The CEOS 20th Anniversary Symposium

CEOS WGCV Presentation

Beijing, China – 15 November 2004

CEOS

Working Group on Calibration and Validation

Stephen Ungar - CEOS WGCV Chair

CEOS 20th Anniversary Symposium
Beijing, China - November 15, 2004

CEOS WGCV

The Working Group on Calibration and Validation (WGCV) was established in 1984. This resulted from the recognition that calibration and validation activities should play a key role in all satellite Earth Observation missions to ensure the clear and quantitative understanding of the data they generate.

Definitions

Committee on Earth Observation Satellites

Working Group on Calibration & Validation

Calibration

The process of quantitatively defining the system responses to known, controlled signal inputs

Validation

The process of assessing, by independent means, the quality of the data products derived from the system outputs

Membership

Membership in the WGCV is open to all members of CEOS as defined in the CEOS Terms of Reference, including observers and affiliates. Members may include in their delegations to WGCV meetings any participants who have relevant expertise to contribute to the objectives of the WGCV. Each CEOS member and affiliate designates a point of contact for WGCV correspondence.

Objectives

The objectives of the WGCV are to enhance coordination and complementarity, to promote international cooperation, and to focus activities in the calibration and validation of Earth observations for the benefit of the CEOS members and the international usercommunity.

Sample Calibration Strategy

Stephen G. Ungar
EO-1 Mission Scientist

A Case Study based on EO-1

LAUNCH

Launch Date: Nov. 21, 2000

Launch Vehicle: Delta 7320

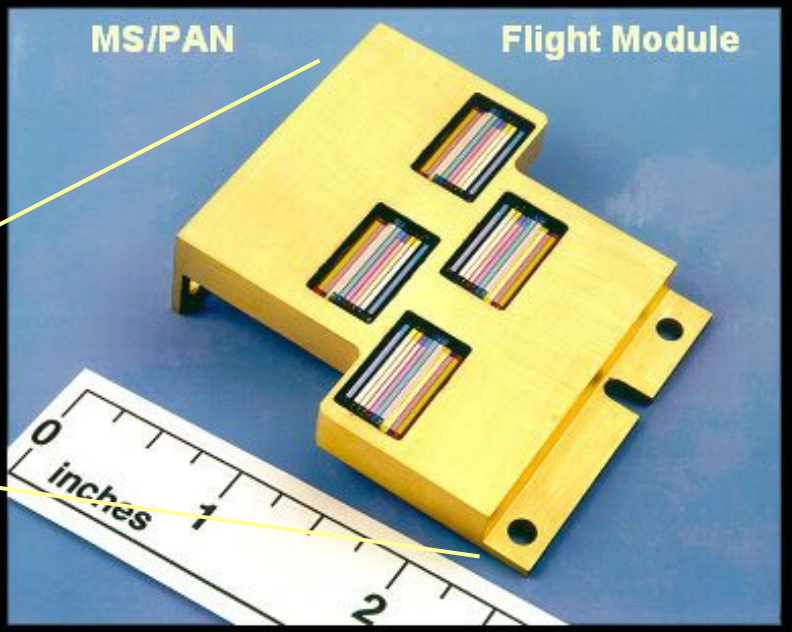
Co-manifested with SAC-C

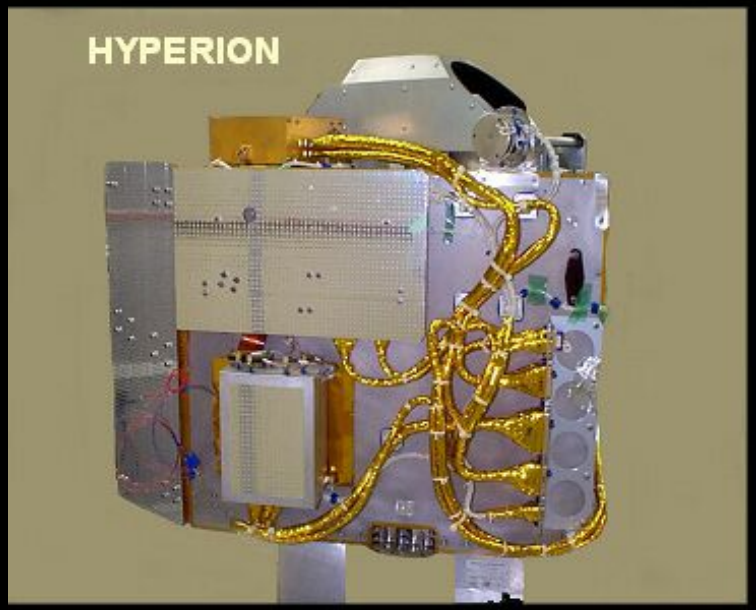
ORBIT

705 Km altitude Sun-synchronous, circular orbit inclined at 98.2°

Descending node with an equatorial crossing about one minute behind Landsat 7

EO-1 Flight Instruments





EO-1 Calibration Strategy

- Prelaunch
  - Calibrate and characterize (component and system level)
  - Characterize the calibration and characterization
- Postlaunch
  - Lamps
  - **Solar**
  - Lunar (astronomical)
  - Vicarious
  - “Special Targets” (limb scanning, active illumination)
  - Statistical (trending, 90° yaw)
  - Direct comparison against other satellites

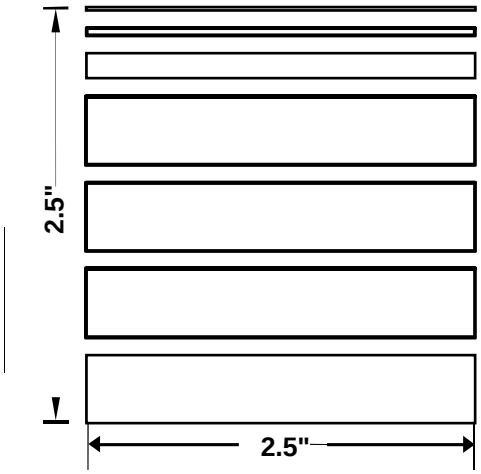
EO-1 ALI CALIBRATION MEASUREMENT MATRIX

	PARAMETER														
	$F(\lambda)$			R_N			S_o			$(x, y)_N$			MTF		
	MS	W	G	MS	W	G	MS	W	G	MS	W	G	MS	W	G
COMPONENT TESTS AND ANALYSIS	●	○	—	○	○	○	○	○	○	—	—	—	○	○	○
SUBSYSTEM TESTS: TELESCOPE, GIS, WIS AND MS/PAN	○	●	○	○	○	○	○	○	○	●	●	○	○	○	○
INSTRUMENT LEVEL LABORATORY TESTS	○	○	●	●	●	●	○	○	○	○	○	●	●	●	●
ON-ORBIT MEASUREMENTS															
- SOLAR DIFFUSER	—	—	—	●	●	●	○	○	○	—	—	—	—	—	—
- CLOSED APERTURE COVER	—	—	—	—	—	—	●	●	●	—	—	—	—	—	—
- INTERNAL SOURCES	—	—	—	○	○	○	—	—	—	—	—	—	—	—	—
- LUNAR SCANS	—	—	—	○	○	○	○	○	○	—	—	—	○	○	○
- EARTH SCENES	—	○	○	○	○	○	—	—	—	○	○	○	○	○	○

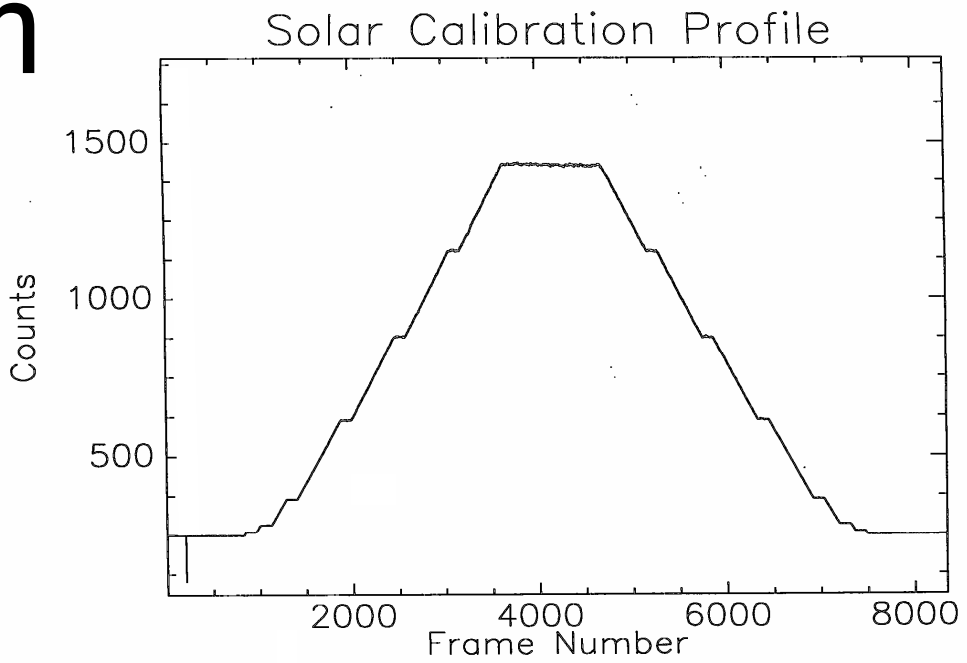
● PRIMARY MEASUREMENT ○ SECONDARY MEASUREMENT

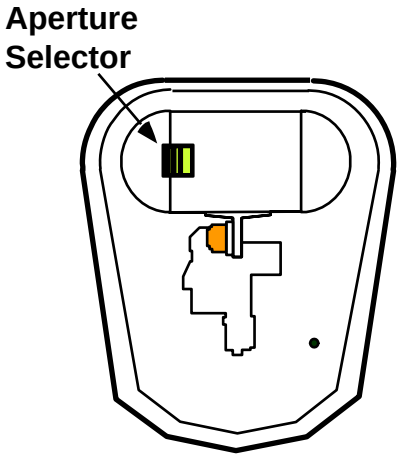
Solar Calibration

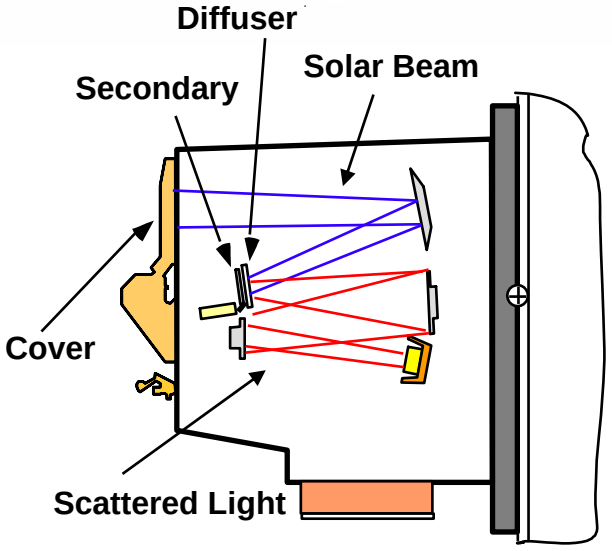
ALI



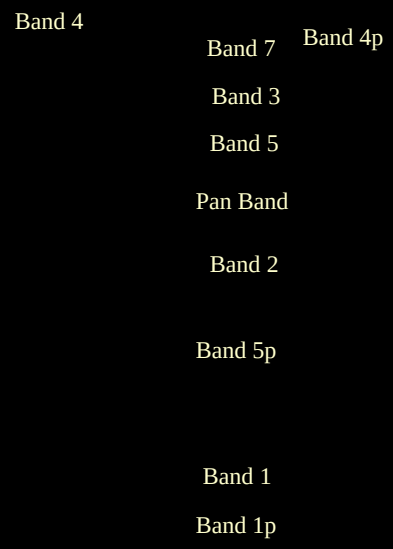
Signal Level	Cumulative Signal
1%	1%
2%	3%
7%	10%
20%	30%
20%	50%
20%	70%
20%	90%







Solar Calibration Response



Extra-terrestrial calibration!

(Views with the EO-1 ALI Pan band)

Full Moon

Jupiter

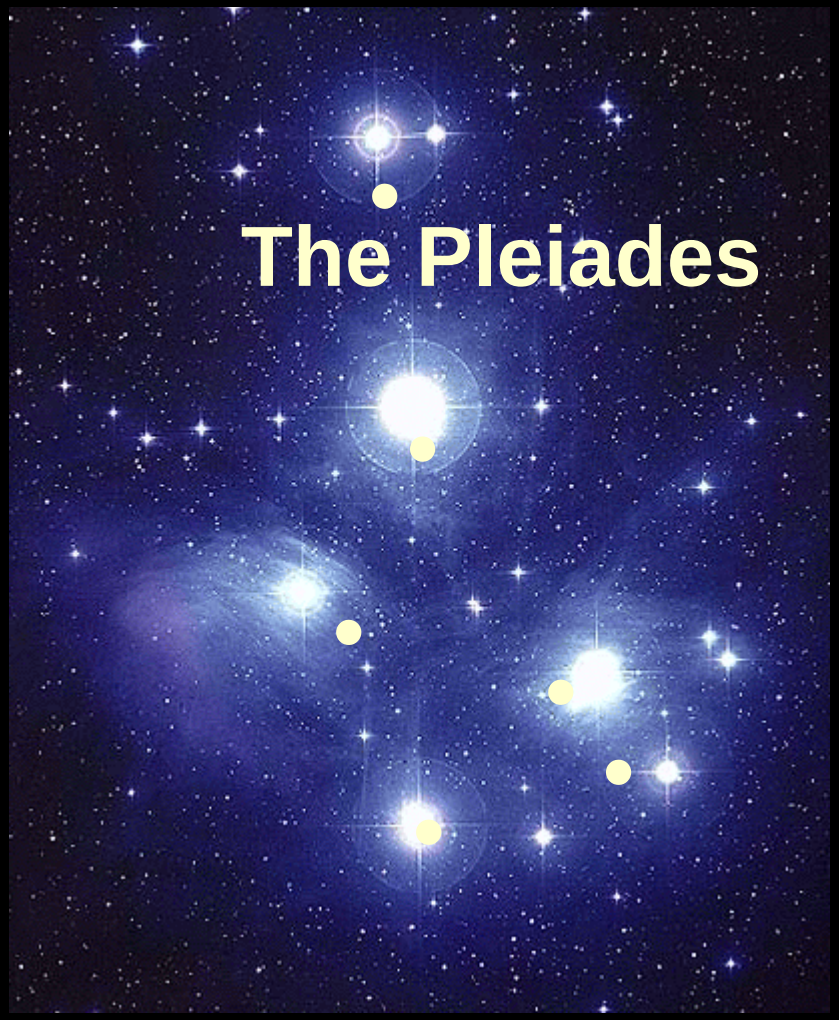
Venus

Half Moon

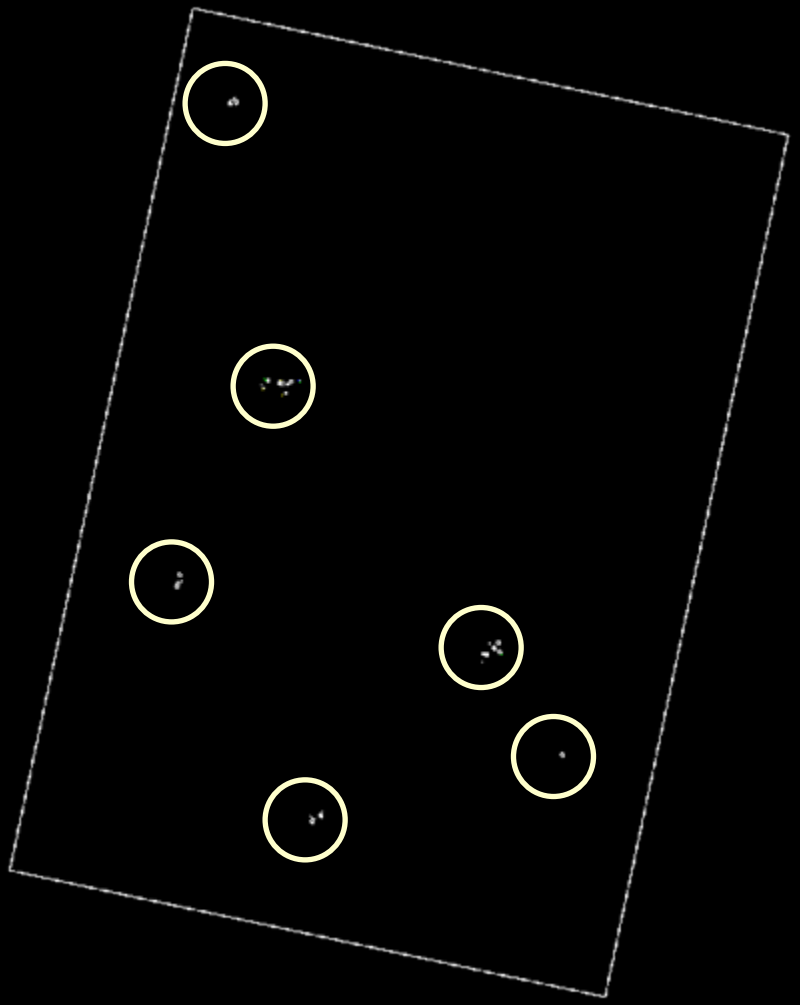
Saturn

Extra-terrestrial calibration!

(Views with the EO-1 ALI Pan band)



Photograph



ALI detections

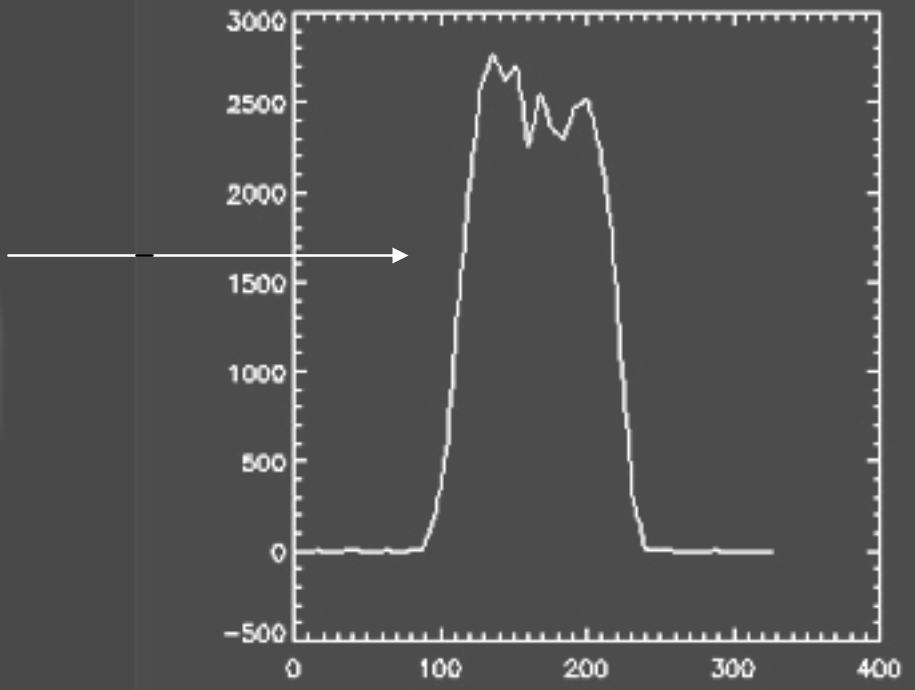
Radiometric Calibration

- Lunar Calibration
  - Calculate Lunar spectral irradiance ($E_M(\lambda)$)
  - Compare to the USGS Robotic Lunar Observatory lunar irradiance model

- Intersatellite Comparison
  - Landsat 7
  - Sites Compared
    - CA Super Site Jan 2001
    - Railroad Valley Jan 2001
    - Lake Frome Jan 2001
  - Compared Bands 1, 2, 3, 5, 7 due to similarity of spectral responses
  - Terra comparisons forthcoming

Image Quality (Edge Sharpness)

Lunar Image Expanded by a Factor of 8

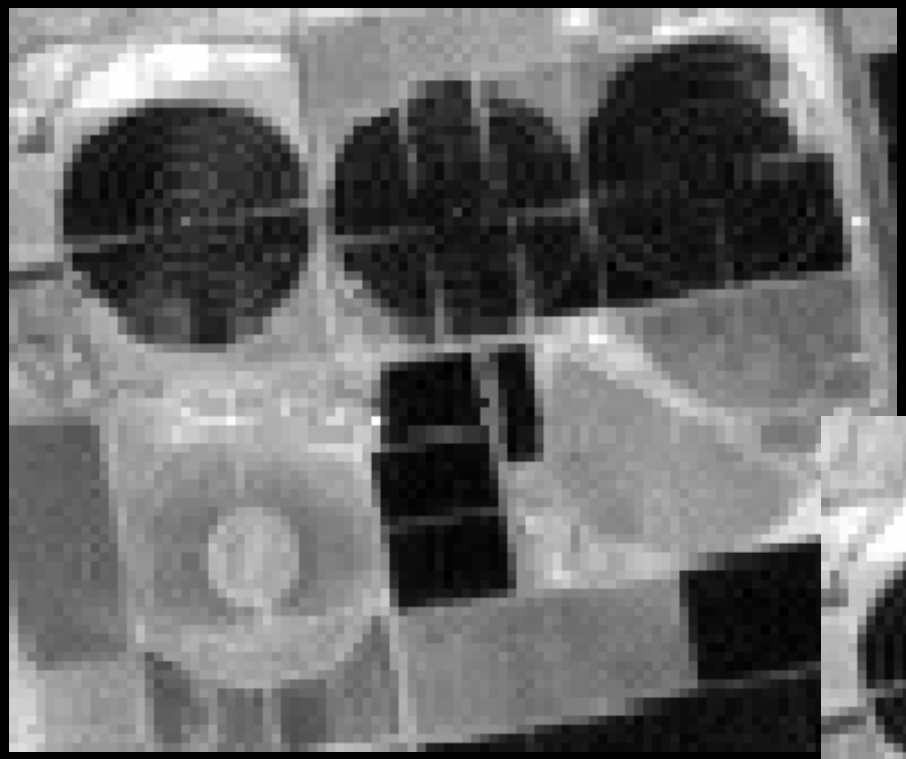


Horizontal Slice Through Expanded Lunar Image Rise and Fall About 1 Pixel in Normal Image.

Focus : Lunar Edge

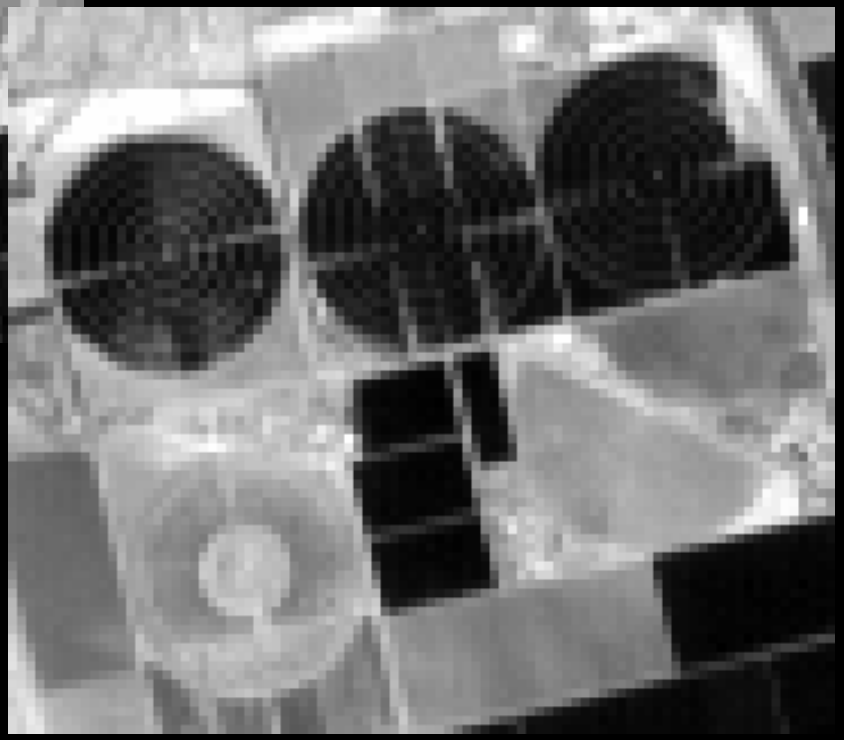
ALI versus ETM+ Local Geometry

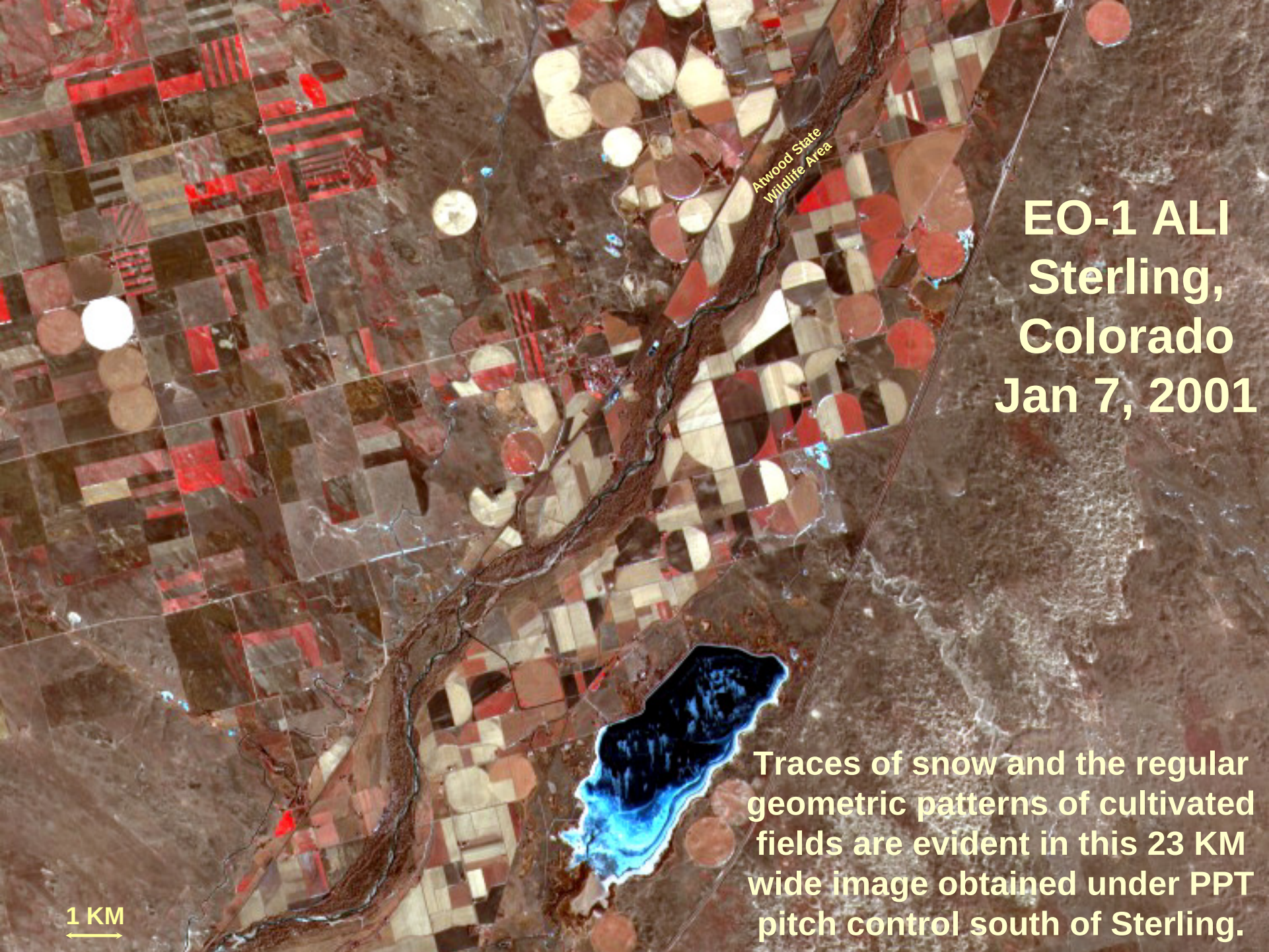
Maricopa July 27, 2001 (DOY208)



ETM+
L1G
band 1

ALI
L1R
band 2




Atwood State
Wildlife Area
EO-1 ALI
Sterling,
Colorado
Jan 7, 2001
Traces of snow and the regular geometric patterns of cultivated fields are evident in this 23 KM wide image obtained under PPT pitch control south of Sterling.
1 KM

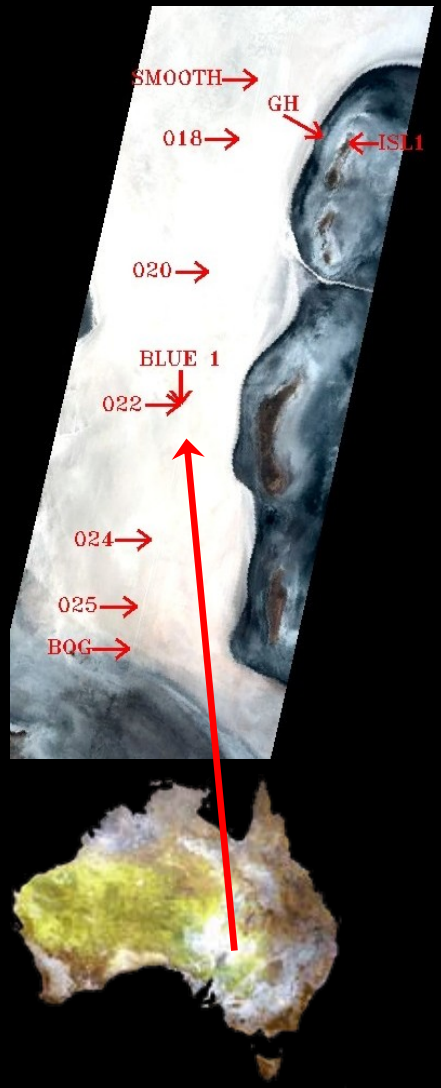
Hyperion Characteristics

Characteristic	Pre-launch Cal	On-orbit Cal
GSD (m)	29.88	30.38
Swath (km)	7.5	7.75
No. of Spectral Channels	220	200 (L1 data)
VNIR SNR (550-700nm)	144-161	140-190
SWIR SNR (~1225nm)	110	96
SWIR SNR (~2125nm)	40	38
VNIR X-trk Spec. Error	2.8nm@655nm	2.2nm
SWIR X-trk Spec. Error	0.6nm@1700nm	0.58
Spatial Co-Reg: VNIR	18% @ Pix #126	*
Spatial Co-Reg: SWIR	21% @ Pix #131	*
Abs. Radiometry(1Sigma)	<6%	3.40%
VNIR MTF @ 630nm	0.22-0.28	0.23-0.27
SWIR MTF @ 1650nm	0.25-0.27	0.28
VNIR Bandwidth (nm)	10.19-10.21	*
SWIR Bandwidth (nm)	10.08-10.09	*

* Consistent with Pre-Launch Calibration or not measured

Desert Sites used for Vicarious Calibration

Lake Frome



RR Valley

Arizaro/Barreal Blanco

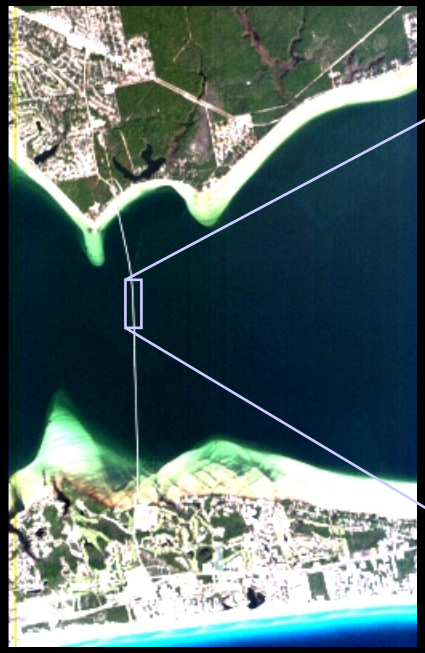
Post Launch MTF Approach

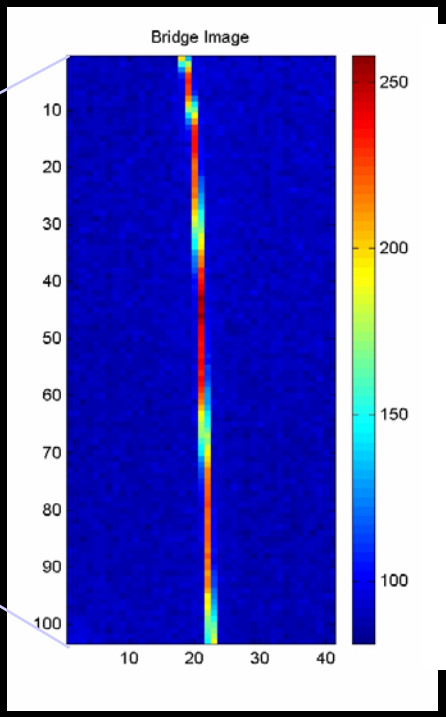
- Calculate cross-track and in-track MTF using a step response and impulse response example

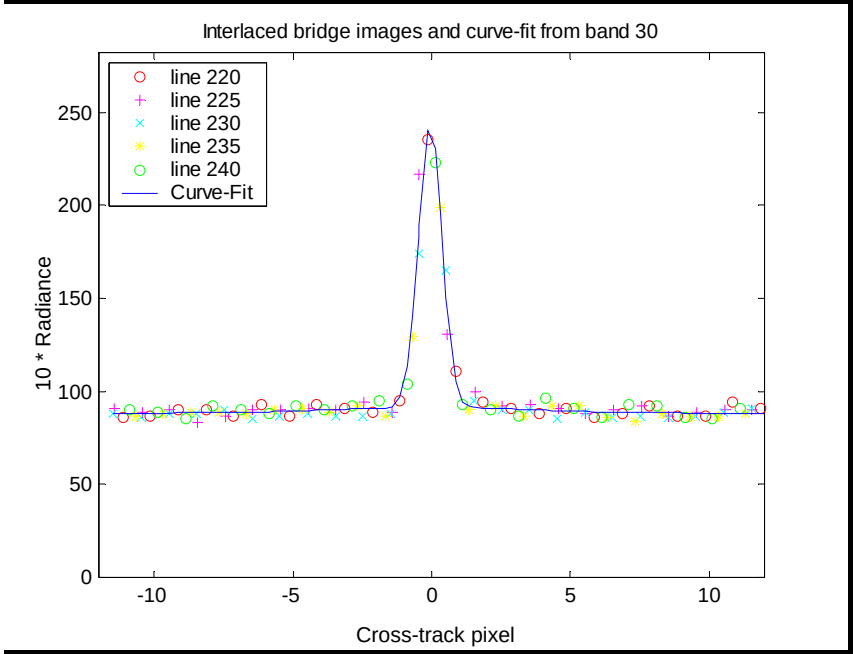
- Results of on-orbit analysis give good agreement with the pre-launch laboratory measurements

Example: Cross-track MTF

- Scene is Port Eglin from Dec 24, 2000. Bridge is the Mid-bay bridge . Bridge width is 13.02 meters.
- Bridge angle to the S/C direction is small so every 5th line is used to develop the high resolution bridge image.
- MTF result at Nyquist is between 0.39 to 0.42 while the pre-flight measurement was 0.42.



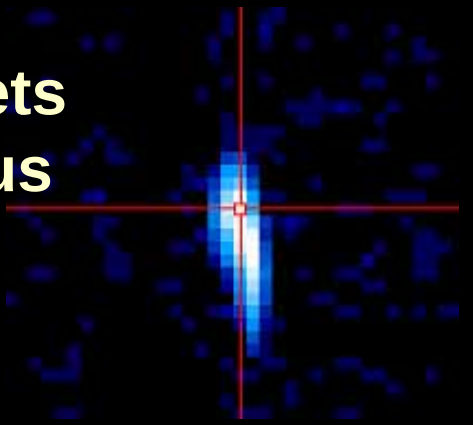




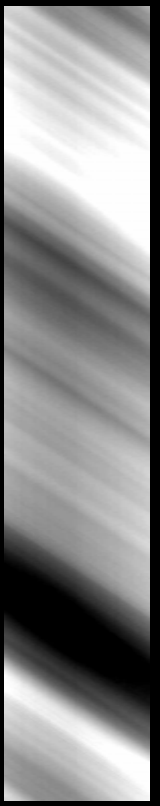
Special targets for characterization

Searchlights
-California

Planets
-Venus

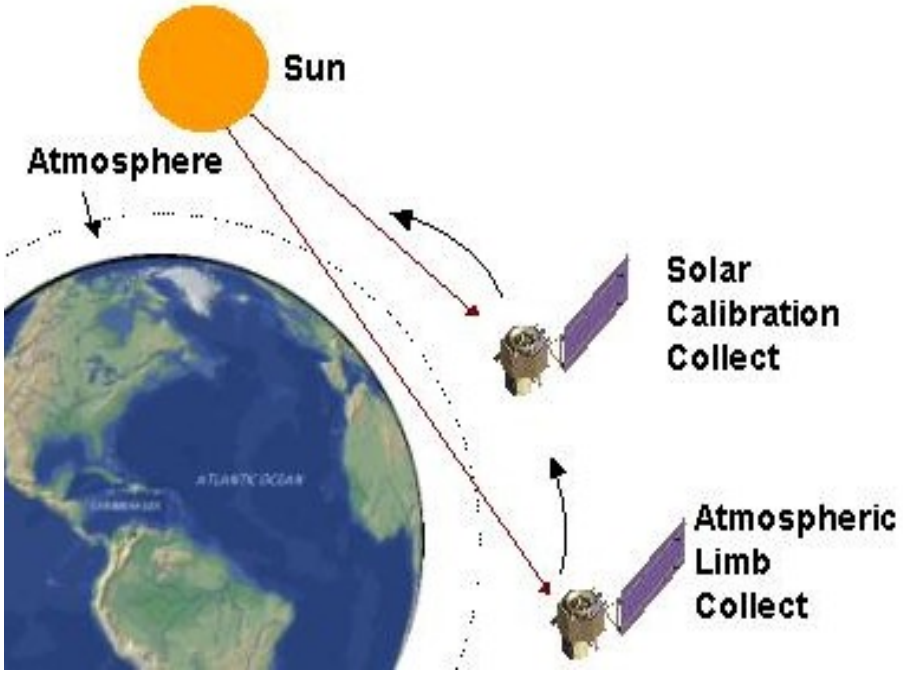


Gas Flares
-Moomba



90 deg Yaw

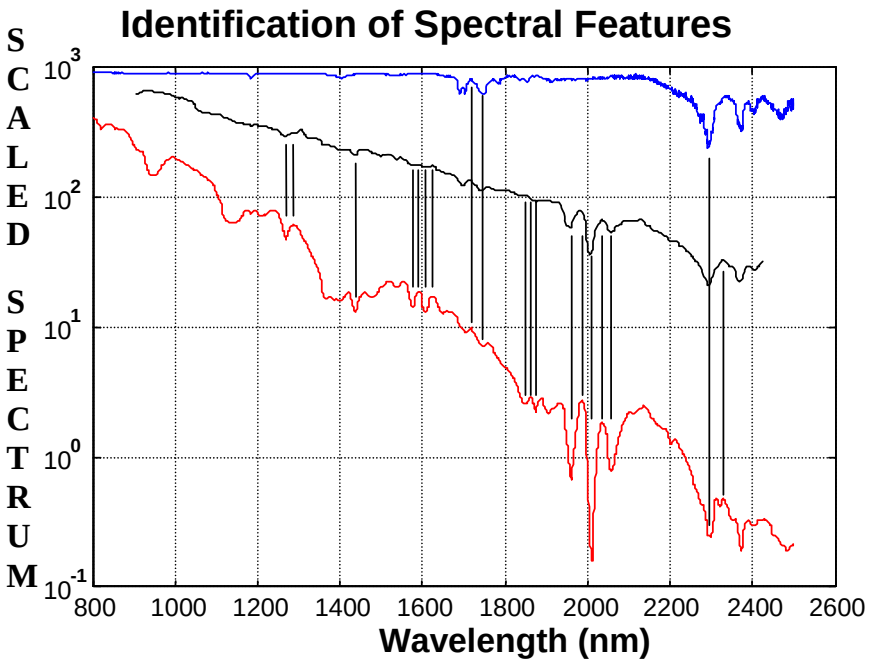
Hyperion Spectral Calibration atmospheric absorption lines



Hyperion Spectra – red

Atmospheric Reference – black

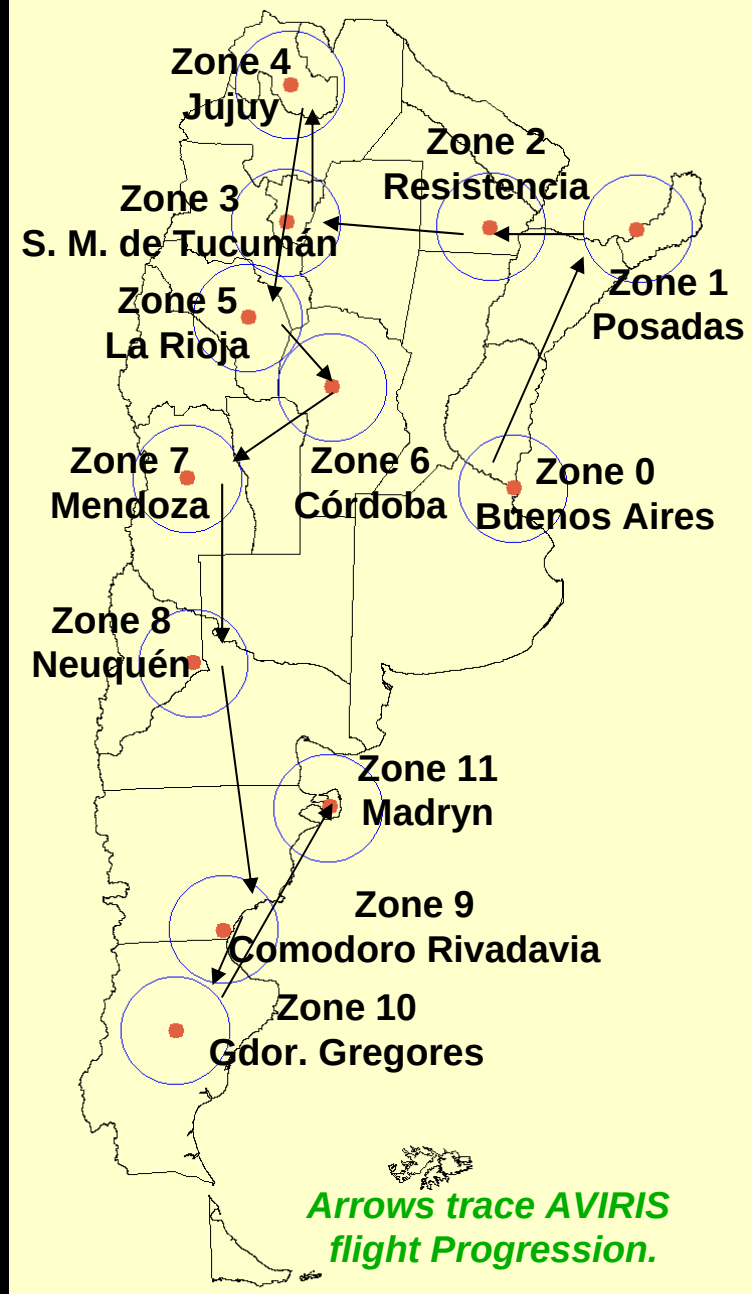
Diffuse Reflectance of cover – blue



EO-1 Accelerated Mission Southern Hemisphere Field Campaigns

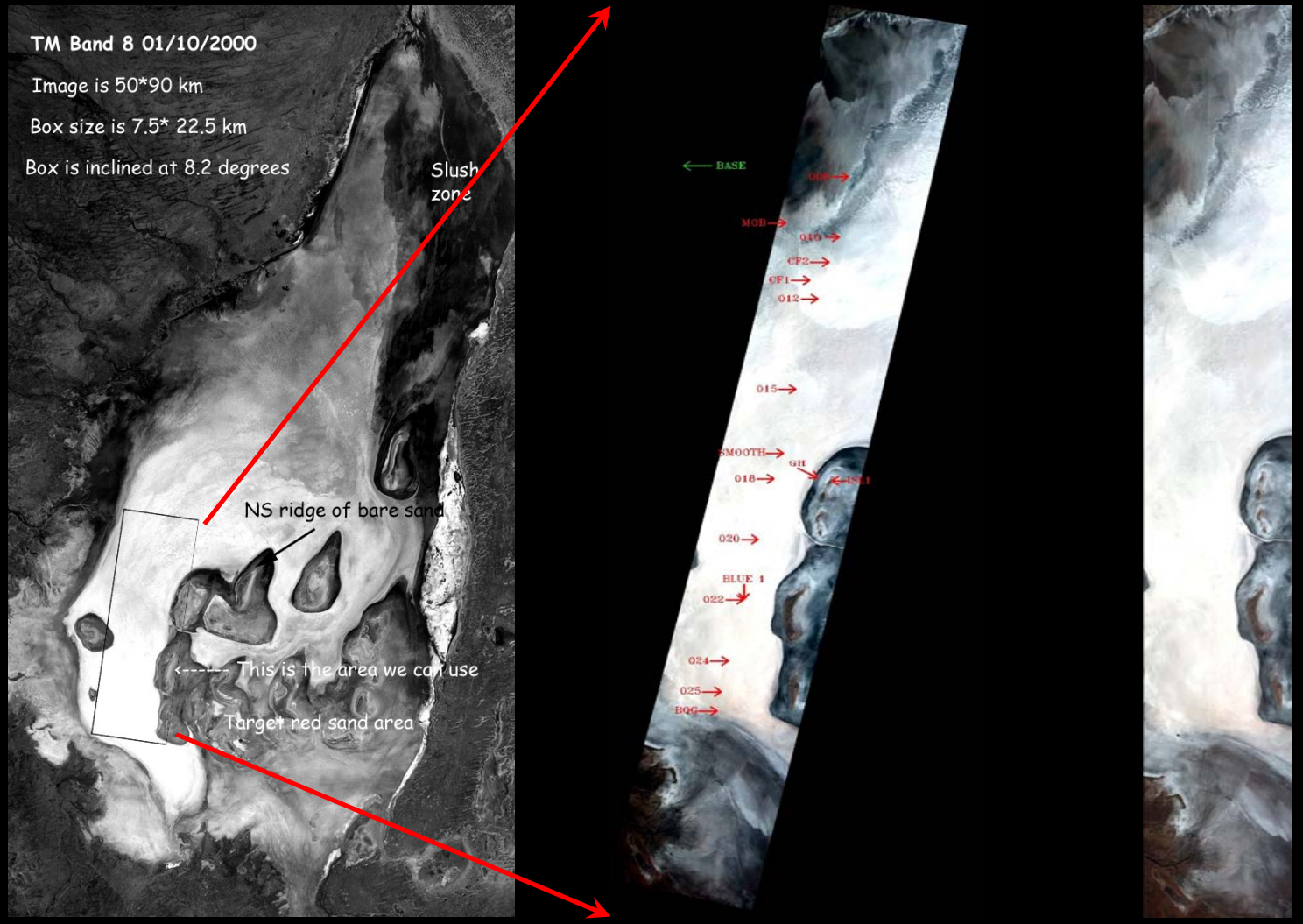
January – February 2001

Australian Test Sites



Argentine/AVIRIS Sites

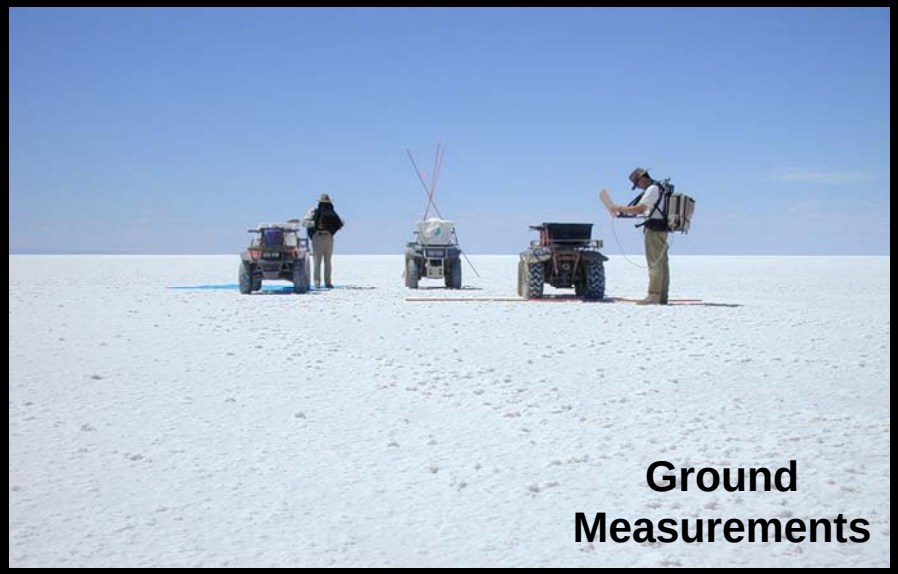
Lake Frome Calibration Site

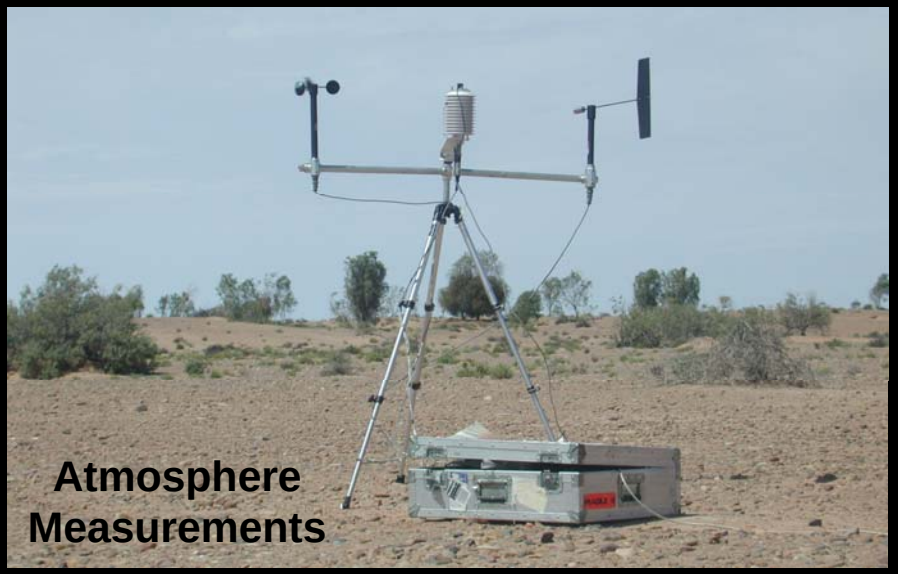


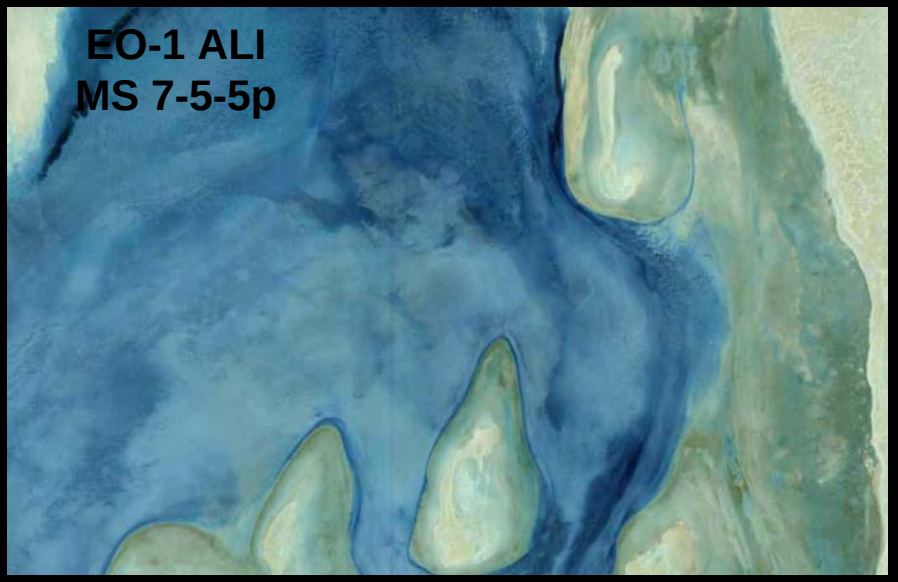
Instrument deployment coincident with EO-1 ALI and Landsat7 ETM+ overpasses

Venice field site

Ground Truth Site: Lake Frome, Au








AVIRIS
Twin Otter

Radiometric Calibration

- **Ground Truth Referencing**
  - **Lake Frome, Au ground truth collected by CSIRO.**
  - **Barreal Blanco and Arizario Argentina ground truth collected by U. of Arizona and U. of Colorado**
  - **Ivanpah Playa ground truth collected by U. of Arizona**
  - **AVIRIS underflights**

EVEOSD Vegetation Sampling

Field Data Collection

Forest Growth

Leaf & Canopy Chemistry

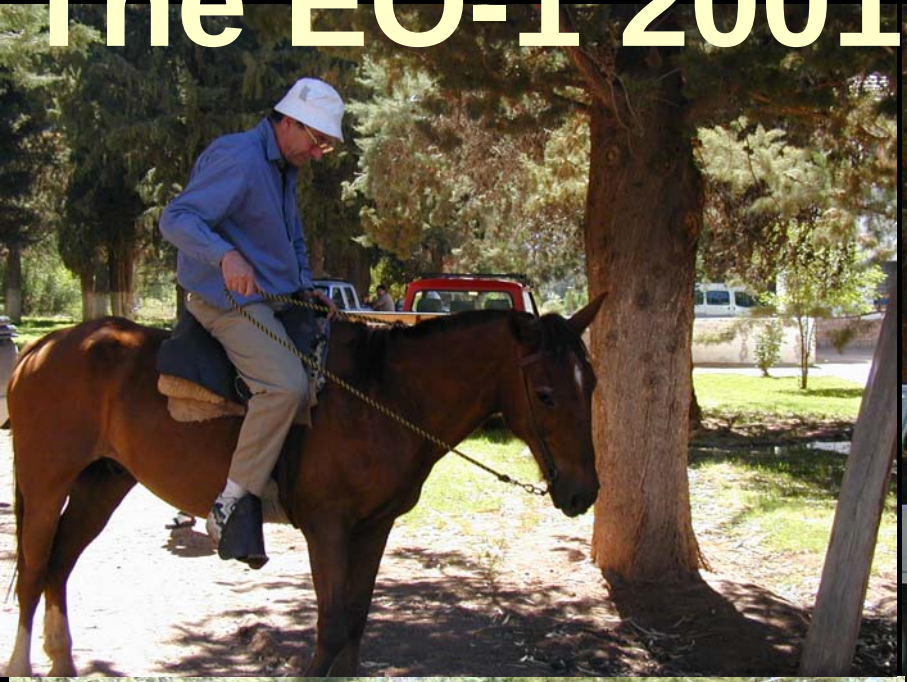
Canopy Structure

Soil & Water Chemistry

The EO-1 2001 Field Campaign

AVIRIS Overflights

The EO-1 2001 Field Campaign



Barreal Blanco

The EO-1 2001 Field Campaign

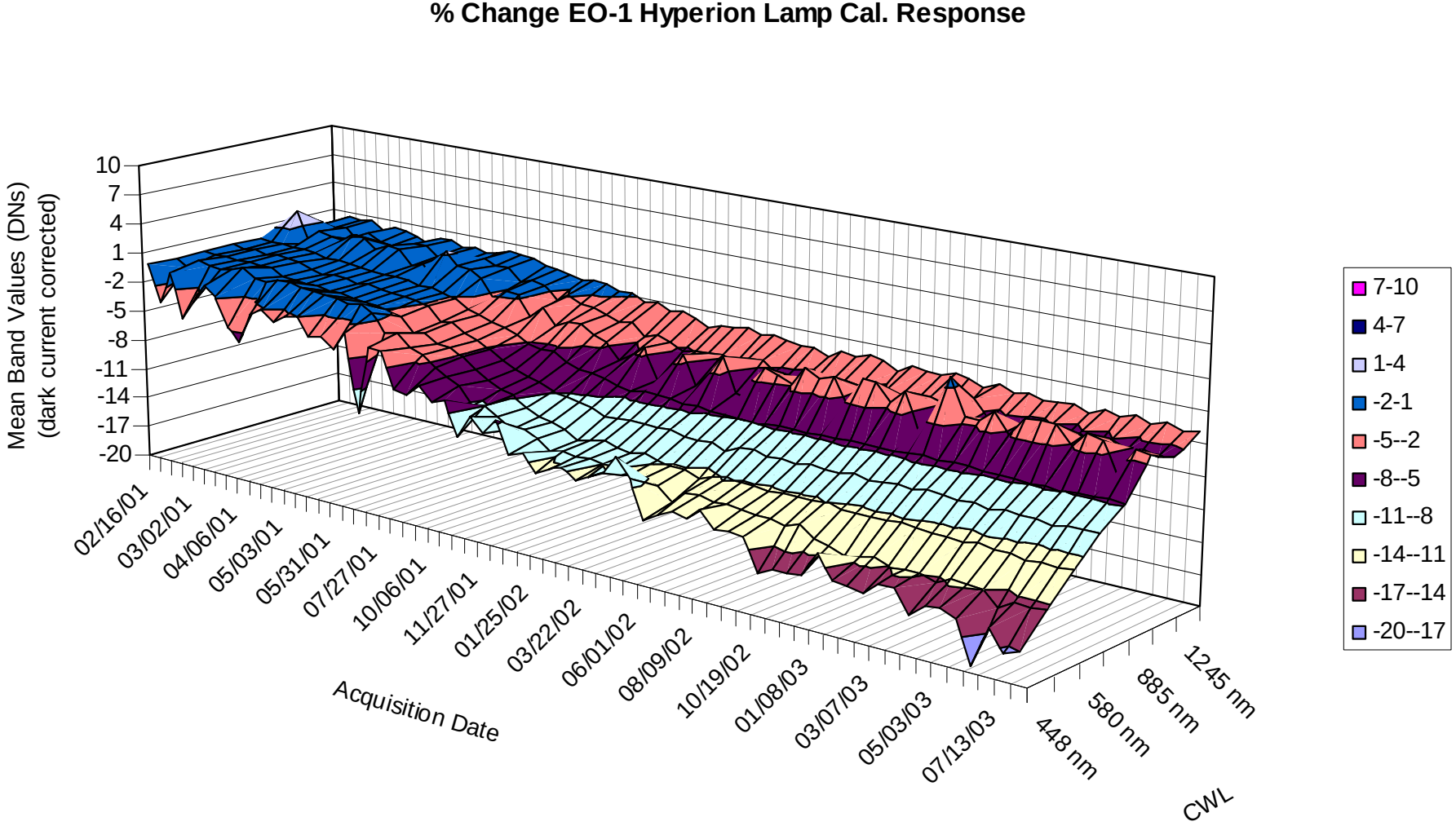
Central Australia

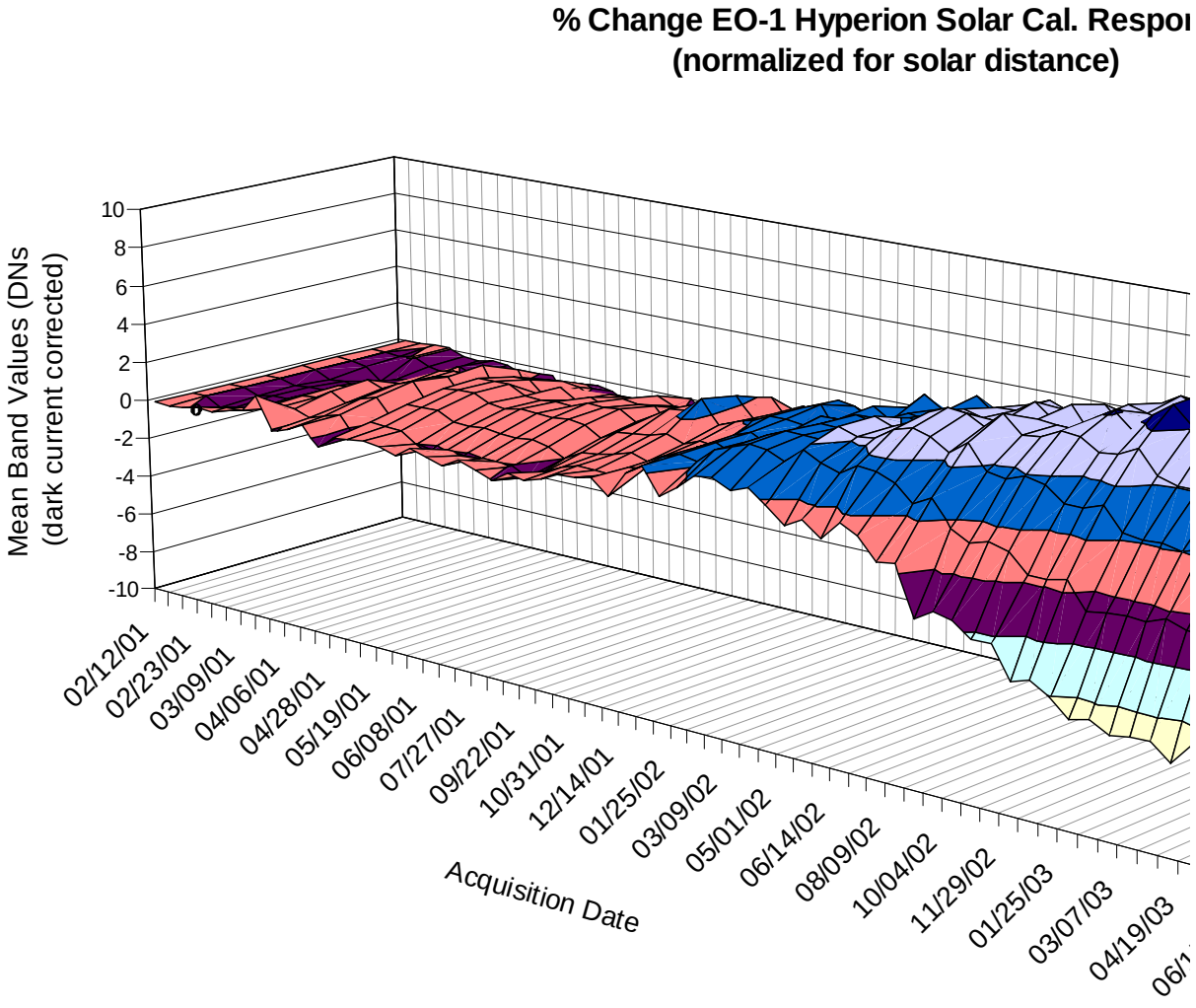
Show Barreal field site

Show Arizaro field site

The EO-1 2002 Field Campaign

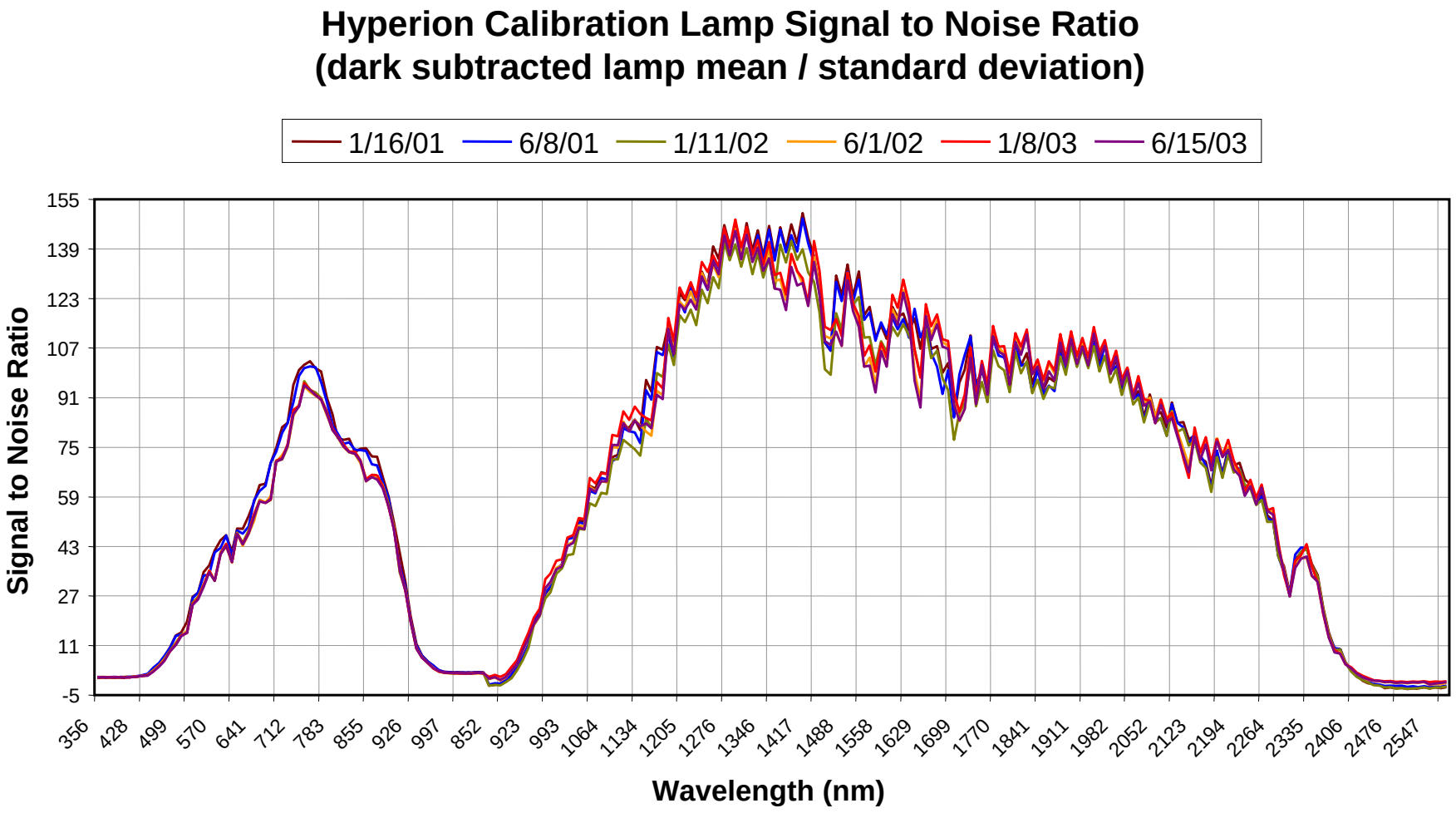
Salar de Arizaro - 11 Dec. 2002


% Change EO-1 Hyperion Lamp Cal. Response
Mean Band Values (DNs)
(dark current corrected)
10
7
4
1
-2
-5
-8
-11
-14
-17
-20
02/16/01
03/02/01
04/06/01
05/03/01
05/31/01
07/27/01
10/06/01
11/27/01
01/25/02
03/22/02
06/01/02
08/09/02
10/19/02
01/08/03
03/07/03
05/03/03
07/13/03
Acquisition Date
448 nm
580 nm
885 nm
1245 nm
CWL
7-10
4-7
1-4
-2-1
-5--2
-8--5
-11--8
-14--11
-17--14
-20--17


% Change EO-1 Hyperion Solar Cal. Respo
(normalized for solar distance)
Mean Band Values (DNs
(dark current corrected)
10
8
6
4
2
0
-2
-4
-6
-8
-10
02/12/01
02/23/01
03/09/01
04/06/01
04/28/01
05/19/01
06/08/01
07/27/01
09/22/01
10/31/01
12/14/01
01/25/02
03/09/02
05/01/02
06/14/02
08/09/02
10/04/02
11/29/02
01/25/03
03/07/03
04/19/03
Acquisition Date

Show stats by date

Show stats by channel


Hyperion Calibration Lamp Signal to Noise Ratio
(dark subtracted lamp mean / standard deviation)
1/16/01
6/8/01
1/11/02
6/1/02
1/8/03
6/15/03
Signal to Noise Ratio
155
139
123
107
91
75
59
43
27
11
-5
356
428
499
570
641
712
783
855
926
997
852
923
993
1064
1134
1205
1276
1346
1417
1488
1558
1629
1699
1770
1841
1911
1982
2052
2123
2194
2264
2335
2406
2476
2547
Wavelength (nm)

Hyperion Calibration Solar Signal to Noise Ratio
(normalized solar mean / standard deviation)