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Instrument requirements for a next generation 1km resolution hyperspectral imaging spectrometer

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SPIE 2006,
San Diego

paper ID: 6296-46

August 16, 2006

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What is ARIES?

- **1 km Horizontal Spatial Resolution (Like MODIS)**
  - Mitigates Problems with Scene Inhomogeneity
  - Mitigates Effects of Clouds
  - Improves Identification of Sources and Sinks of Trace Gases
  - Improves Observation of Water Vapor Transport and Surface Emissivity
- **High Spectral Resolution (like AIRS)**
  - Improves atmospheric correction
  - Better Radiometry
  - Better Surface Properties (SST, Emissivity, NDVI) Characterization
  - Better water vapor characterization

This is all possible because of new technology not available during the build of AIRS and MODIS.

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ARIES Products

- ARIES Products From MODIS
  - Land:
    - Surface Reflectance, Land Surface Temperature and Emissivity, Land Cover/Change, Vegetation Indices, Thermal Anomalies/Fire, LAI/FPAR, Net Primary Vegetation Production, BRDF/Albedo, Vegetation Conversion/Continuous Fields
  - Atmospheres
    - Aerosols, precipitable water, cloud parameters, total ozone and atmospheric profiles, polar winds
  - Oceans
    - SST, Chlorophyll Concentration
- ARIES Products From AIRS
  - Atmospheric Temperature and Water Vapor Profiles
  - Atmospheric Composition (Mid Troposphere)
  - Surface Temperature and Emissivity
  - Aerosols and Cloud Properties
- New Products
  - Water Vapor and Trace Gas Sources and Sinks
  - Surface-Atmosphere Coupling Parameters
  - Surface Spectral Emissivity (for NWP models)

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Relation to NPOESS

- NPOESS
  - System designed for operational capability
  - Requirements not established for climate quality observations
  - NPOESS is continuation of majority of current capability of AIRS and MODIS; not an improvement
- ARIES provides higher resolution observations for advancing science; not operations
- ARIES is a cross-calibration sensor
  - Can synthesize response of MODIS, VIIRS, AIRS or CrIS
- ARIES provides several P-I Products at high spatial resolution
  - CO, CH_4, CO_2
- ARIES could evolve into follow-on operational instrument to CrIS and VIIRS

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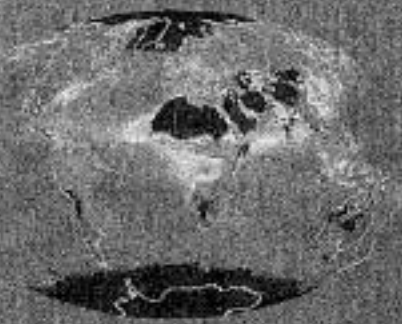
MODIS Products

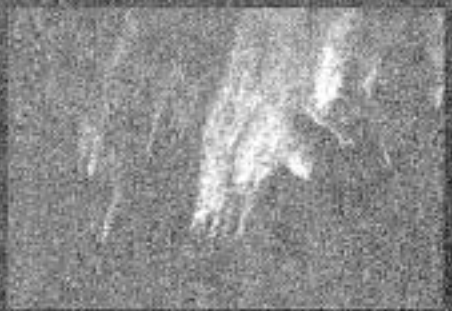
Aerosols



Polar Winds

Ocean Chlorophyll

Fires



SST

NDVI

Vince Salomonson, IAC Earth Observation Symposium, 2002

AIRS Products

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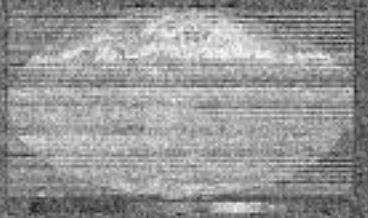
Temperature Profiles

Water Vapor Profiles

Clouds

Ozone

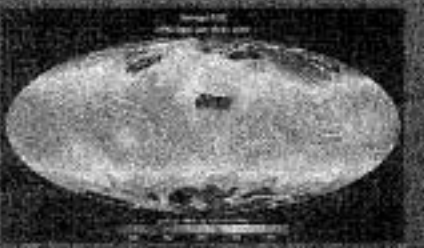


CO

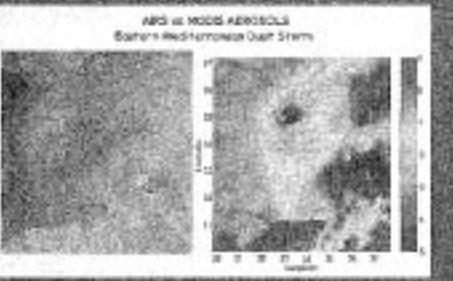
SO2

Methane

CO2



Aerosols



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Trace Gas Products from AIRS

gas	Range (cm^{-1})	Precision	Interference
O_3	1025-1050	10%	H2O,emissivity
CO	2080-2200	15%	H2O,N2O
CH_4	1250-1370	20 ppb	H2O,HNO3
CO_2	680-795 2375-2395	2 ppm 2 ppm	H2O,O3
SO_2	1340-1380	100%	H2O,HNO3
HNO_3	880-920 1320-1380	40% 25%	emissivity H2O,CH4
N_2O	1250-2316 2180-2250	10% 10%	H2O H2O,CO
$CFCl_3$ (F11)	830-860	20%	emissivity
CF_2Cl (F12)	900-940	20%	emissivity
CCl_4	790-805	50%	emissivity

In Work

Haskins, R.D. and L.D. Kaplan 1993

ARIES Combines AIRS and MODIS Measurements into One System

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Improved:
- Horizontal Resolution
- Spectral Resolution
- Product Accuracy

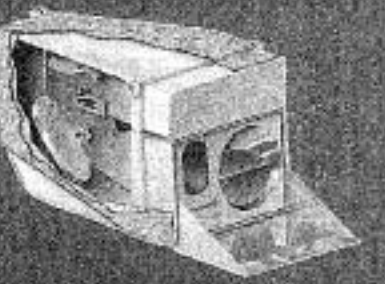
AIRS High Spectral

AIRS
- 13.5 km IR IFOV
- 3.7-15.4 μm IR
- 2378 IR Channels
- $\lambda/\Delta\lambda$ = 1200
- NEdT = 0.05 - 0.3 K
- ± 50° FOV

High Spatial / High Spectral

ARIES
- 1 km IR IFOV
  0.25 km VIS, 0.5 km SW
- 0.4-15.4 μm
- >2000 Channels
- $\lambda/\Delta\lambda$ > 1000 (IR)
- NEdT = 0.1 - 0.3 K
- ± 55° FOV

MODIS High Spatial



MODIS
- 1 km IR IFOV
  0.25-0.5 km VNIR/SW
- 0.4-14.2 μm IR
- 20 RSB, 16 IR Channels
- $\lambda/\Delta\lambda$ = 20-50
- NEdT = 0.05 - 0.3 K
- ± 55° FOV

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Requirements Definition

- Must meet all MODIS and AIRS Capabilities
- Must have enhanced capability of combined spectral and spatial
- Must have modest size, mass, power, data rate, and cost
- Requirements Divided into Four Categories
  - Spatial
  - Spectral
  - Radiometric
  - Resources
- All Requirements Based on Simulation of Detailed Instrument Concept

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National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Spatial

ARIES Scans Wide Slit Along Track

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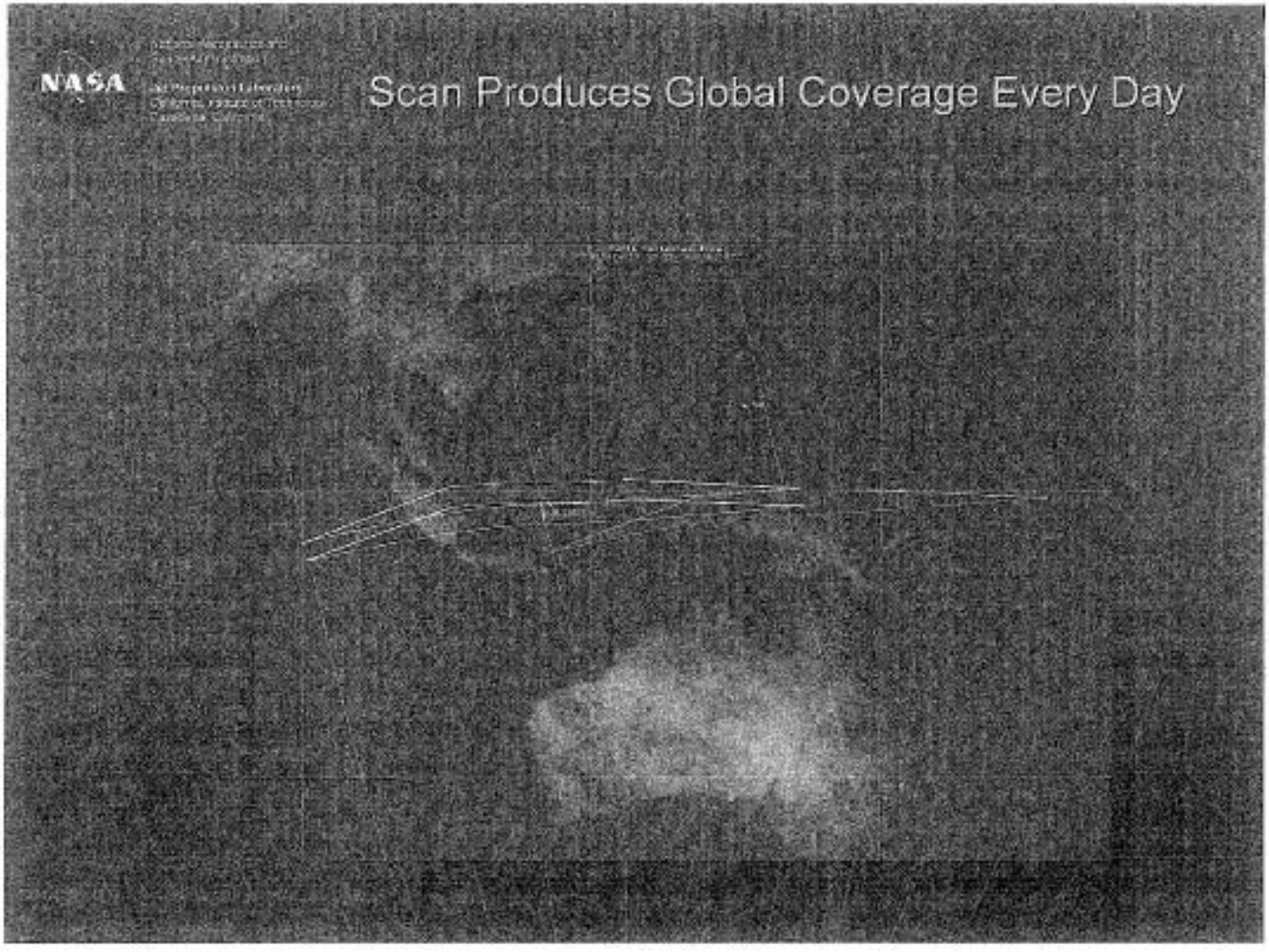
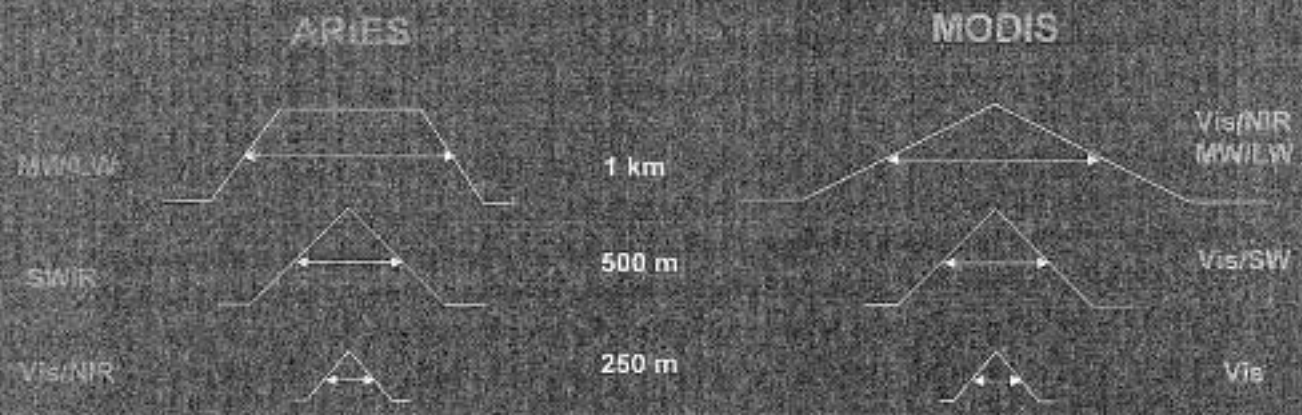
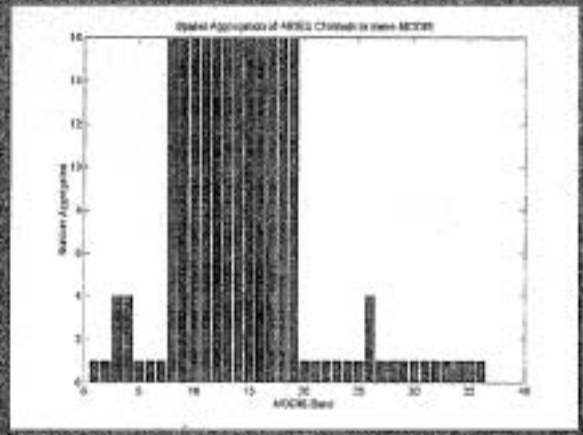
Scan Produces Global Coverage Every Day



ARIES Spatial Resolution Like MODIS



Number of ARIES Pixels Needed to make a MODIS Pixel



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Jet Propulsion Laboratory

Spectral

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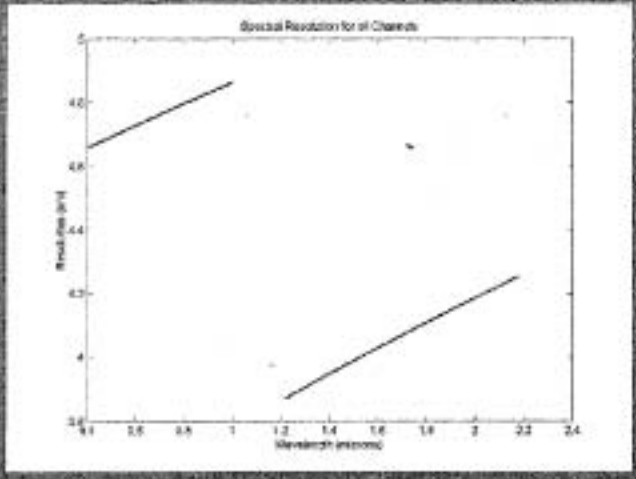
ARIES Bands and Resolution Requirements

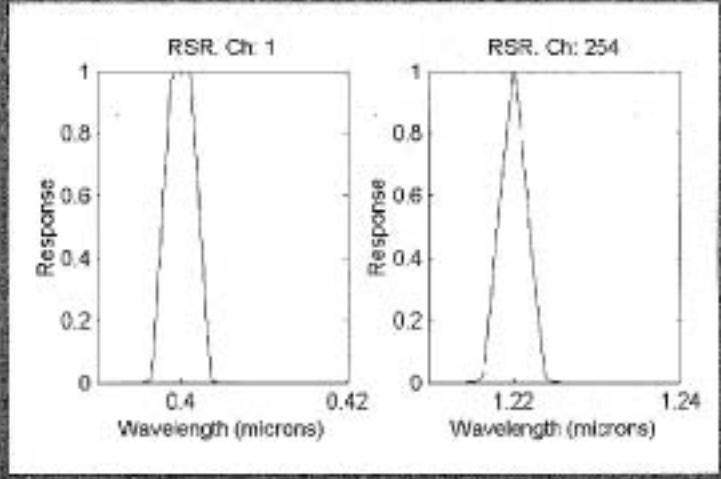
Reflective	**IFOV (km)**	λ_1 **(μm)**	λ_2 **(μm)**	$\Delta\lambda$ **(nm)**	N_{chan}
Ocean, Land, Atmosphere	0.25	0.40	1.00	4.8	254
Snow/Ice, Cirrus, Albedo	0.50	1.22	2.18	3.9	254
Emissive	**IFOV (km)**	ν_1 **(cm^{-1})**	ν_2 **(cm^{-1})**	$\Delta\nu$ **(cm^{-1})**	N_{chan}
Temperature, CO_2, CH_4, N_2O	1.00	2100	2950	1.0	787
Water, CH_4, SO_2, HNO_3	1.00	1150	1613	0.5	999
O_3, HNO_3	1.00	880	1150	0.5	637
Temperature, CO_2	1.00	650	880	0.5	674

Vis/NIR/SWIR Spectral Resolution Requirements

Reflective Bands
4 – 5 nm Resolution

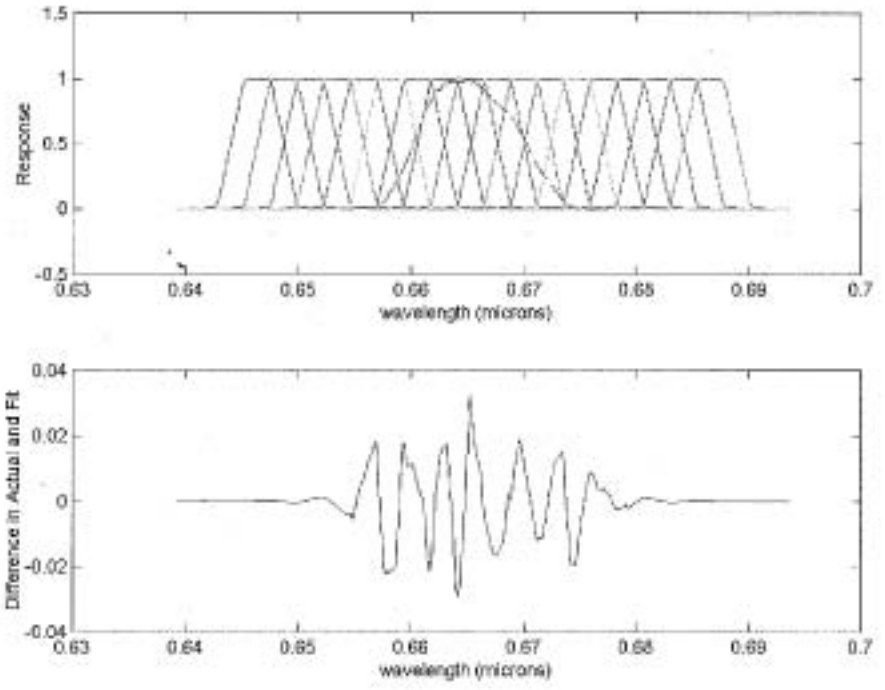


Spectral Shape



All Requirements Based on Analytical Model Design

ARIES Synthesizes MODIS Band 13



Simulation Shows better than 4% Response Error Possible

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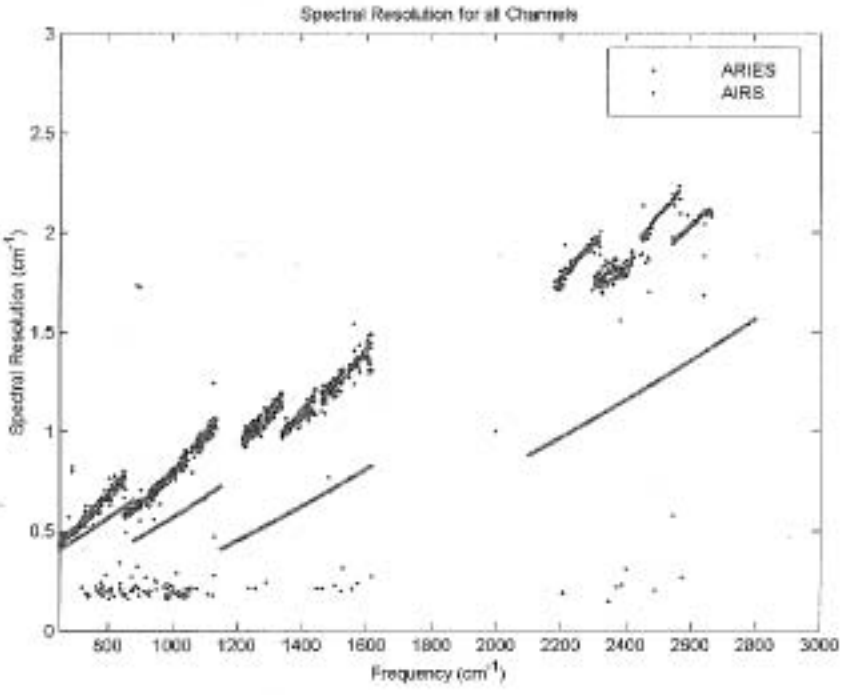
Emissive Bands Resolution Required to be 2x Better than AIRS in SW



All Requirements Based on Analytical Model Design

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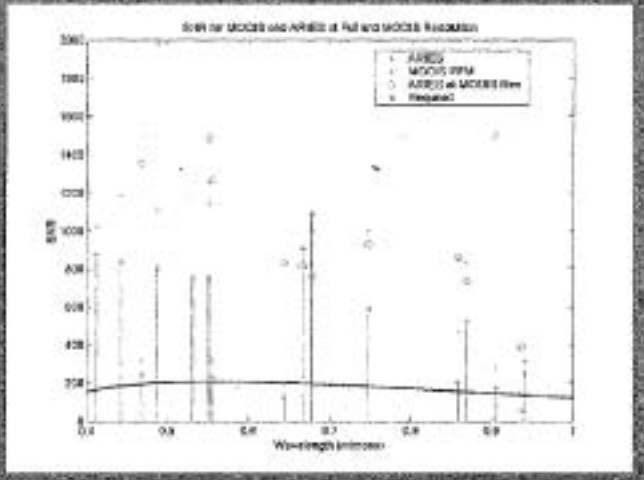
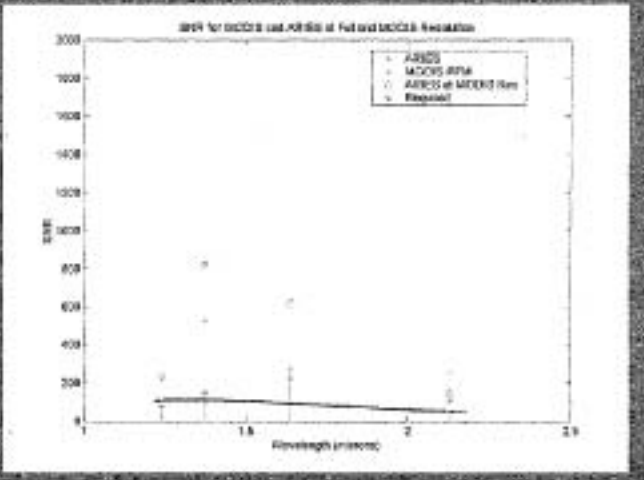
Radiometric

ARIES Meets MODIS SNRs Except Bands 13 and 14

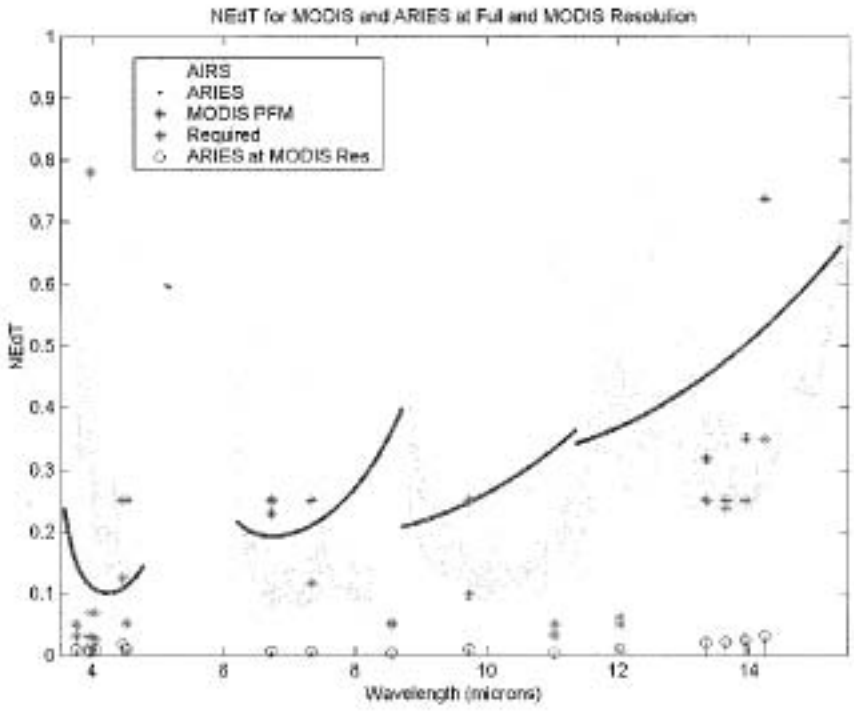
Vis/NIR



SWIR



ARIES Meets AIRS and MODIS NEdTs



Resources

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ARIES Instrument Requirements

Size	0.5 x 0.5 x 1.0	m^3
Mass	150	kg
Power	200	W
Data Rate	60.3	Mbps
Orbit	705.3	km
Swath (±55°)	256 x 2330	km
IFOV	0.25, 0.5, 1.0	km
Spectral Range	0.4 - 15.4	µm

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ARIES Data Rate Requirements

	IFOV	#Chan	Internal Rate	Duty Cycle	Net Rate
	(km)		(Mbps)		(Mbps)
Full Resolution	Full	3605	1071.8	2%	21.4
MODIS Sim	MODIS	36	10.0	100%	10.0
AIRS Global	5 km	514	27.9	100%	27.9
Overhead					1.0
Total Data Rate					**60.4**

Technology Developments Since AIRS Allow ARIES Today

AIRS
1 x 165 x 17

Rockwell
PV HgCdTe
256 x 256 x 6

SIRAS IIP1
Refractive 16°
Grating Spectr

AIRS
Reflective 1.1°
Grating Spectr

ARIES

AIRS
Large Dewar

SIRAS IIP3
High Efficiency
Mini Dewars

NGST
Small Single
Pulse Tube
Cooler

AIRS
Large Dual Pulse
Tube Coolers

Developed under NASA Technology Development Programs (IIP, etc.)

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Conclusions

- AIRS and MODIS were Unqualified Success
- ARIES is Next Generation/Follow-on to AIRS and MODIS
- Science community would benefit significantly from a higher resolution product
  - Spectral resolution of AIRS with Spatial Resolution of MODIS
  - Improved land surface product accuracies
  - Improved regional weather forecasting
  - Improved water vapor retrievals
  - Improved trace gas retrievals
- Requirements Call for High Level of Spatial, Spectral and Radiometric Capability
- Spacecraft Resource Requirements Modest
- Technology Development Since AIRS Allows ARIES