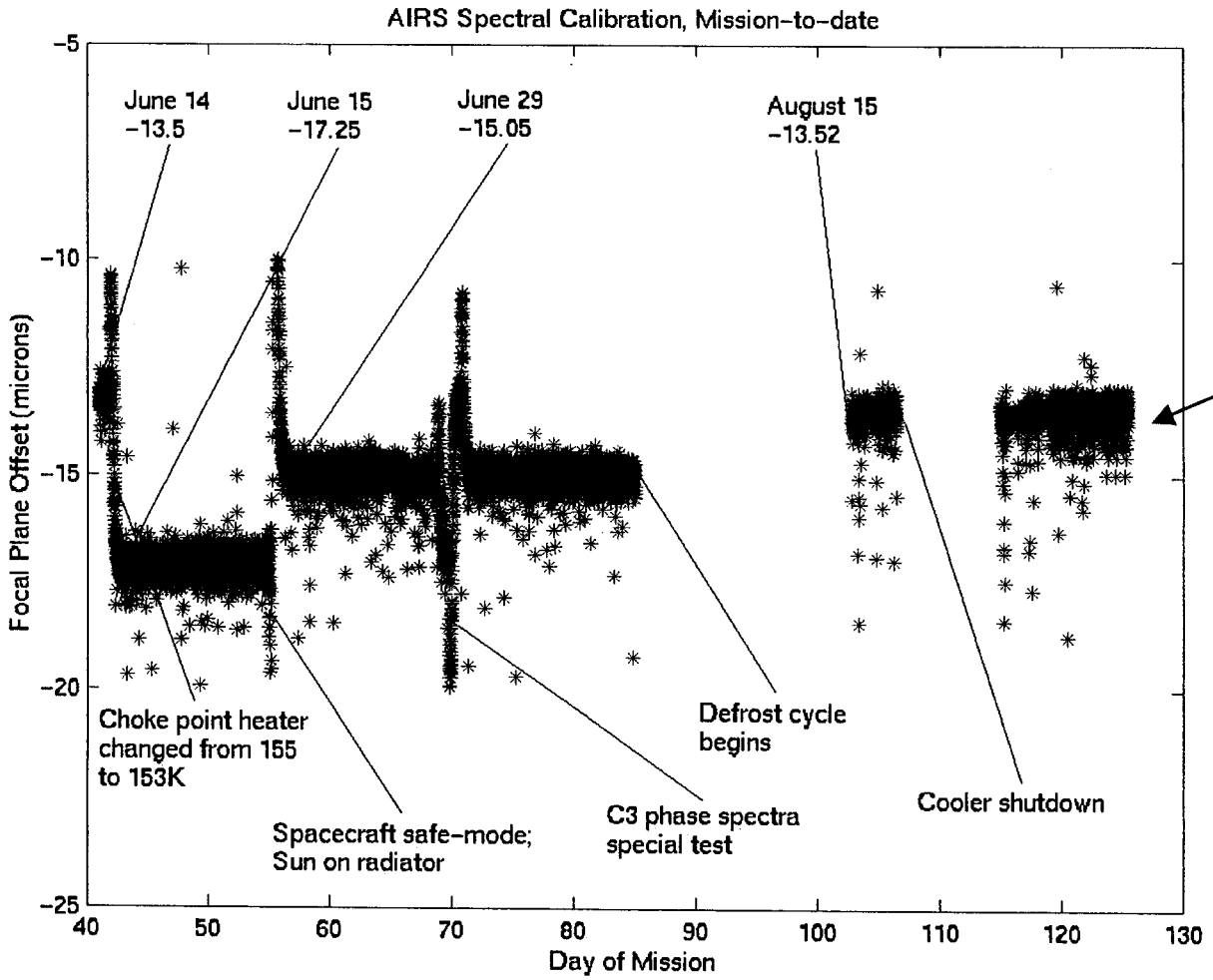
Analysis by L. Strow of UCMB

UPWELLING ALLOWS CHARACTERIZATION OF SPECTRAL CENTROIDS



- Upwelling spectra fit to atmospheric features for certain modules
- Remainder of channels fit by use of pre-flight calibration and design constraints
- Accuracy +/- 0.5% DI

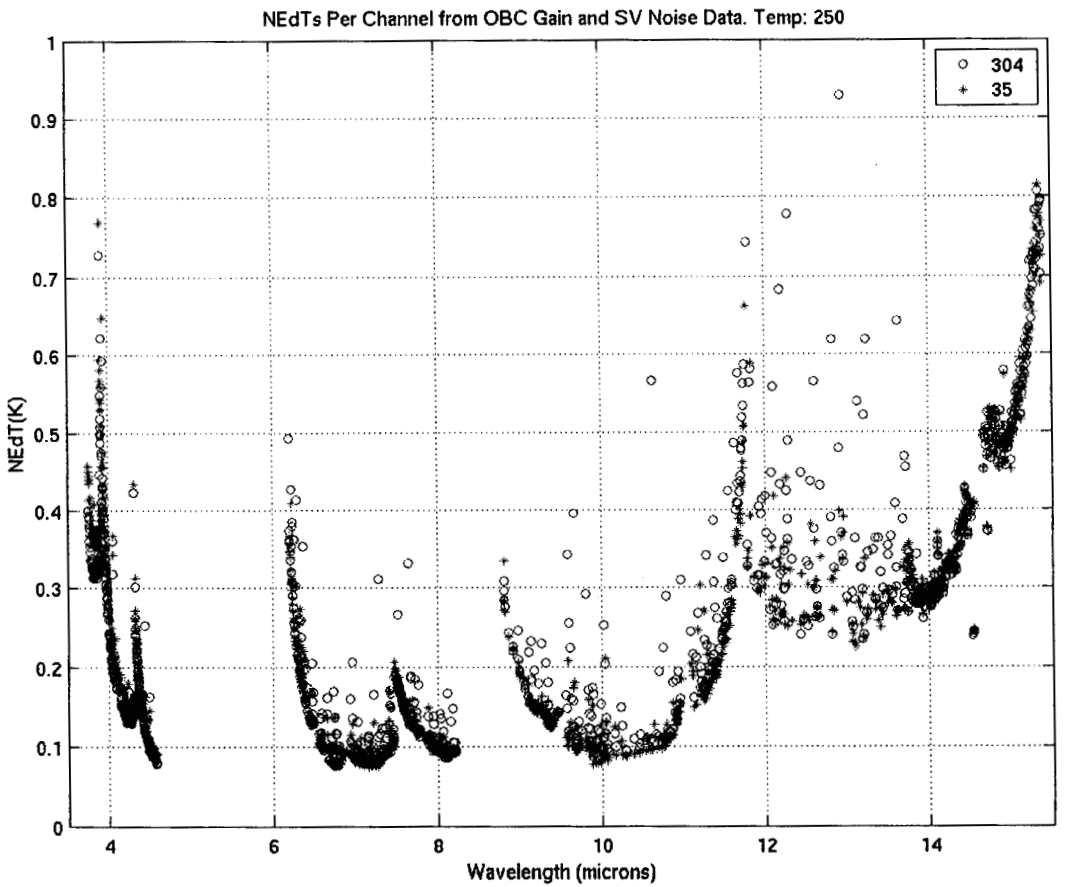
SPECTRAL: CENTROIDS TRACKED TO +/- 0.5 MICRONS (0.5% Width of SRF)



Current position is –13.5mm relative to June 2000 L. Strow Grating Model

AIRS NEDTS LOOK GOOD IN ORBIT

- AIRS can stop mirror and stare in spaceview or at OBC blackbody
- Appx 30,000 footprints of noise are acquired
- Provides excellent noise statistics
- Provide noise signal dependence
- NeDt calculated at 250k for reference

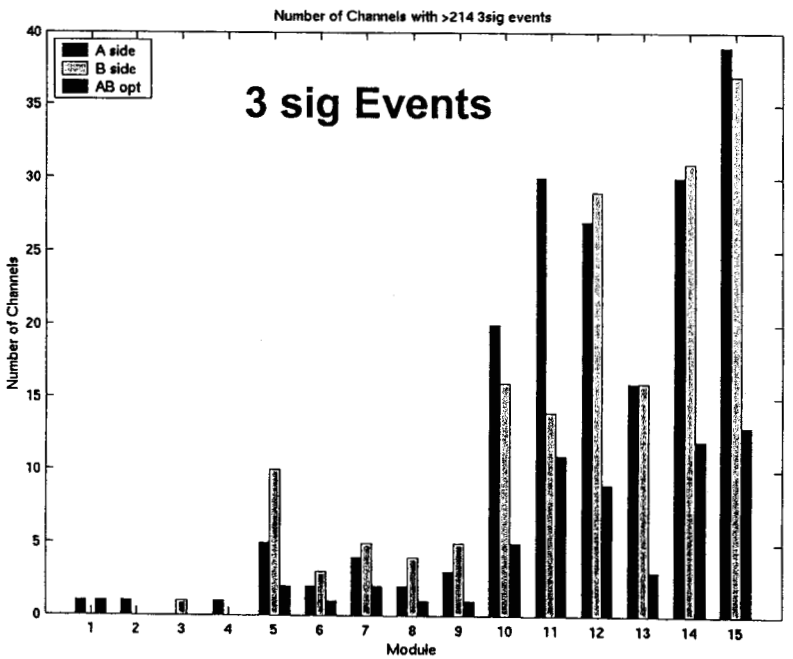


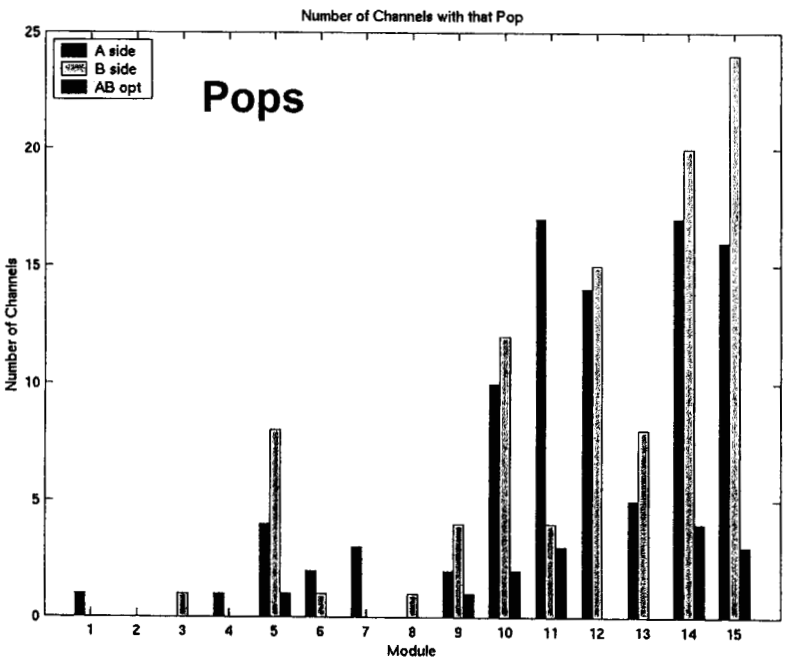
$$NEN_{scene} = Gain \times \sqrt{\left(\frac{N_{scene}}{N_{obc}}\right)\left(DN_{obc}^{2} - DN_{sv}^{2}\right) + DN_{sv}^{2}}$$

RESULTS SHOW GAIN TABLES WELL OPTIMIZED

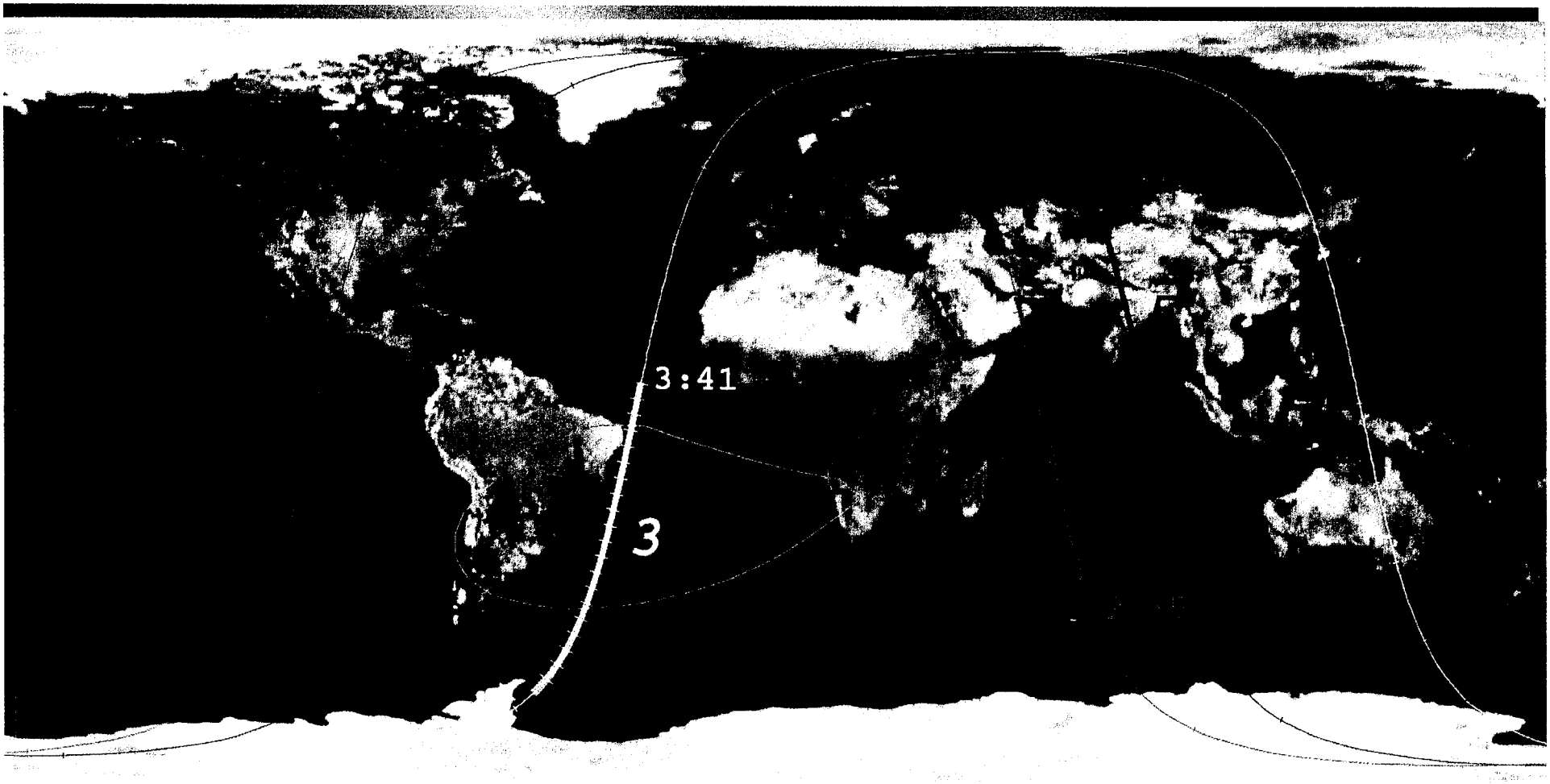
Number of Channels that did not pass during 40,000 sample test:

	A	B	AB Opt
3sig Events:	181	171	61
Pops:	92	98	14
High Noise:			131
Total Now:			206



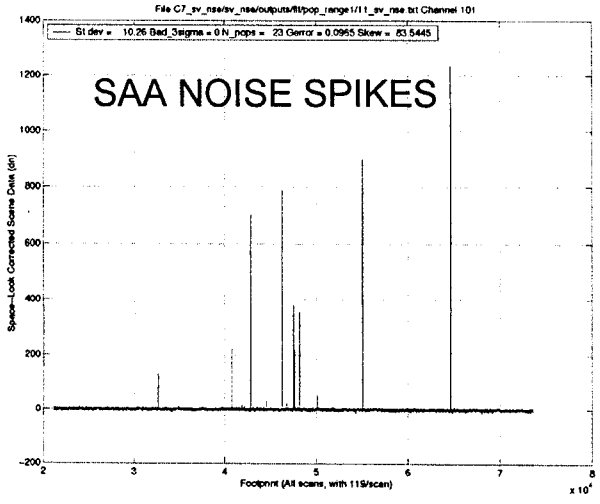


SPACE VIEW NOISE TEST ACQUIRED IN SAA

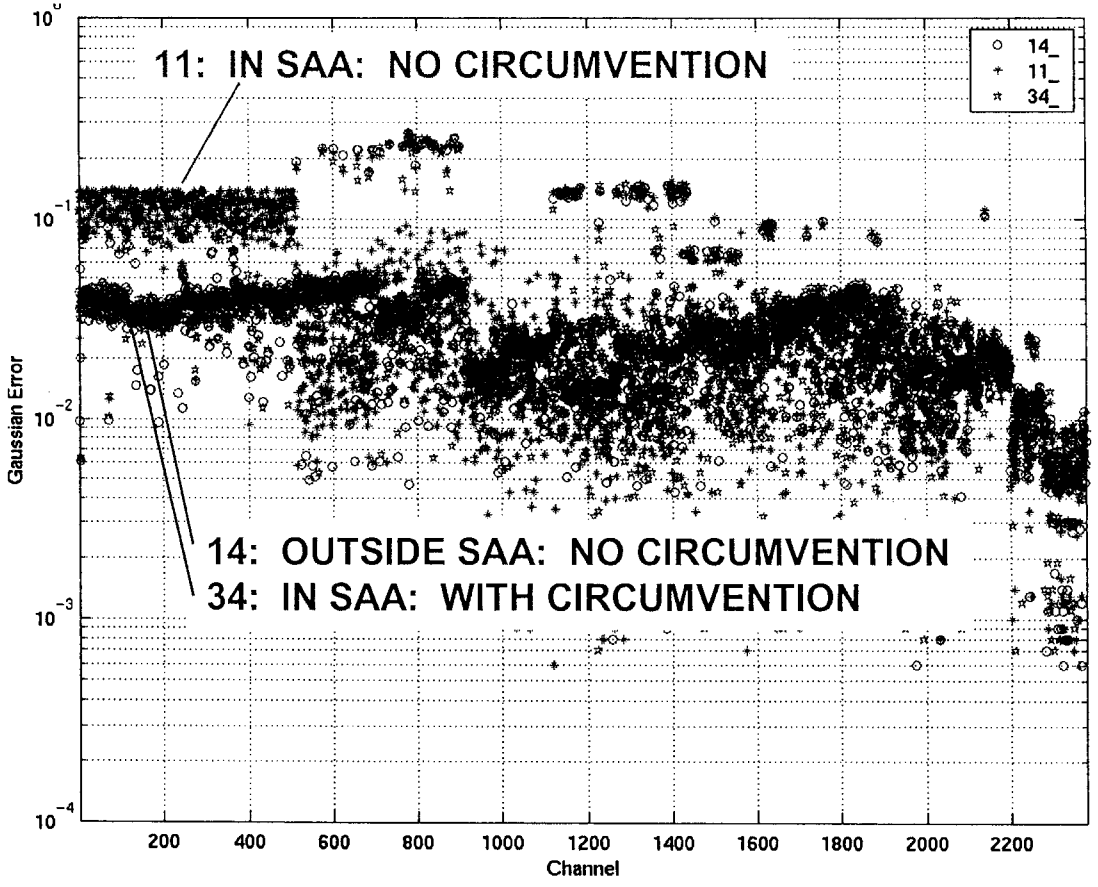


RADIATION CIRCUMVENTION PROCESSOR IS WORKING IN ORBIT

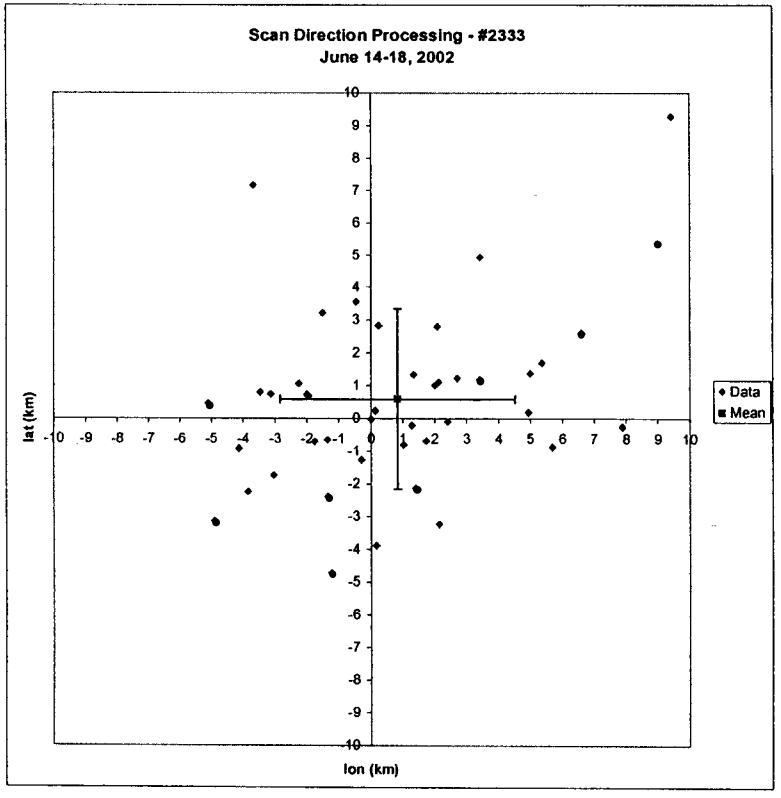
- **Noise spikes seen in the South Atlantic Anomaly (SAA)**
- **Radiation Circumvention activated. Levels set.**
- **Noise spikes due to SAA eliminated.**

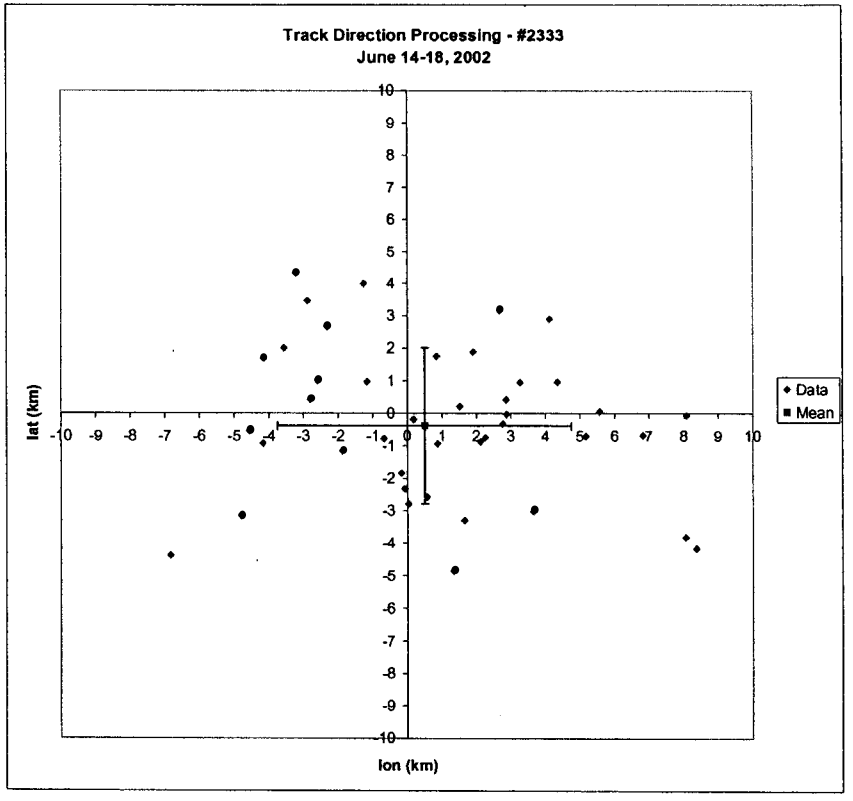


NON-GAUSSIAN NOISE FACTOR VS CHANNEL FOR AIRS



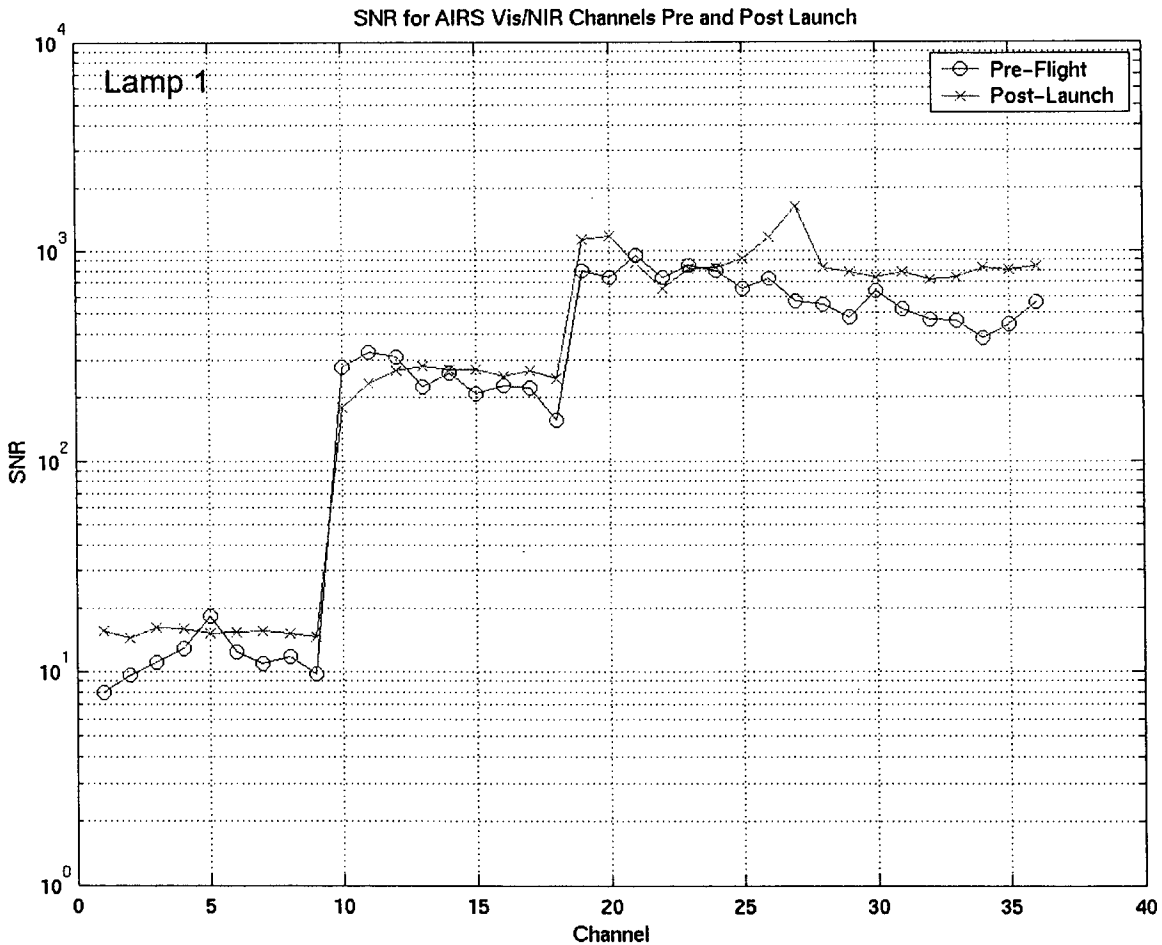
SPATIAL: BORESIGHT POSITION STILL REMAINS <+/- 1 KM FROM NOMINAL





lat diff s	lon diff s		latdiff t	lon diff t		
0.5918	0.8431		-0.3804	0.5072	mean	
2.7515	3.6836		2.3950	4.2506	std dev	
0.4196	0.5617		0.3652	0.6482	std dev mean	

VIS SNRs LOOK GOOD PRE AND POST LAUNCH



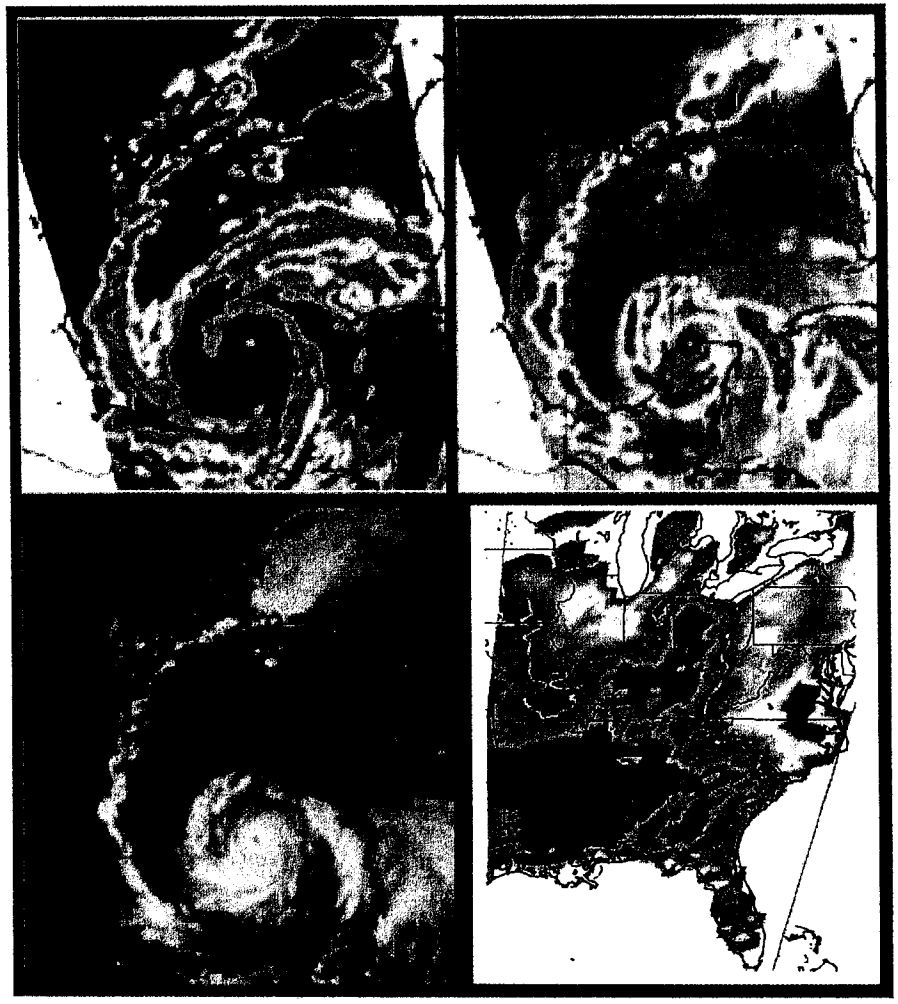
Hurricane Isidore September 22, 2002

AIRS
Ch. 2616

HSB
Ch. 150 Ghz

AIRS
Vis/NIR

Flooding (difference)
HSB Sept 28-Sept 10



SUMMARY

- AIRS Launch and Activation Successful
- All AIRS Subsystems functioning normally
- Instrument Radiometric, Spatial and Spectral performance looks nominal
- Exceptional temperature/performance stability achieved in orbit
- In-Flight Calibration Complete
- Science team is very excited and impressed by the performance observed by the instrument and the radiance products
- Level 2 Algorithms showing good agreement with models
- Weather Centers have begun data assimilation