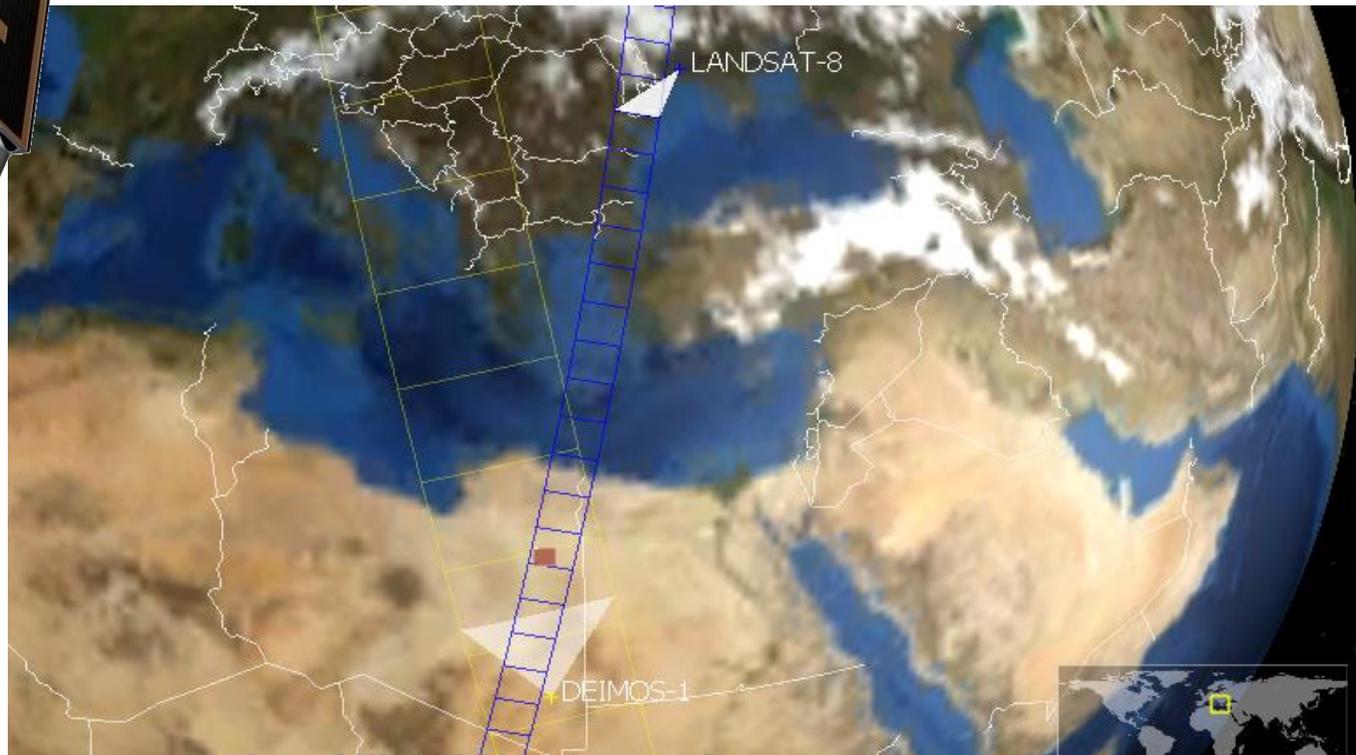




Deimos-1 Cross-calibration with Landsat-7 & Landsat-8



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IMAGING, Spain

JACIE 2014

13th Annual Civil Commercial Imagery Evaluation Workshop
Louisville, KY - March 26-28, 2014

- **The DEIMOS-1 Earth Observation System**
- **Landsat-7 & Deimos-1 systems comparison**
- **Cross-calibration with Landsat 7 ETM+**
- **Landsat-8 & Deimos-1 systems comparison**
- **Cross-calibration with Landsat-8 OLI**
- **Results, conclusions and on-going work**
- **Q&A**

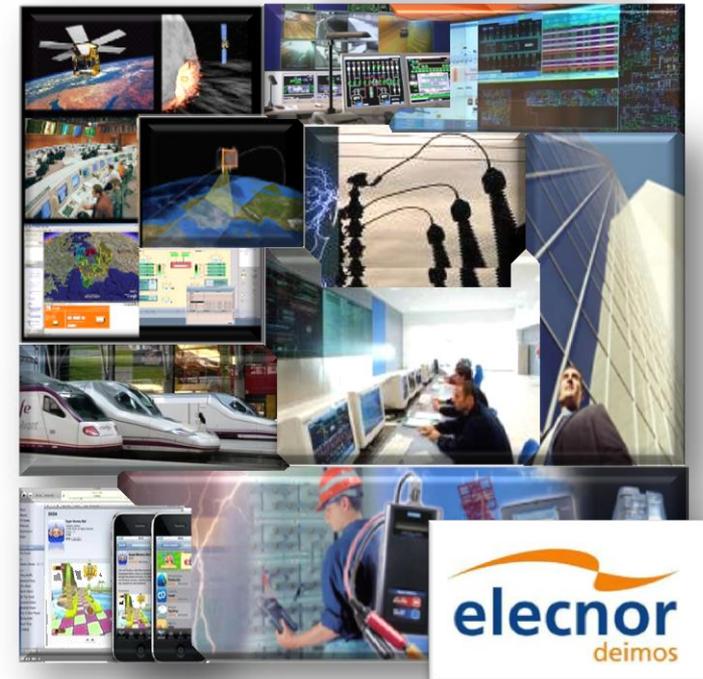
1 The DEIMOS-1 Earth Observation System



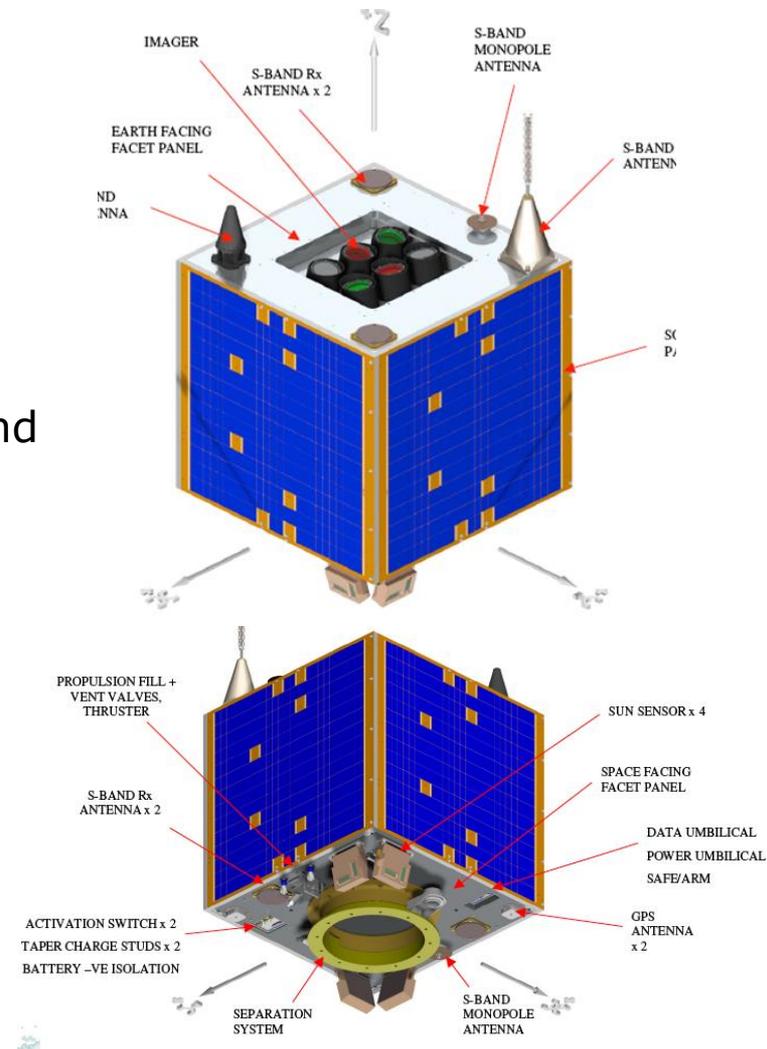
- Fully owned and operated by **ELECNOR DEIMOS IMAGING**
- Subsidiary of **ELECNOR**, one of the largest industrial private groups in Spain
- Member of the **Disaster Monitoring Constellation (DMC)**
- Launched in July 2009, operational since March 2010
- Sun-Synchronous orbit at 650 km
- Expected lifetime: 10 years



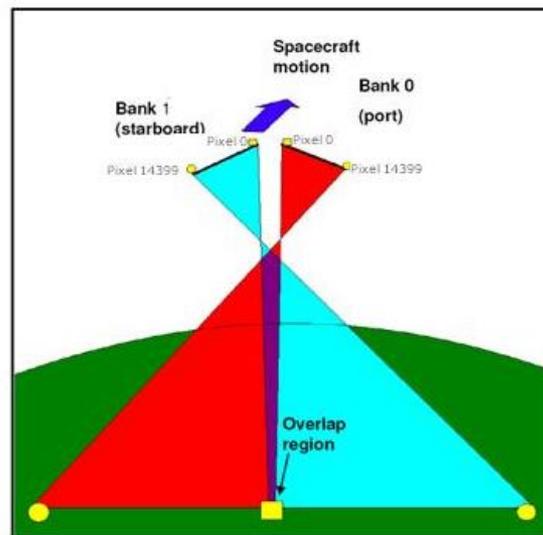
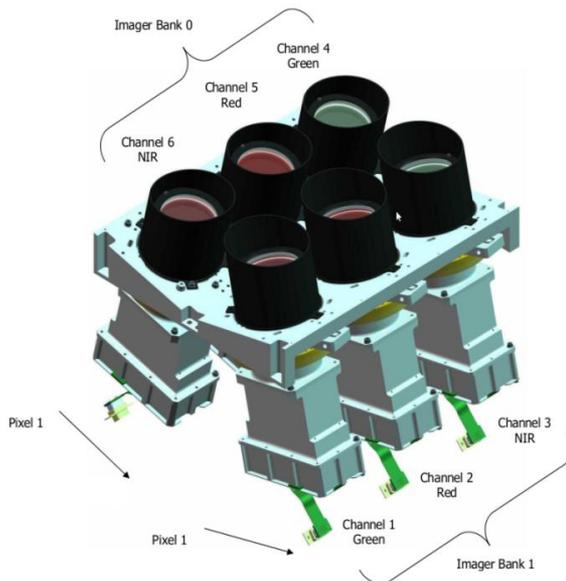
CONUS by Deimos-1, July 2011



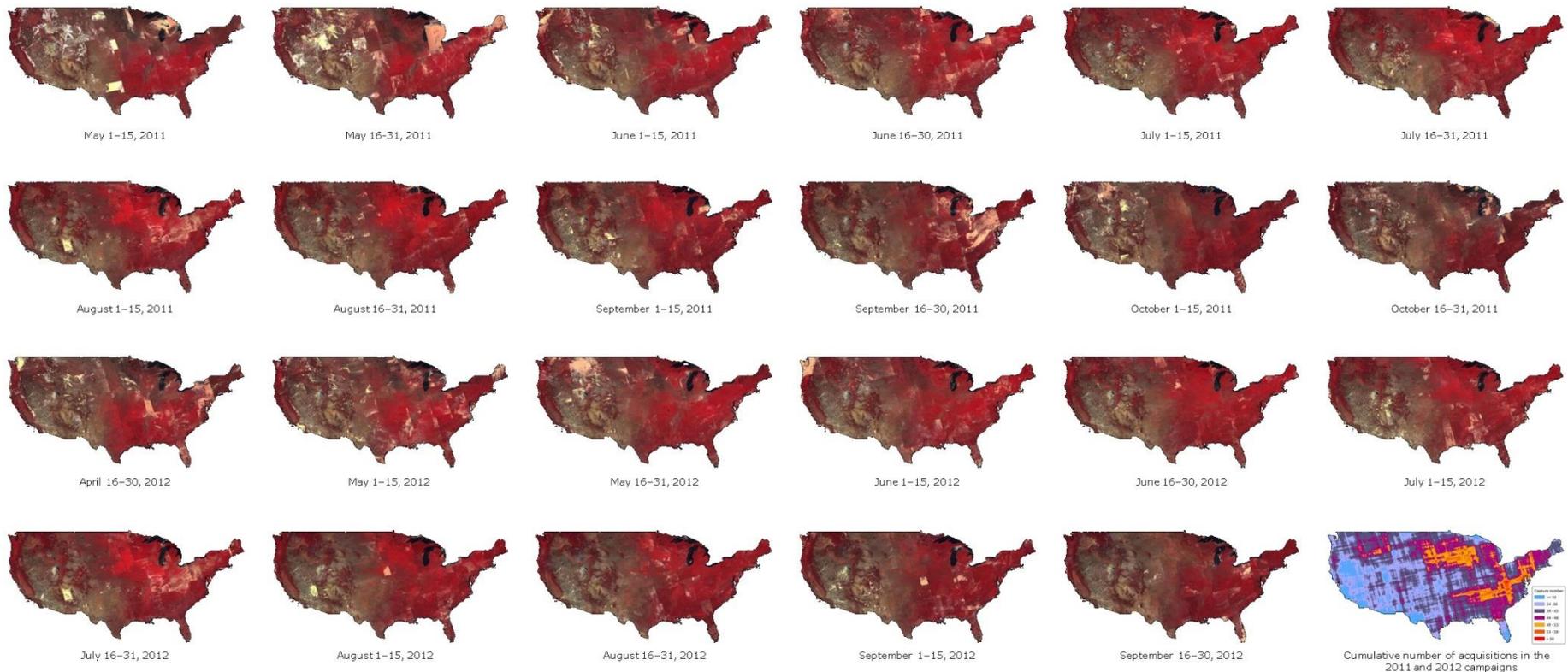
- Built by SSTL (UK)
- Mass: 100 Kg
- Nadir-pointing platform
- 8-Gb on-board solid state recorder
- X-band antenna for data transmission
- S-band antenna for telemetry & telecommand



- Dual-bank pushbroom CCD, 3 cameras per bank
- Spatial resolution of **22m GSD** at 10 bits
- The wide **>620-km swath** allows to have a high frequency of observation of any given point on Earth
- **Three bands (R,G,NIR)** similar to Landsat to assure continuity with existing tools and harmonization with historical data
- Synthetic blue band can be generated for natural-color imagery



- 34 bi-weekly cloud-free coverages of the US provided to USDA via SICORP during 2011, 2012 and 2013 crop seasons, with DEIMOS-1 & UK-DMC2 data



CONUS by Deimos-1 & UK-DMC2, 2011-2012 Crop Seasons

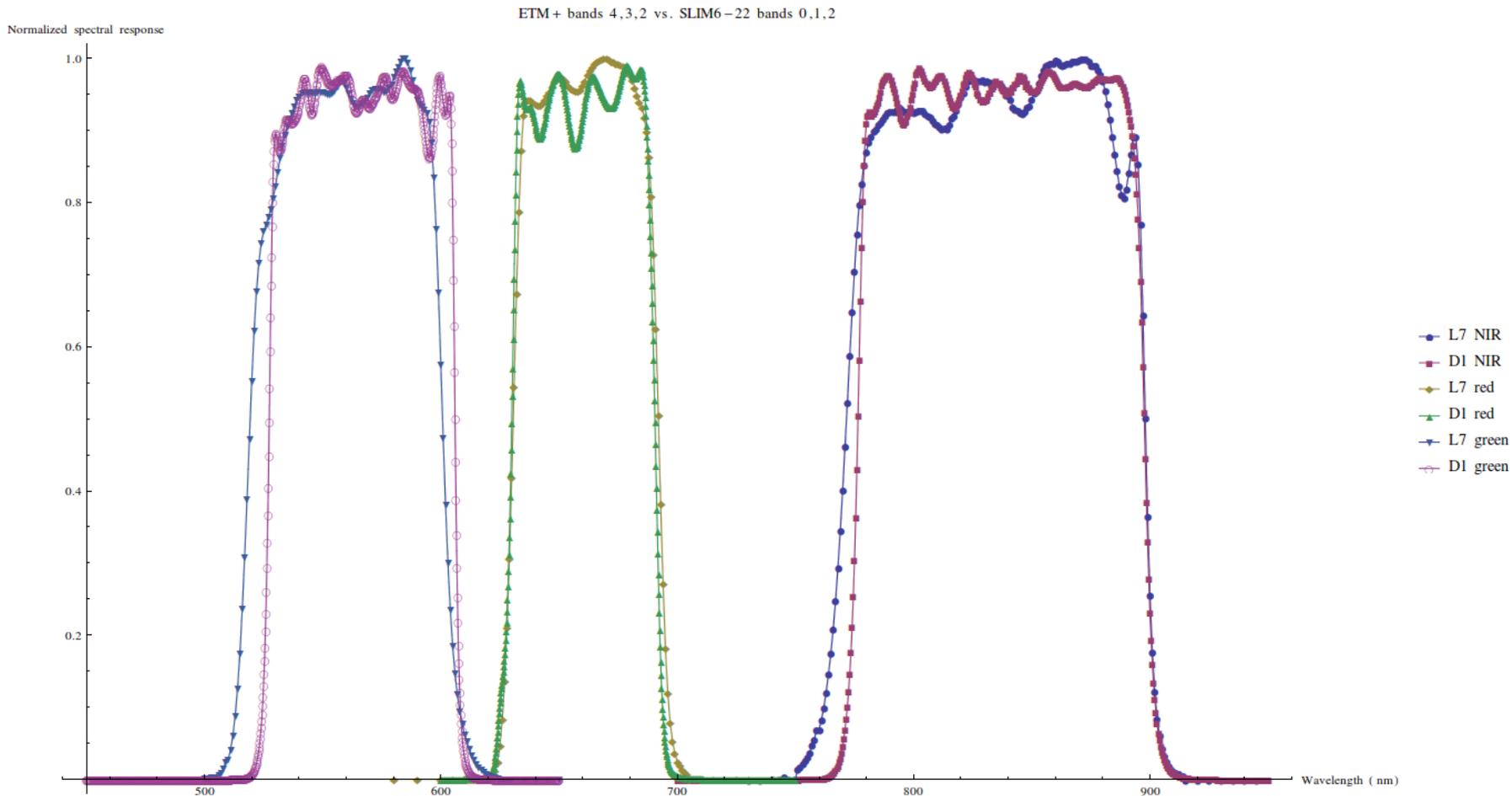
2 Landsat-7 & Deimos-1 systems comparison

Deimos-1 was designed to match Landsat-7 measurements in NIR, red and green bands.

	Landsat-7	Deimos-1
Orbit type	Sun-synchronous (descending)	Sun-synchronous (ascending)
Equatorial crossing	~10:09	~10:39
Height	~702km	~661km
Inclination (deg)	98.23	97.98
Nominal GSD (m)	30 (bands 4,3,2)	22
Band number	8	3
Sampling type	Whiskbroom	Pushbroom
Swath width (km)	185	600
Quantization (bits)	8	10
On-board calibration	Yes	No



Close spectral response for NIR, red and green bands for ETM+ and SLIM6-22



3

Cross calibration with Landsat-7 ETM+

The procedure is inherited from DMC:

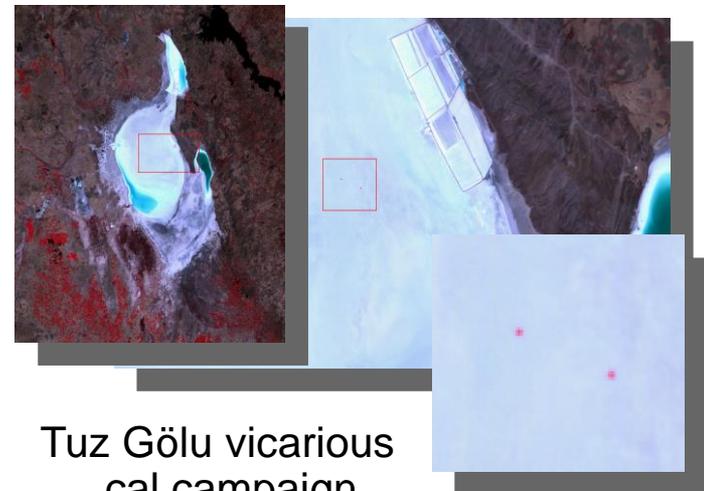
- Deimos-1 lacks on-board calibration devices
- ETM+ is our “golden standard”. We do not cross-calibrate with ETM+, we **calibrate** with ETM+
- Raw material for calibration is gathered by periodically acquiring images over the CEOS pseudo-invariant calibration site Libya-4. Typically twice a month
- These measurements are complemented with acquisitions over Dome-C, the Pacific in eclipse and other PICS in addition to Libya-4
- The calibration is validated through vicarious campaigns



Libya-4



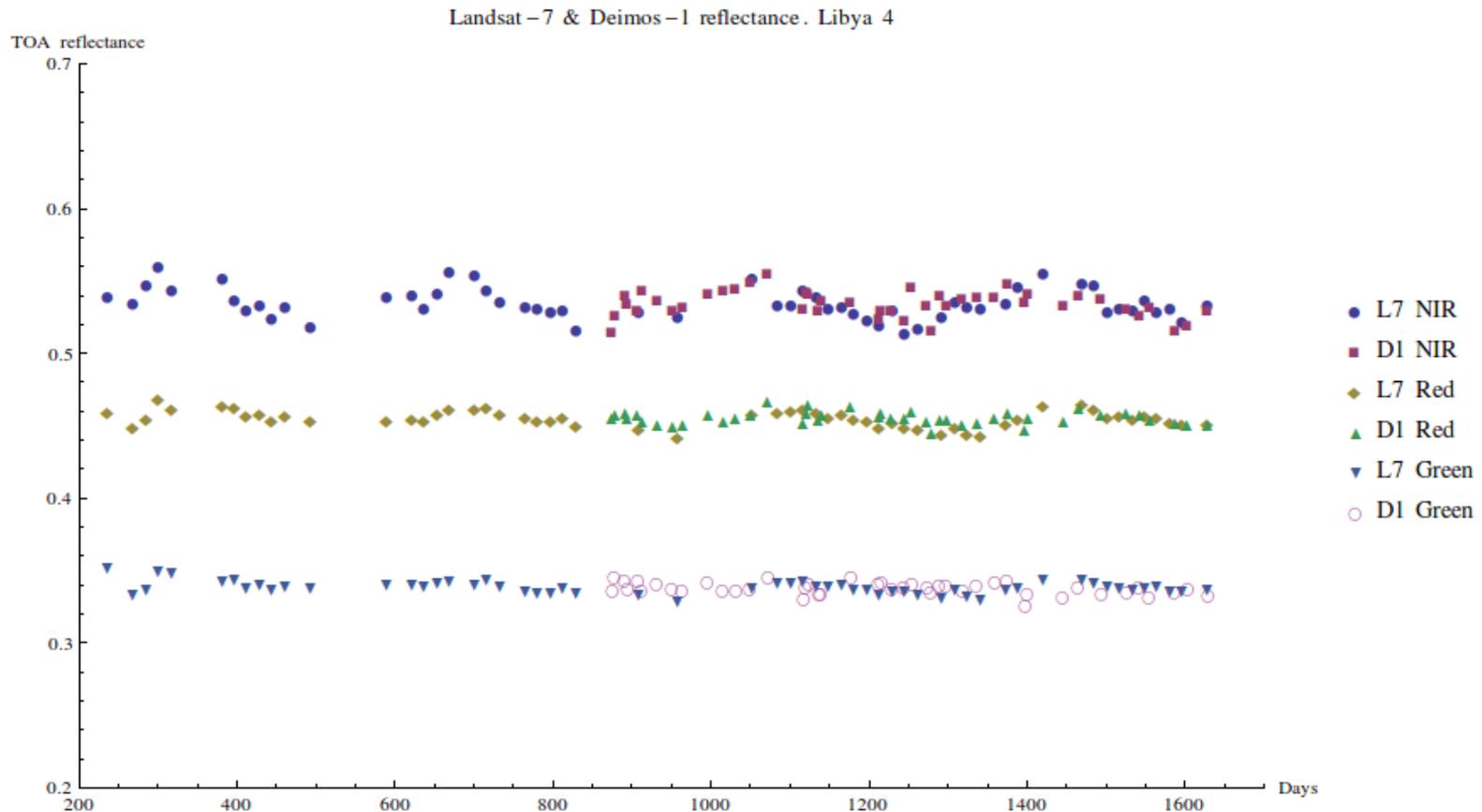
Dome-C



Tuz Gölü vicarious
cal campaign

Libya-4

- Reflectance periodic behavior
- Empirical characterization by fitting sun-sensor viewing geometry to a periodic function

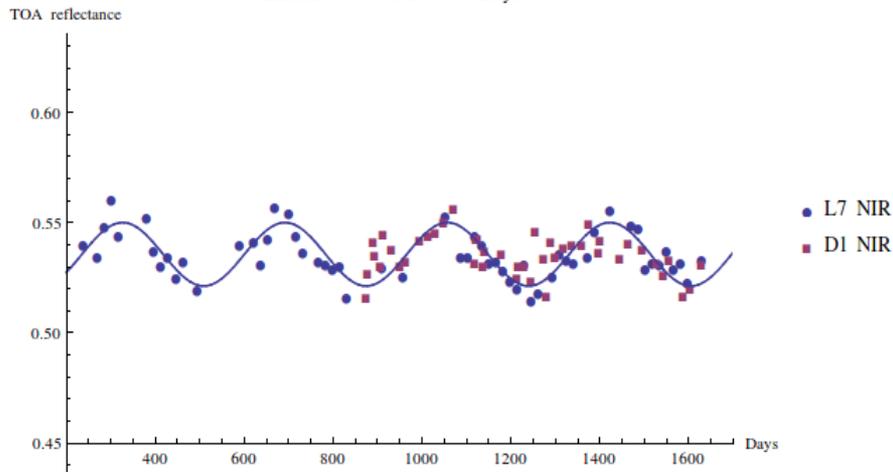




Libya-4 periodic behavior correction.

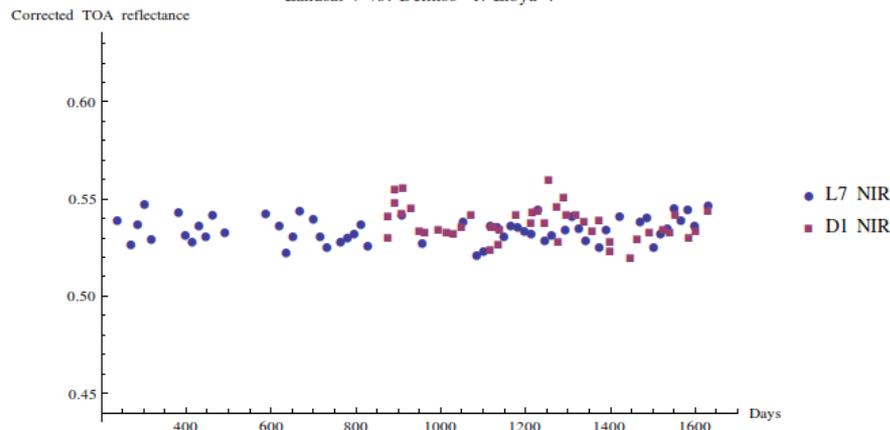
- Reflectance correction using characterization function
- Measurement matching

Landsat 7 vs. Deimos-1. Libya 4



	ETM+ refl.		SLIM6-22 refl.	
	Average	Stddev (%)	Average	Stddev (%)
NIR	0.535	1.22	0.538	1.60
Red	0.455	1.08	0.457	1.45
Green	0.338	1.30	0.340	2.16

Landsat 7 vs. Deimos-1. Libya 4



	SLIM6-22 uncertainty (%)
NIR	2.01
Red	1.80
Green	2.52

4

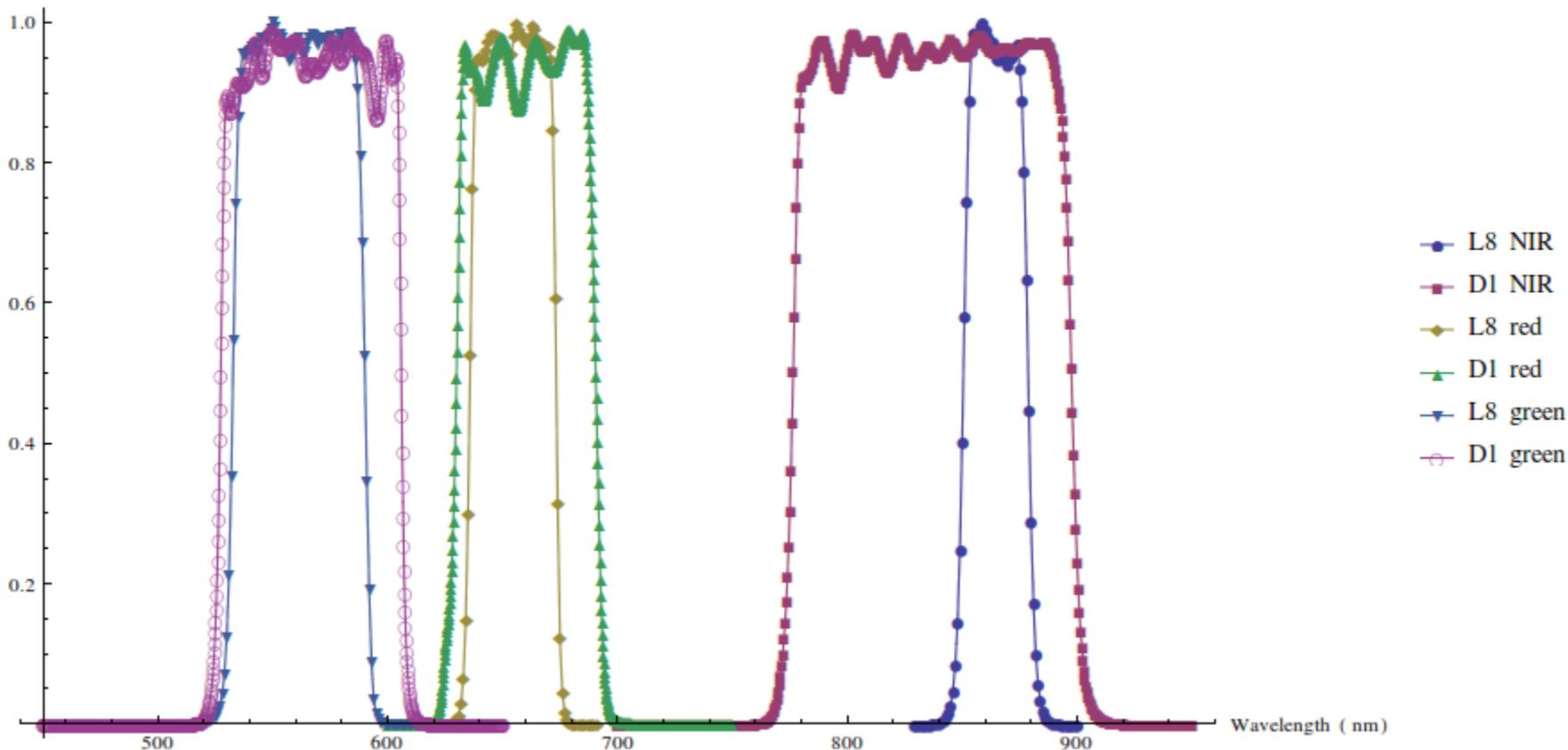
Landsat-8 & Deimos-1 systems comparison

	Landsat-8 (OLI)	Deimos-1
Orbit type	Sun-synchronous (descending)	Sun-synchronous (ascending)
Equatorial crossing	~10:15	~10:39
Height	~702km	~659km
Inclination (deg)	98.18	97.98
Nominal GSD (m)	30 (bands 5,4,3)	22
Band number	9	3
Sampling type	Pushbroom	Pushbroom
Swath width (km)	185	600
Quantization (bits)	12	10
On-board calibration	Yes	No

Meaningful spectral differences between OLI and SLIM6-22, especially in the NIR band

OLI bands 5,4,3 vs. SLIM6-22 bands 0,1,2

Normalized spectral response



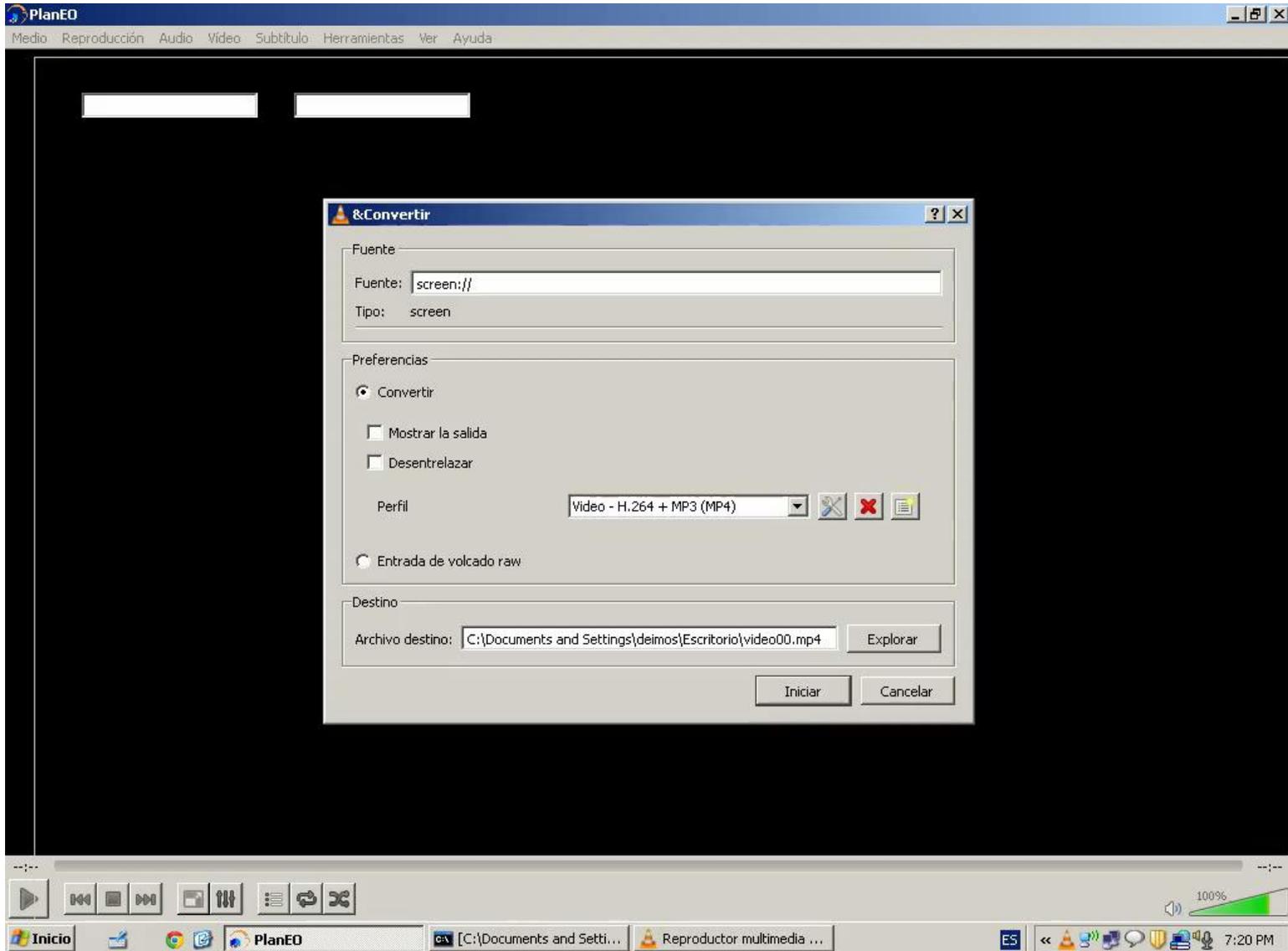
5

Cross calibration with Landsat-8 OLI

New “close approach” methodology

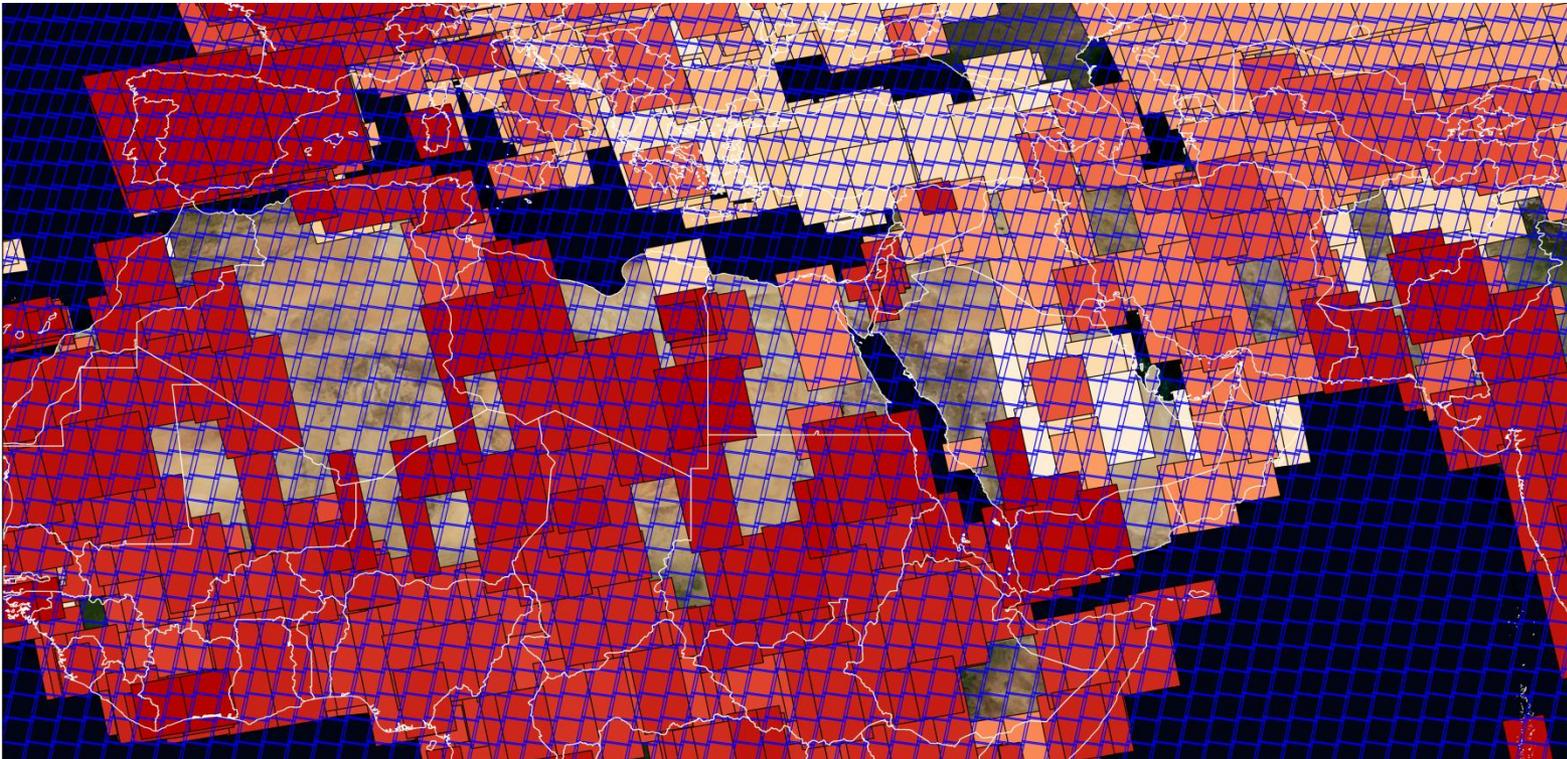
- Not enough Landsat-8 data yet to follow Landsat-7 cross-cal methodology
- Comparison using data from “close encounters”, taking advantage from different orbit direction (D1 ascending, L8 descending)
- We have to rely on a relatively low number of measurements
- Constraints:
 - ± 15 minutes of time gap
 - $\pm 5^\circ$ off-nadir angle
- Reduced experimental error:
 - Atmospheric effects
 - BRDF effects

New "close approach" methodology



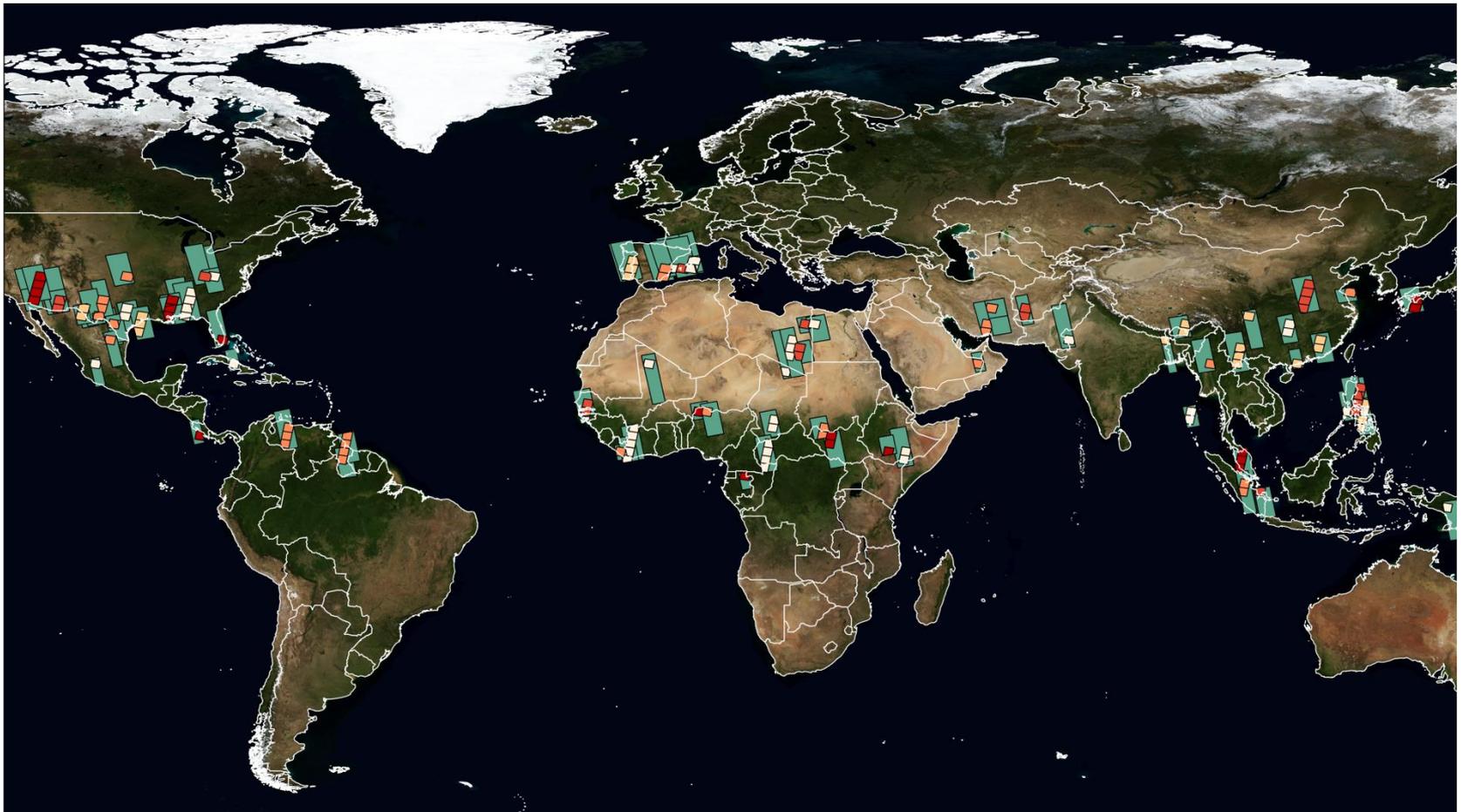
New ad-hoc scheduled acquisitions and catalogue search

- Deimos-1 catalogue and WRS2
- Check time and incidence angle constraints



New ad-hoc scheduled acquisitions and catalogue search

- Test sites candidates

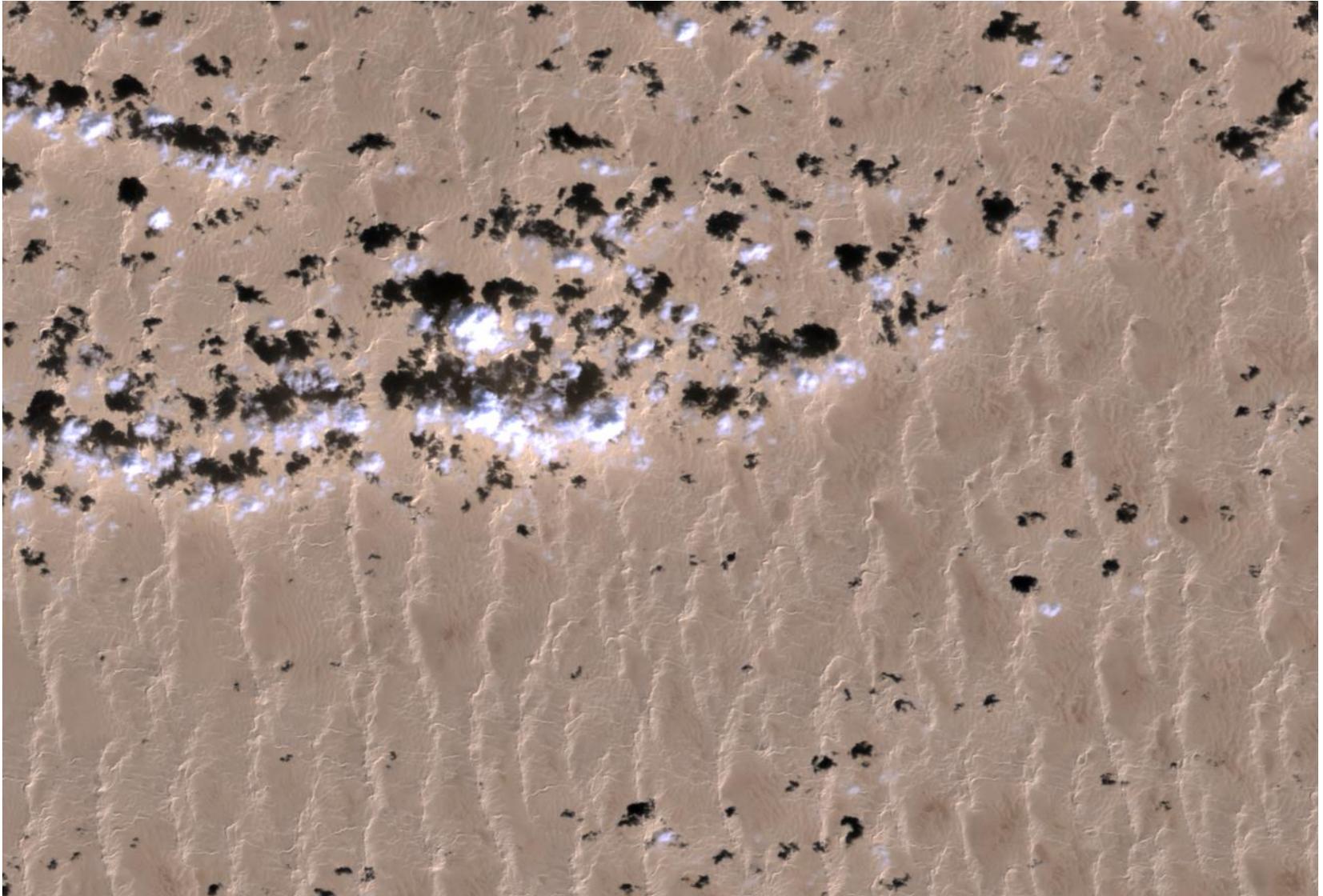


New ad-hoc scheduled acquisitions and catalogue search

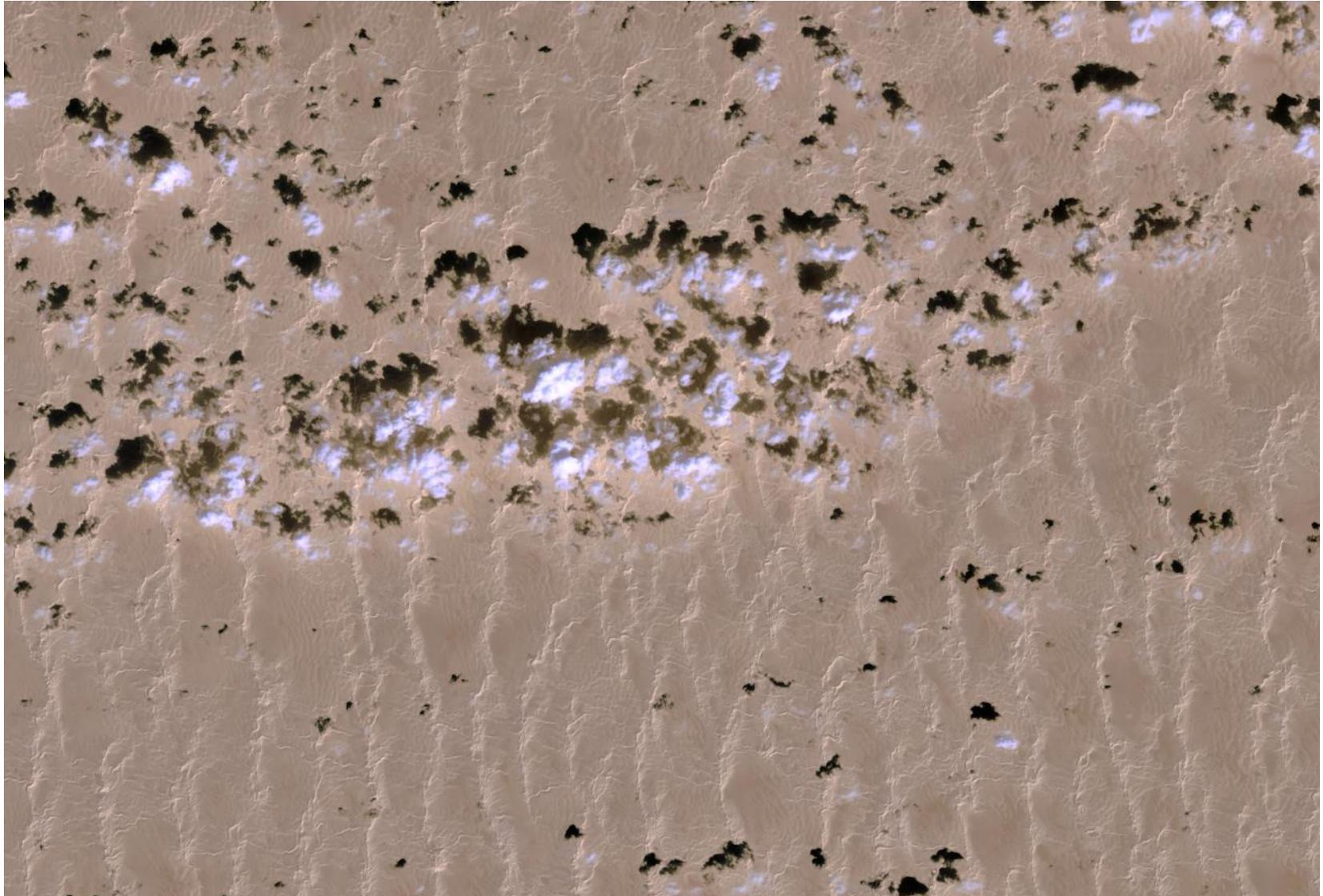
- CEOS reference standard test sites
 - Libya-4
 - Dunhuang (China)
 - La Crau (France)

- Other test sites
 - Dolan Springs (USA)
 - Crop areas
 - Mid-latitude forest
 - Rainforest
 - Savannah

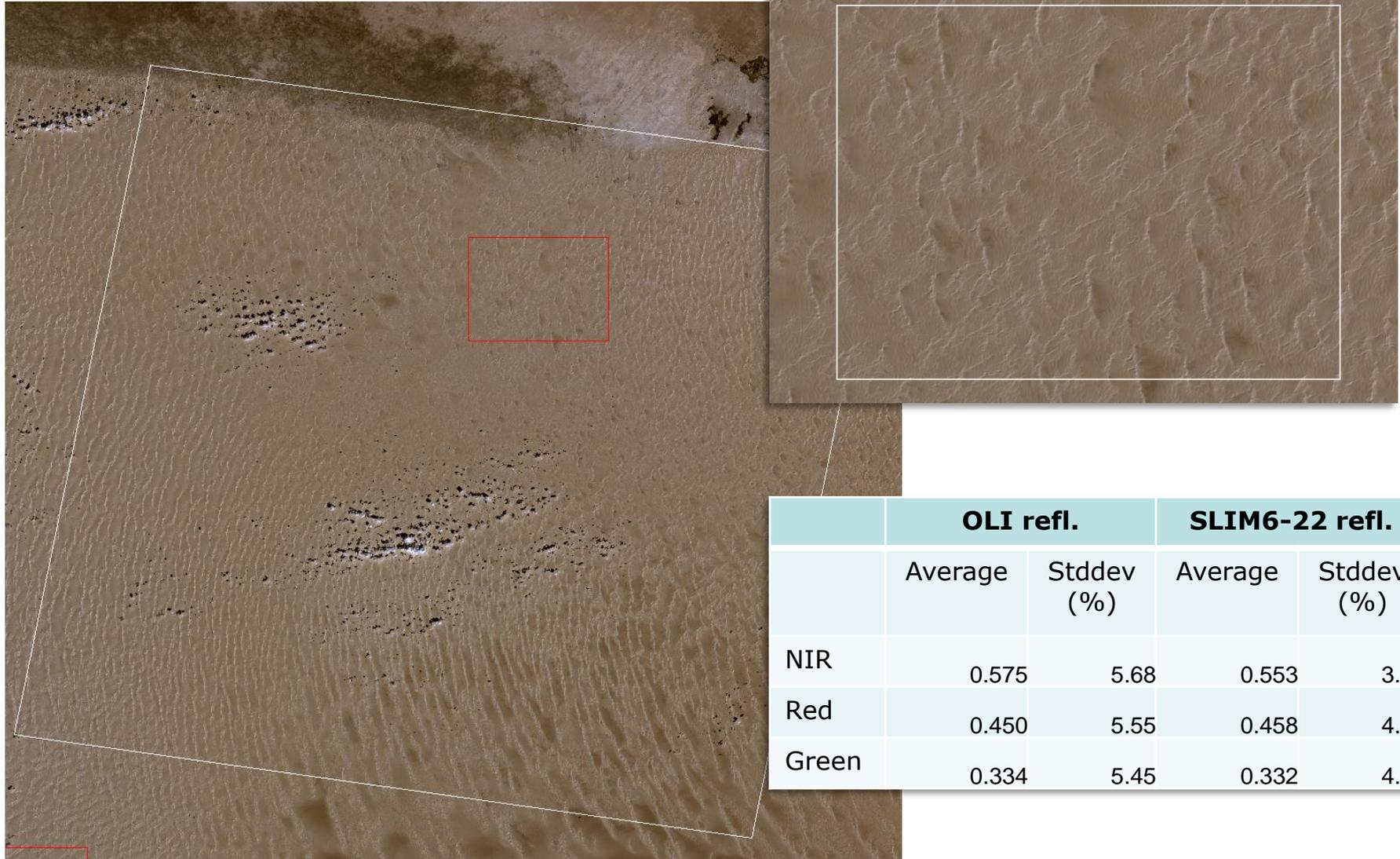
Libya-4 2014-02-14 acquisition. Deimos-1 08:51:28 UTC



Libya-4 2014-02-14 acquisition. Landsat-8 08:56:00 UTC



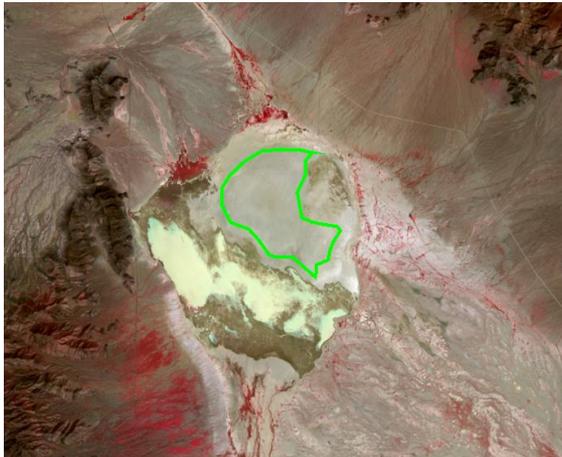
Libya-4 2014-02-14 acquisition



	OLI refl.		SLIM6-22 refl.	
	Average	Stddev (%)	Average	Stddev (%)
NIR	0.575	5.68	0.553	3.92
Red	0.450	5.55	0.458	4.41
Green	0.334	5.45	0.332	4.33

Test sites examples

Dolan Springs



Dunhuang (CEOS)



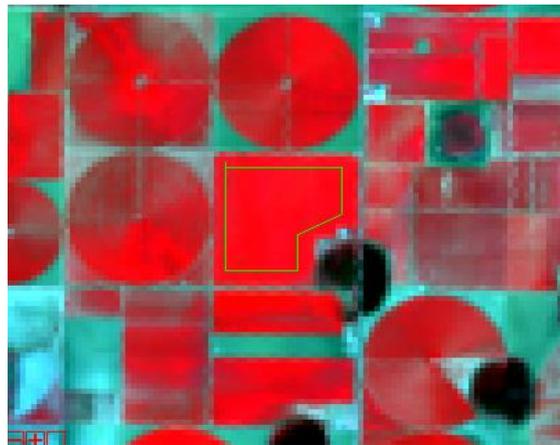
Dunhuang



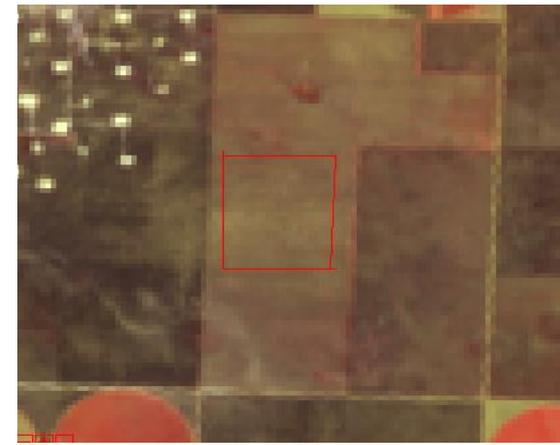
Rainforest



Crops



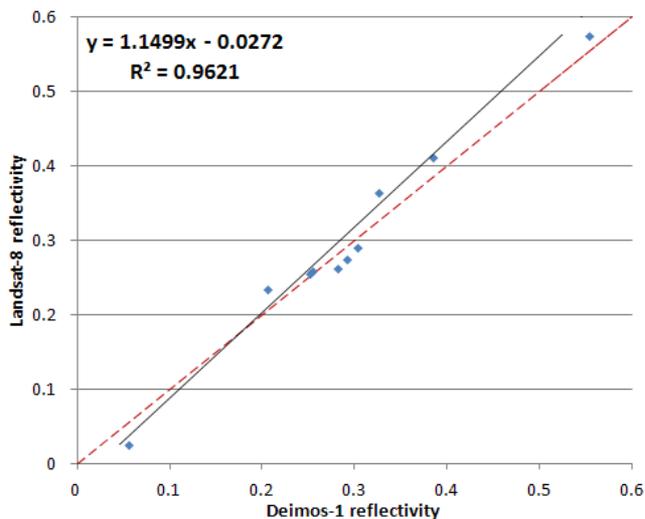
Bare soil



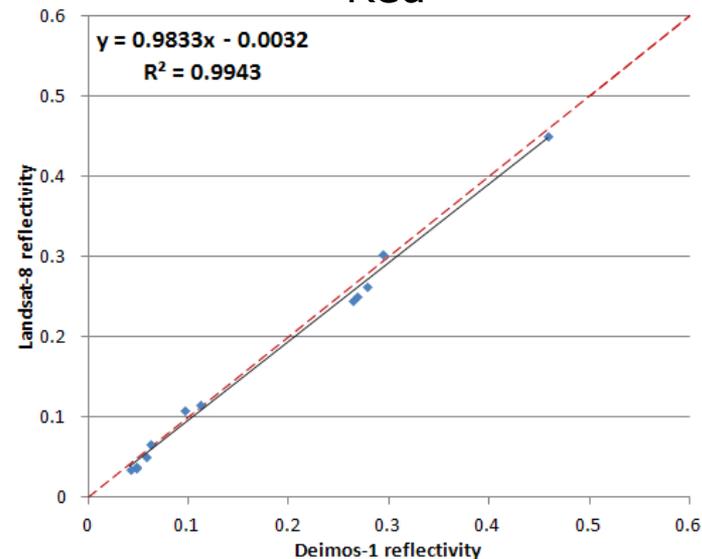
6

Results, conclusions and ongoing work

NIR

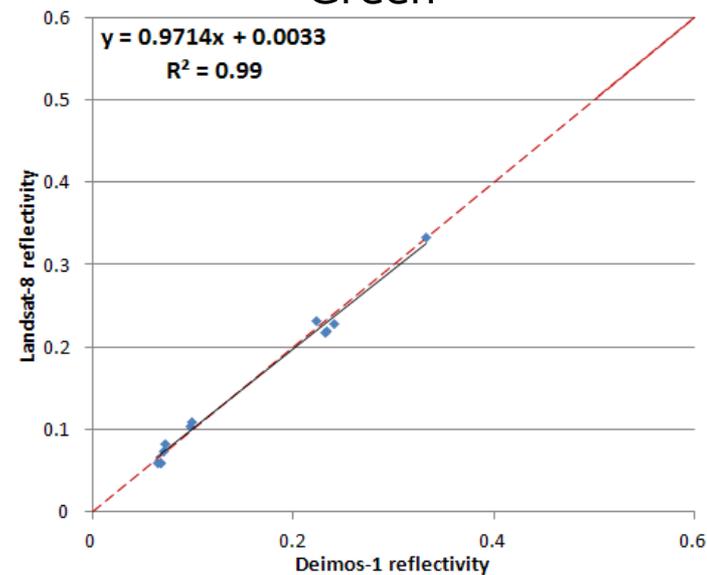


Red



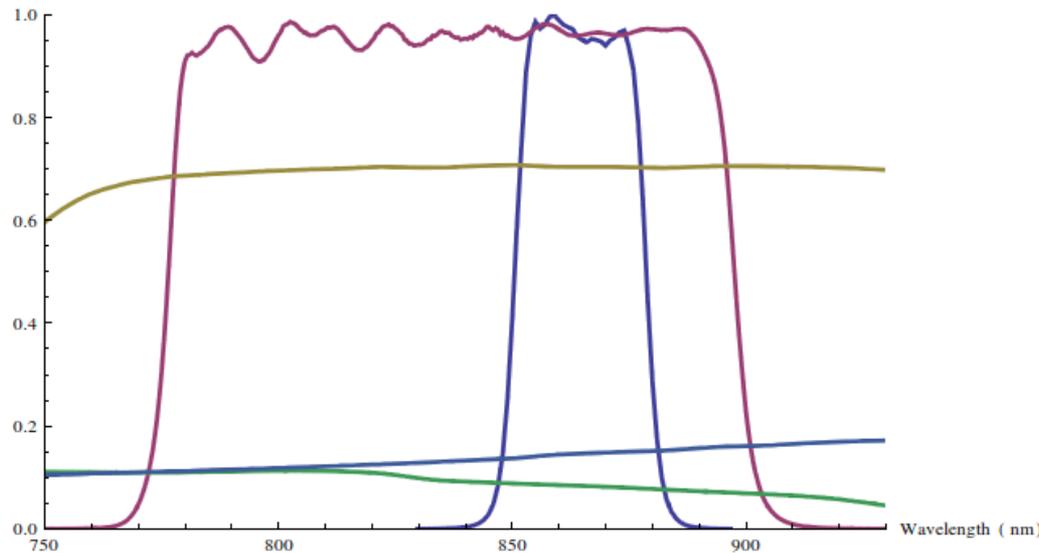
- Red and green bands correlate
- Differences in NIR band are not negligible
- Further research required for NIR band
 - Atmospheric effects
 - Ground spectral response

Green





- Assess ground spectral response impact

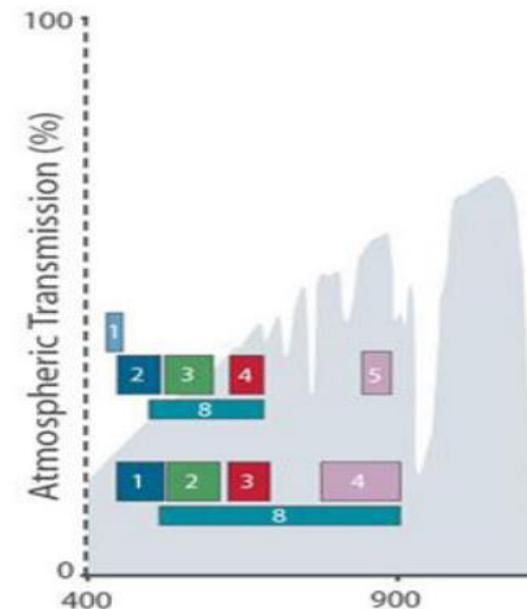


Ground and atmospheric data:

USGS

- L8 NIR
- D1 NIR
- Lawn grass
- Turbid water
- Desert varnish1

- Assess atmospheric water vapor absorption impact



Thank you!

Questions?



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