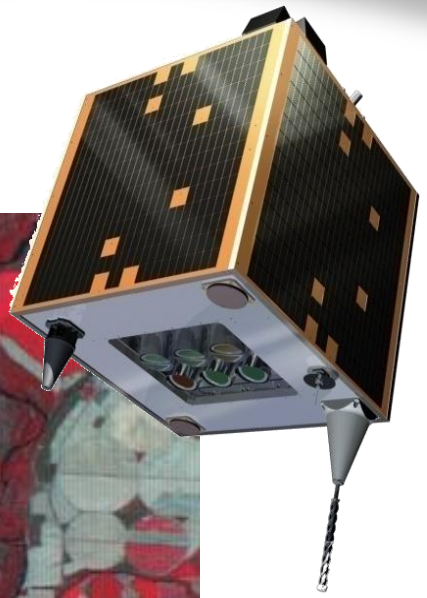

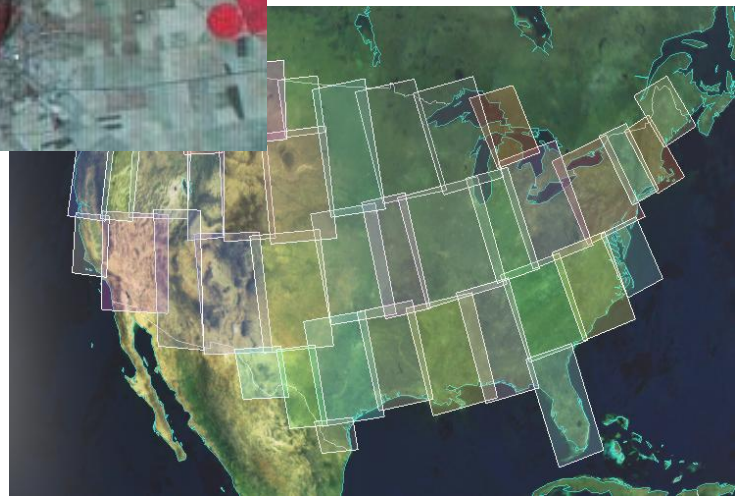

Deimos-1 Absolute Calibration and Data Validation

Fabrizio Pirondini
(Business Development Manager)

Alfredo Romo
Cristina Moclan
Jorge Gil
Mónica Díez

DEIMOS Imaging S.L., Spain

JACIE 2011
10th Annual Joint Agency Commercial Imagery Evaluation Workshop
Boulder, CO - March 29-31, 2011

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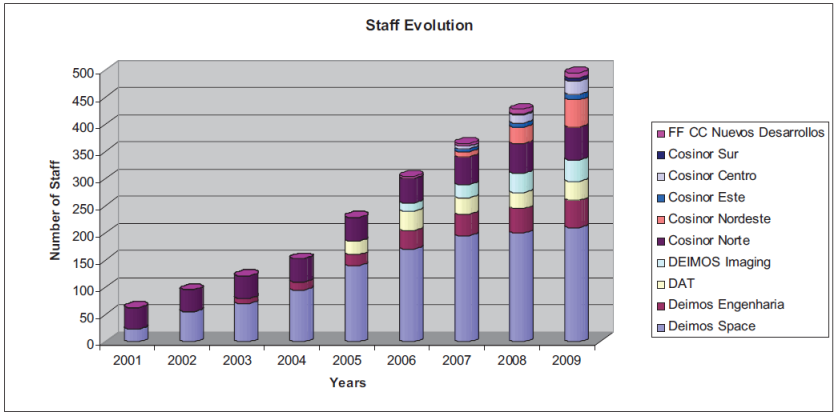
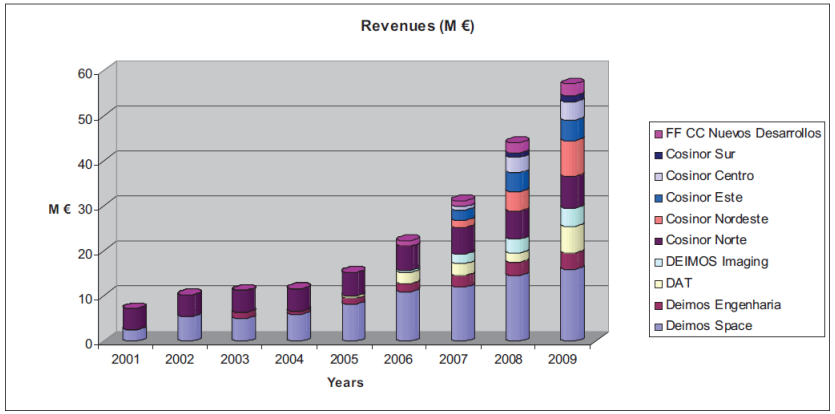
- The Deimos-1 E2E EO System
- Calibration
  - Relative calibration
  - Absolute calibration
  - Cross-calibration
- Data Validation

1 The Deimos-1 E2E EO System

The DEIMOS Group

- **DEIMOS Imaging** is the company devoted to Earth Observation within the DEIMOS Group, the technological branch of **ELECNOR**, one of the largest industrial corporations in Spain
- DEIMOS-1 is part of the DMC, but **DEIMOS Imaging** is the **owner** and **operator** of the **DEIMOS-1 satellite**, and **markets its images and value-added products** worldwide





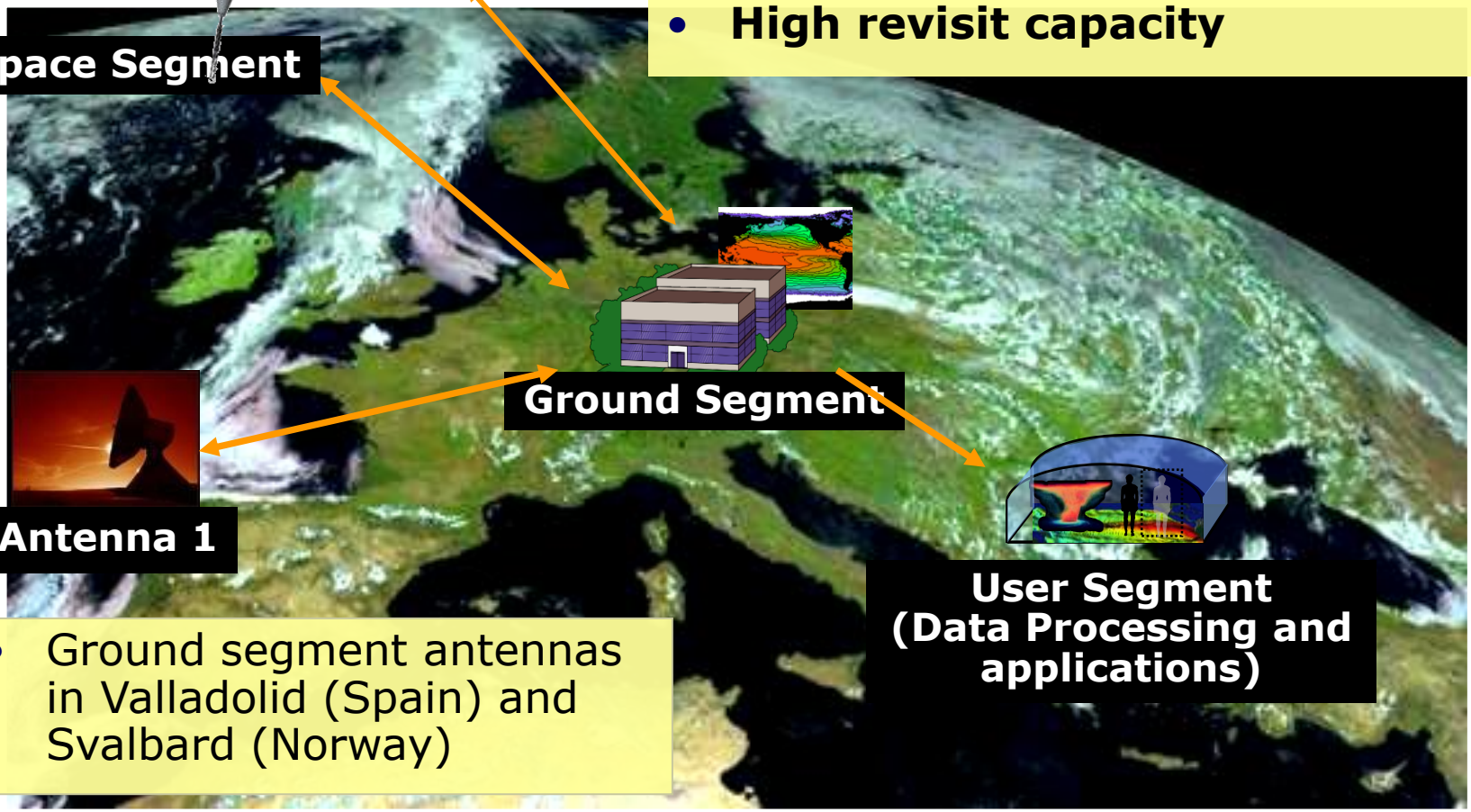
End-to-End EO System

elecnor deimos

Space Segment

Antenna 2

- DEIMOS-1 Multispectral Satellite
- High spatial resolution (20 m)
- **Very large swath (640 Km)**
- **High revisit capacity**



Ground Segment

Antenna 1

User Segment (Data Processing and applications)

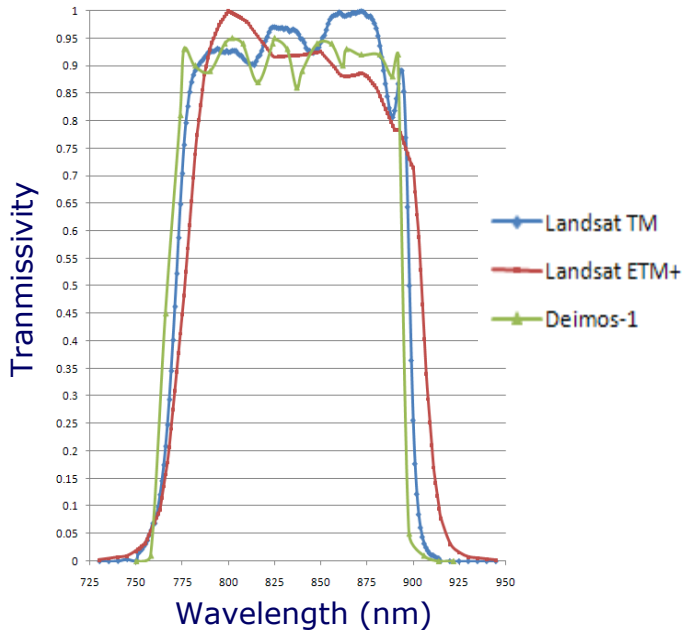
- Ground segment antennas in Valladolid (Spain) and Svalbard (Norway)

Space Segment

- **Combination of high spatial and temporal resolution**
- Spatial resolution of **22m**
- The wide **640-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
- Radiometric resolution dynamically optimized on-board to 8 or **10 bits**

Deimos-1 (22m)

Landsat 7 ETM+ (30m)

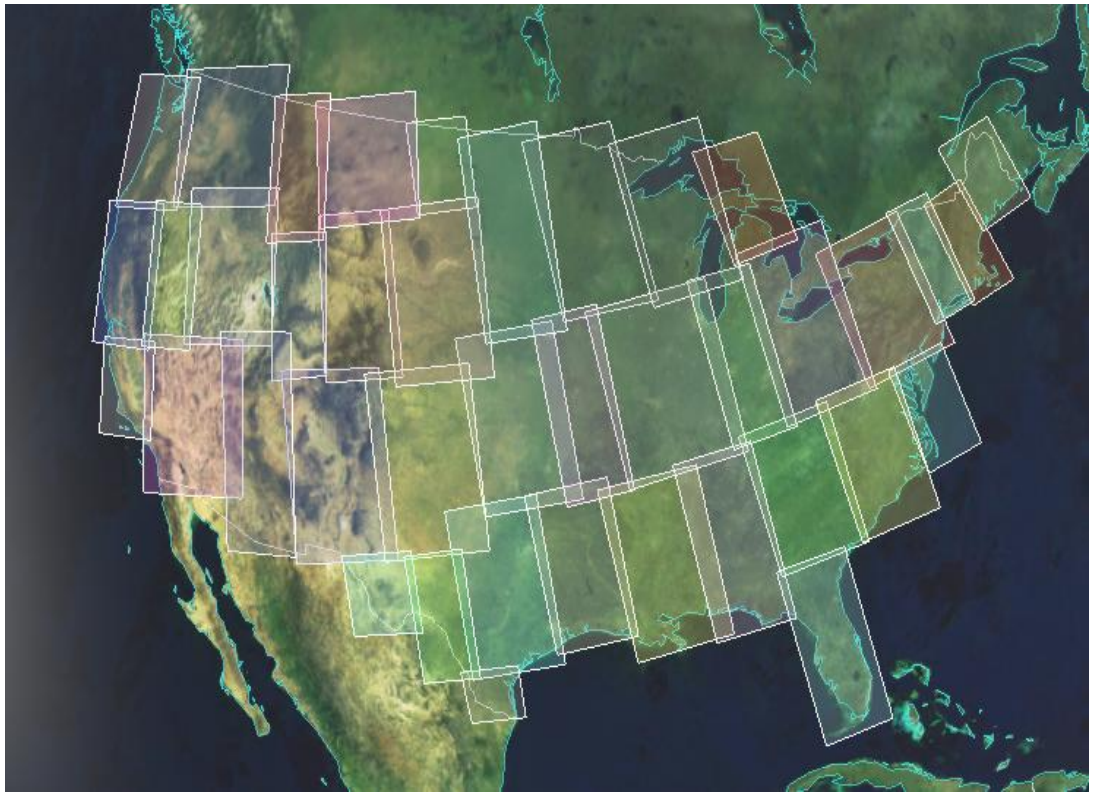


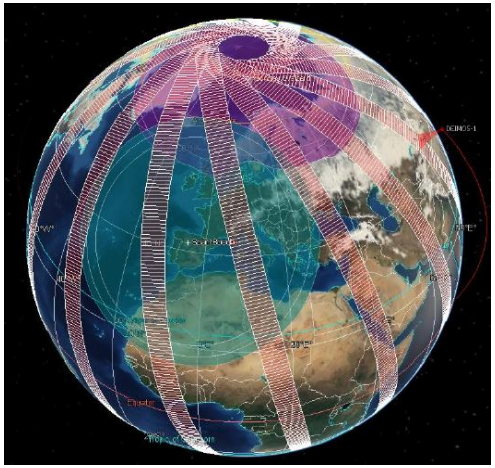
Ground Segment

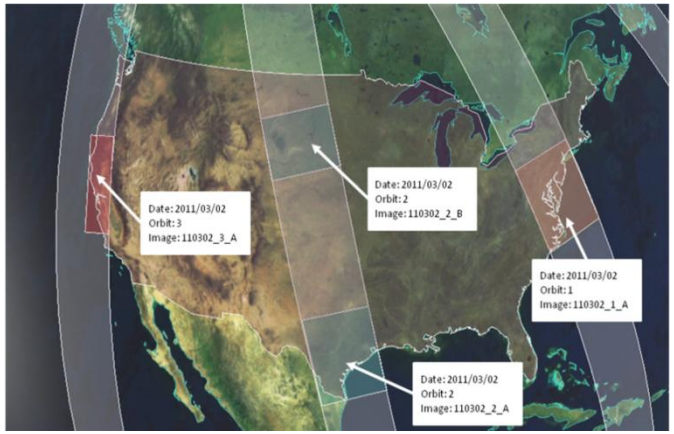
- The **2-station ground segment** is a key asset of the DEIMOS-1 system
- Svalbard (Norway) allows to **download data at each orbit**
- Boecillo (Spain) allows **4 further contacts each day**
- Weekly data volume: 120Gb
- DEIMOS premises in Boecillo have a complete control centre integrated with a user segment
  - Mission Planning
  - Flight Operations
  - Telecommand
  - Telemetry
  - Processing
  - Archive
- **Advanced mission planning system**, developed in-house, allows optimization of large coverage campaigns

System Capacity

- DEIMOS-1 **wide swath** (640 km) combined with **data download at each orbit** assures a high revisit frequency for any given point on Earth
- 2-3 images per day over the US (~1 million sqkm per day)
- **Complete coverage of the US every 2 weeks**

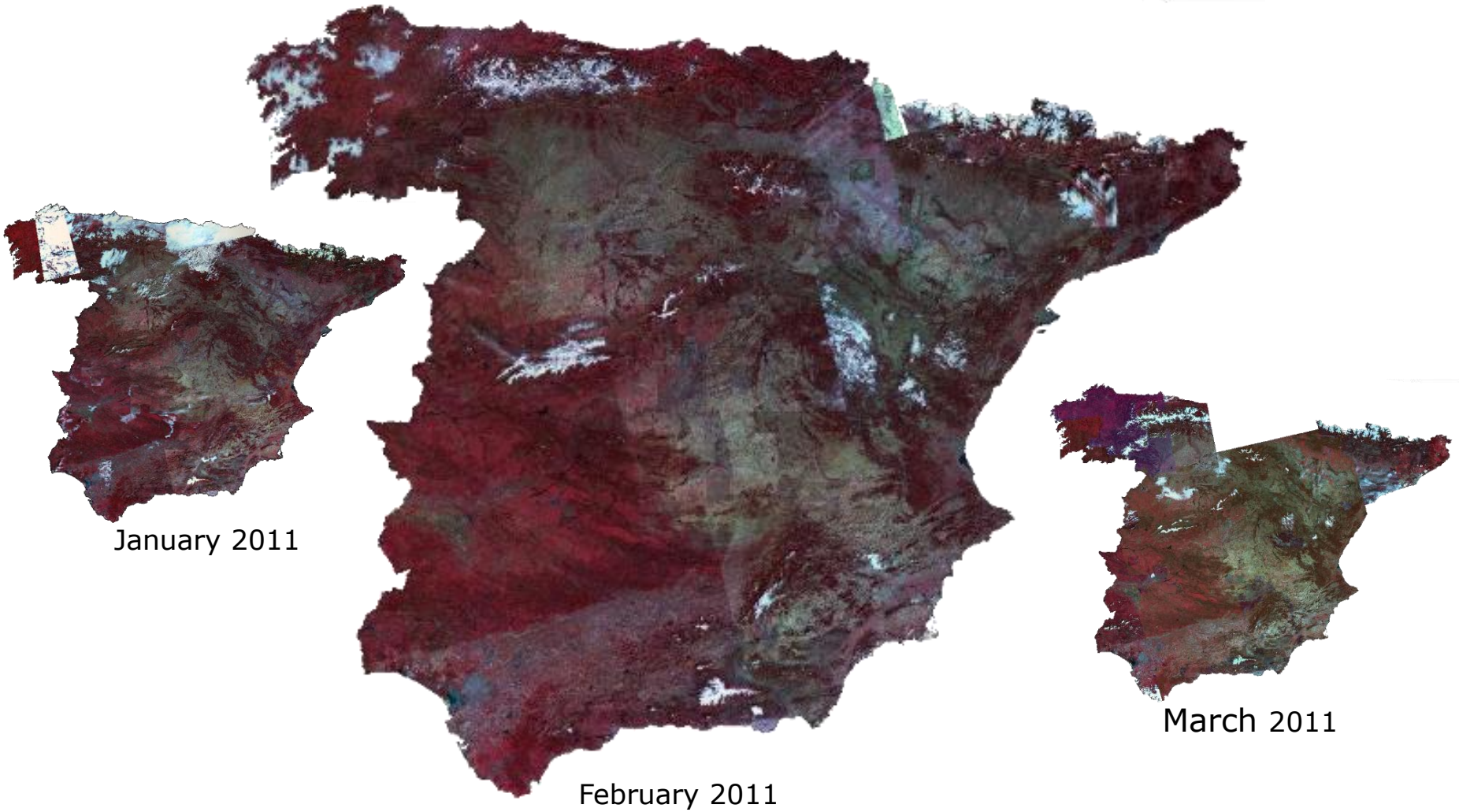






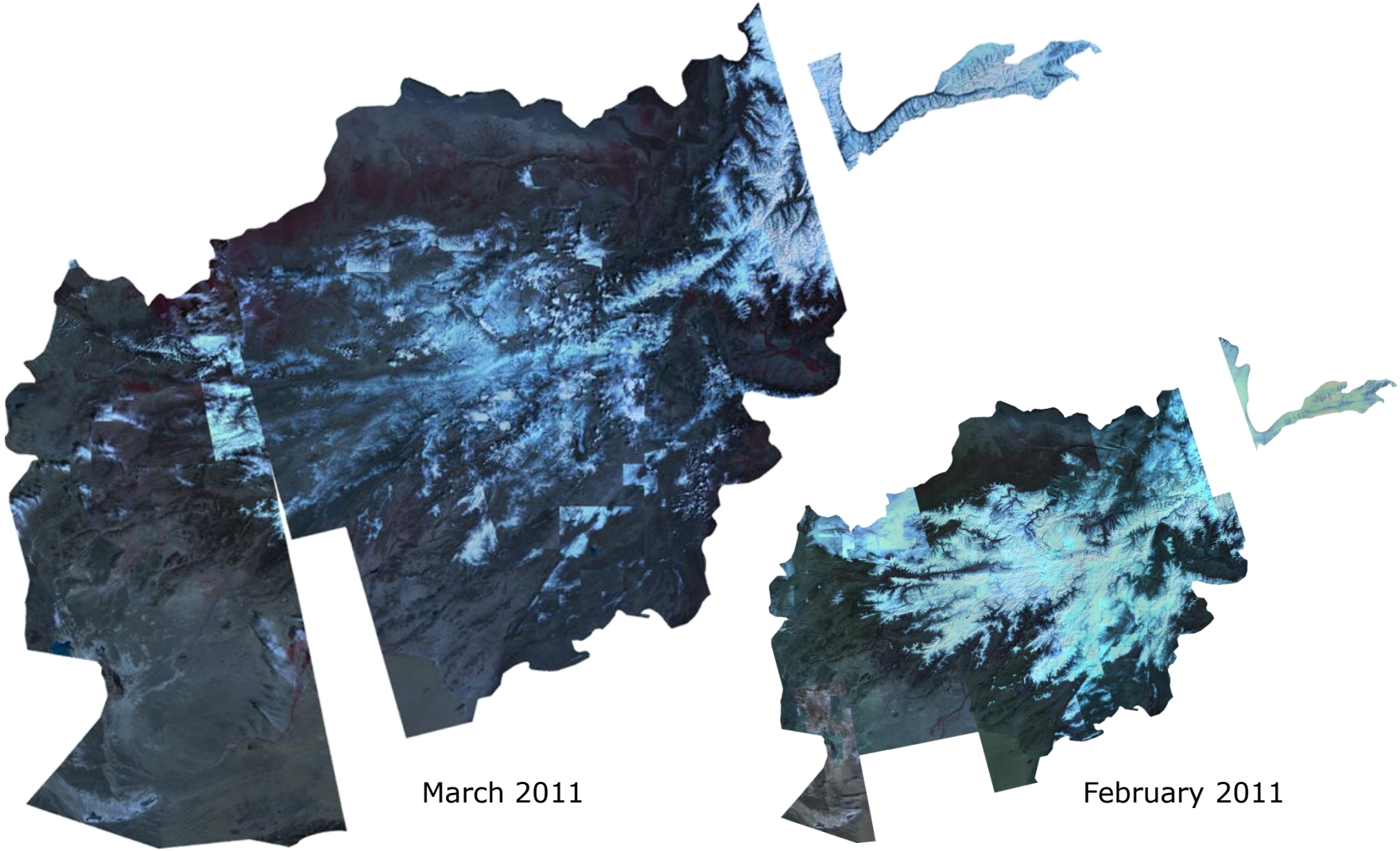
System Capacity

- Example of system capacity: **monthly cloud-free** (>90%) **coverage of Spain**



System Capacity

- Example of system capacity: **monthly coverage of Afghanistan**

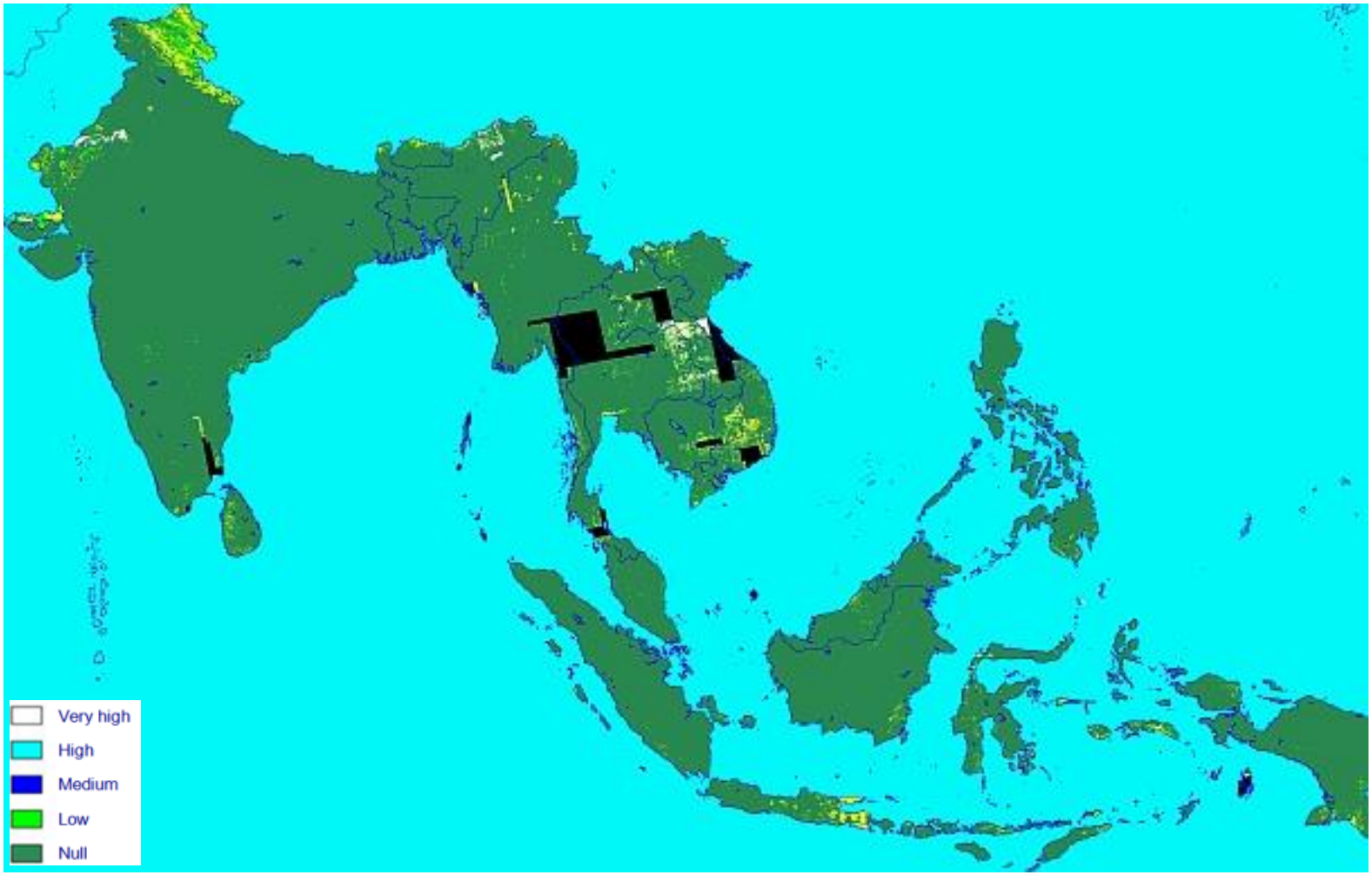


March 2011

February 2011

System Capacity

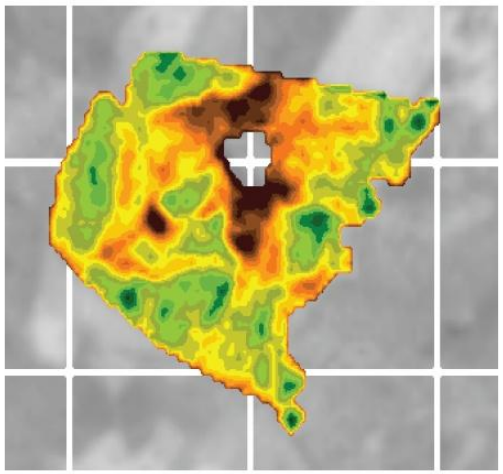
- Example of system capacity: **almost complete cloud-free coverage of South-east Asia in 2010** (ESA TROPFOREST project)

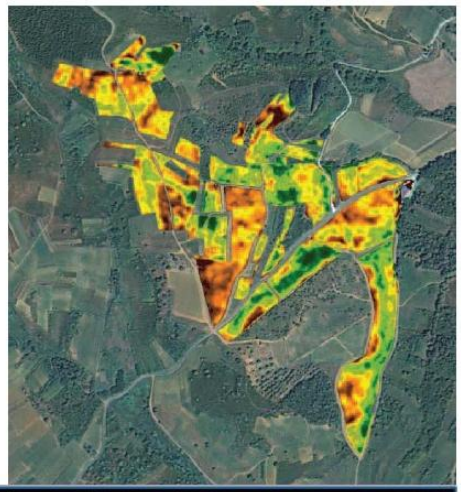


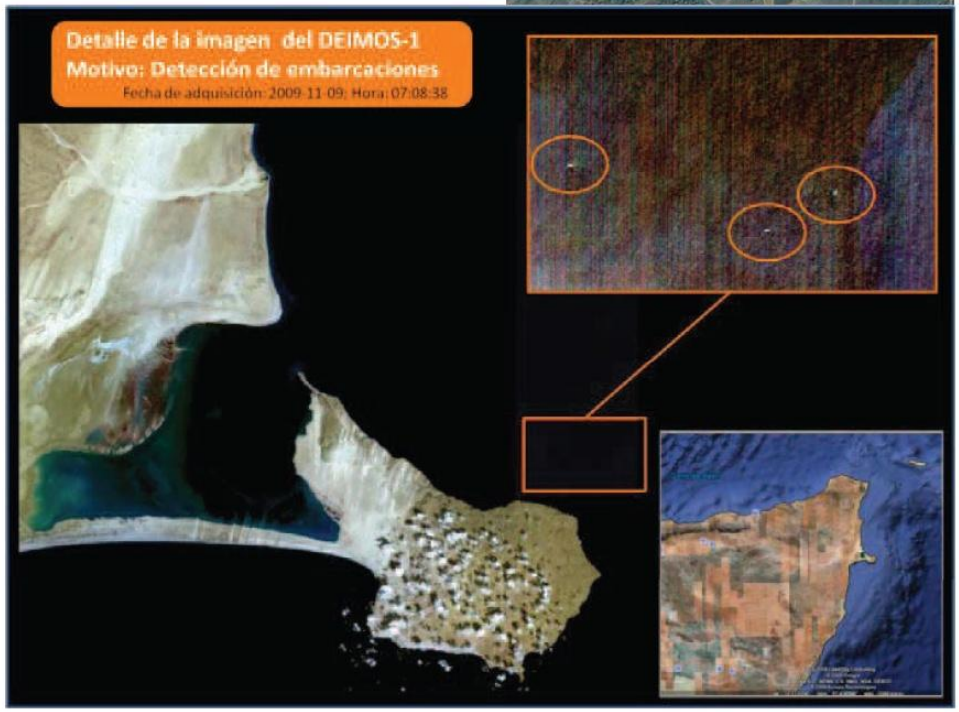
DEIMOS Imaging Products

- DEIMOS Imaging provides **DEIMOS-1 images** to ESA, institutional customers and added value EO companies

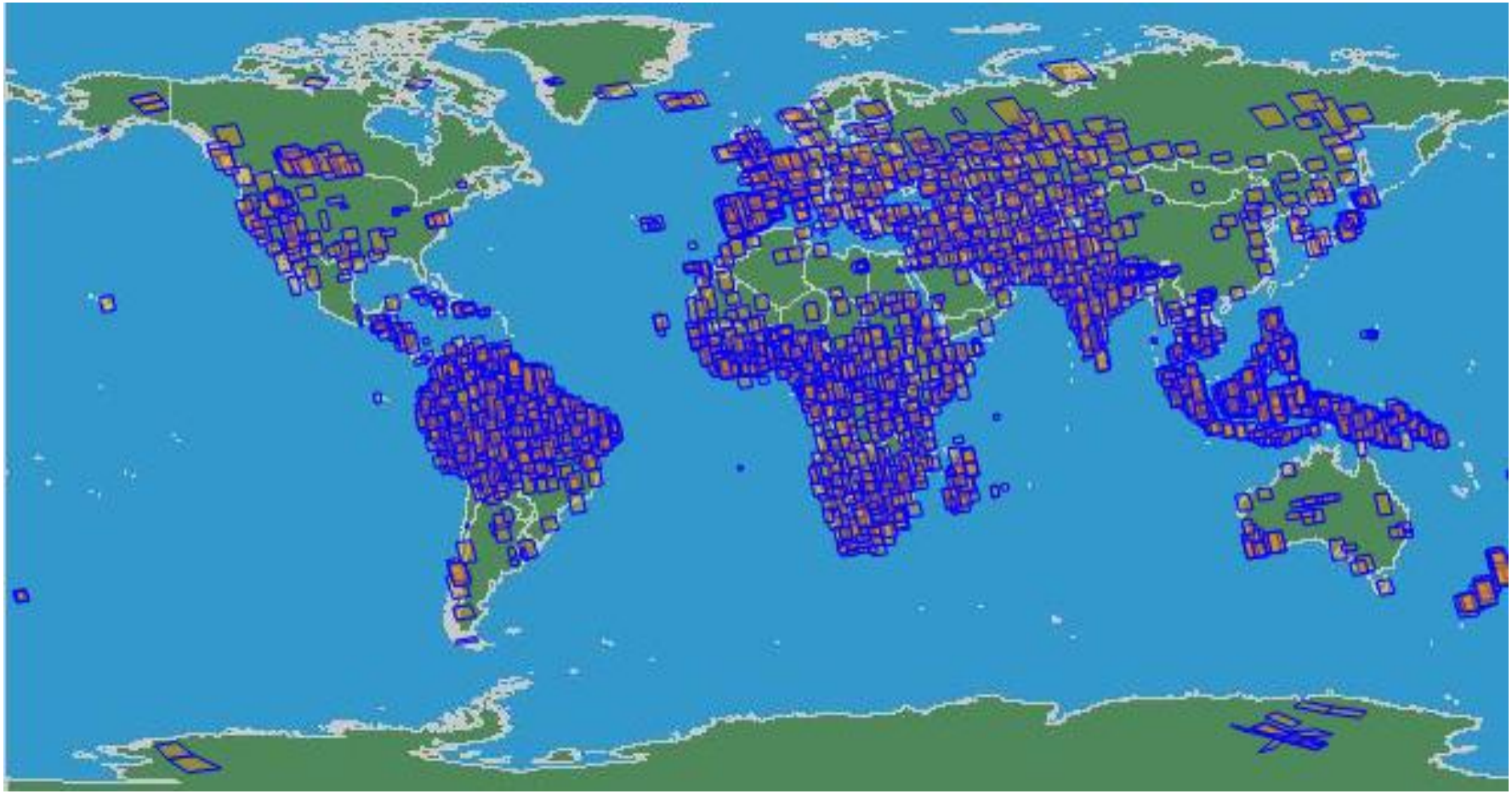
- In addition, DEIMOS Imaging provides final EO **value added products and services** in the following domains:
  - Agriculture
  - Fire Monitoring
  - Environment
  - Insurance
  - Forestry
  - Maritime Surveillance
  - Disaster Monitoring







Online Image Catalog

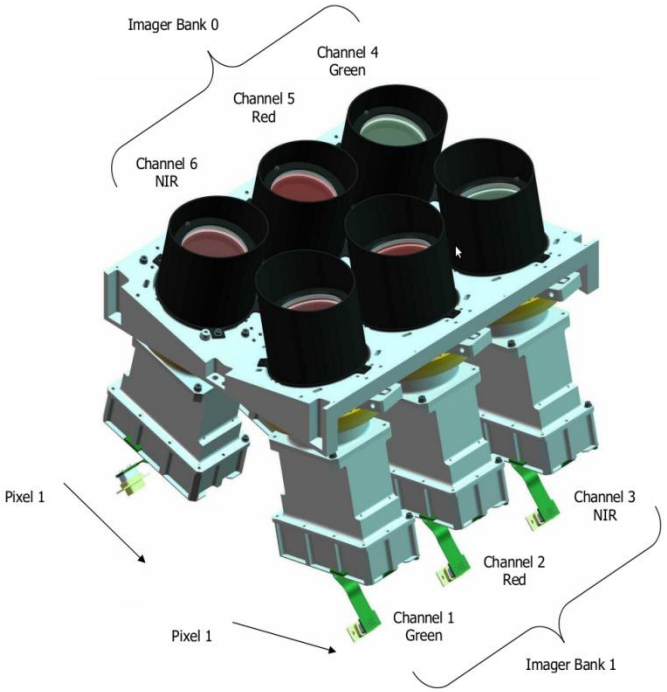


Contents of DEIMOS-1 **online image catalog** (>3000 images)

www.deimos-imaging.com

2 Deimos-1 Calibration

The Deimos-1 Payload



- 2 banks, 3 cameras per bank
- 3 bands (NIR,R,G Landsat equivalent)
- 22 m GSD
- 320-km swath per bank

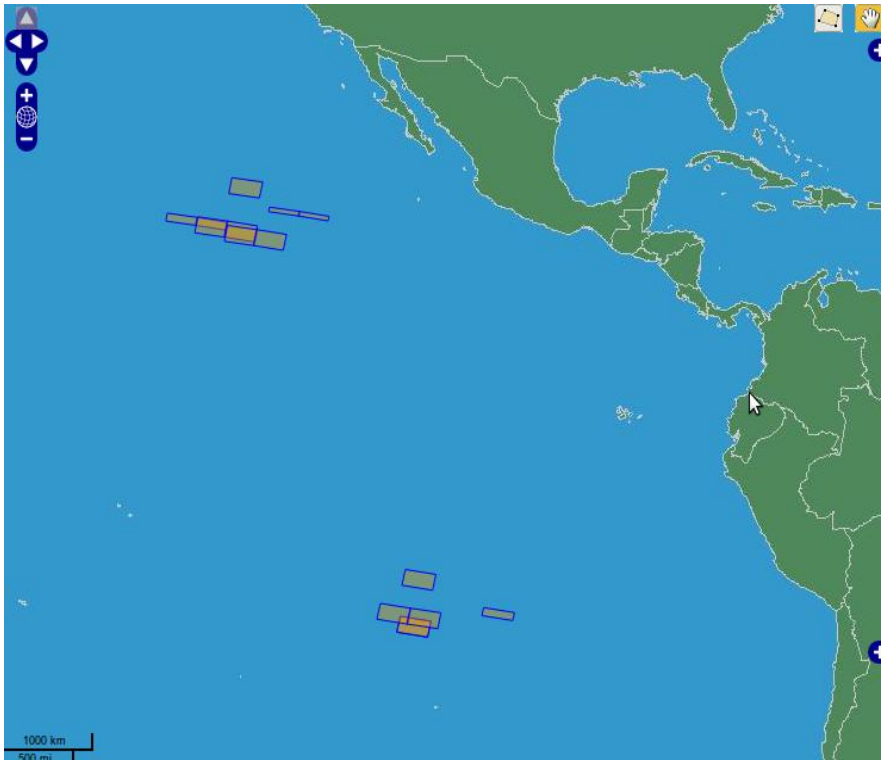
- SLIM6 pushbroom CCD
- ~ 14,400 detectors per camera
- Radiometric resolution: 8 or 10 bits
- Each detector is considered a radiometer and has to be characterized

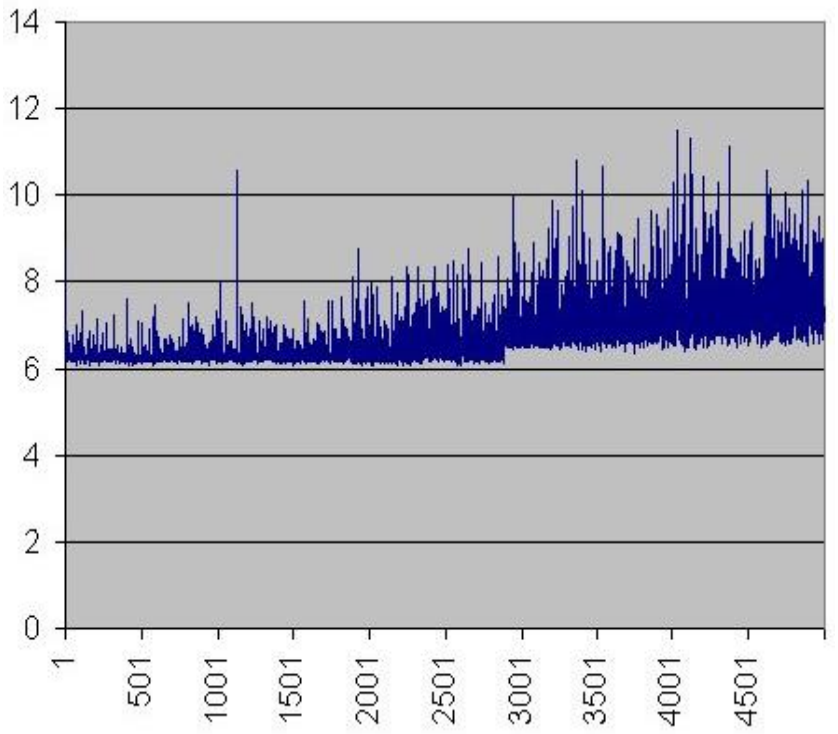
Calibration Strategy

- On-board measurement of noise parameters and on-ground de-noising
- **Dynamic Calibration**: on-board control of gain parameters (rescaling from 14 to 8 or 10 bits) as a function of the type of the target, to optimize the radiometric resolution of the data

- **Absolute and relative calibration pre-launch, and complete post-launch calibration campaigns (periodically updated):**
  - Sensor relative calibration / detectors equalization
  - **Absolute calibration** (annually on Tüz Gülü, CEOS-endorsed, with ground team)
  - **Cross-calibration with other DMC platforms** (annually on Dome-C, CEOS-endorsed)
  - **Cross-calibration with the "gold standard" Landsat 7** (annually on Libya, CEOS-endorsed and Dome-C)
  - **Tracking of cross-calibration with Landsat 7** (monthly in Spain and Libya)
  - Analyses of cross-calibration with other platforms: SPOT-5, Formosat-2
- **Combination of DMCii constellation calibration and DEIMOS activities**

Relative Calibration





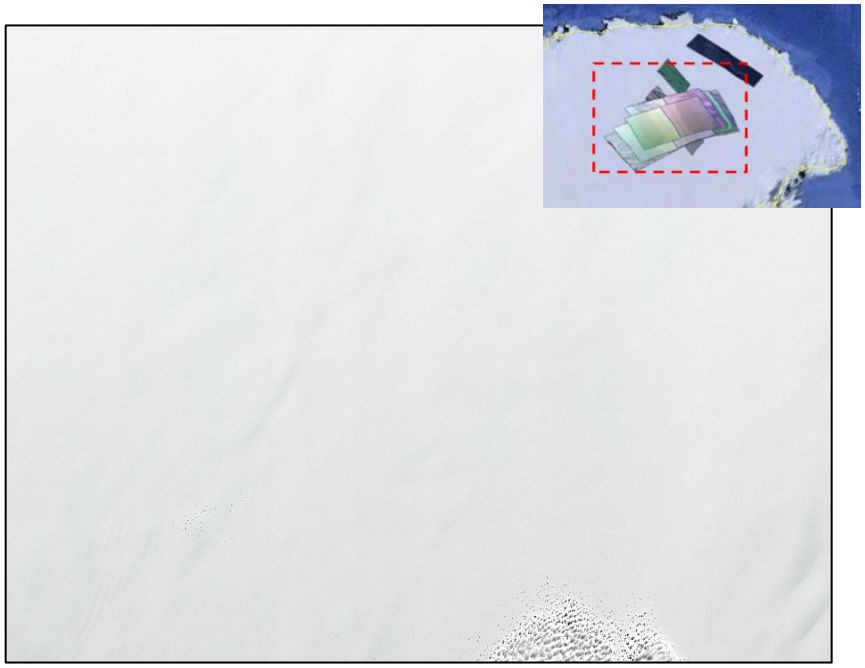
(Source: Dr. S. Mackin, DMCii)

- Post-launch commissioning campaign
- Assess background signal for each detector and estimate noise
- Full-swath images over the Pacific, at night, avoiding natural and artificial light sources (dark frame)

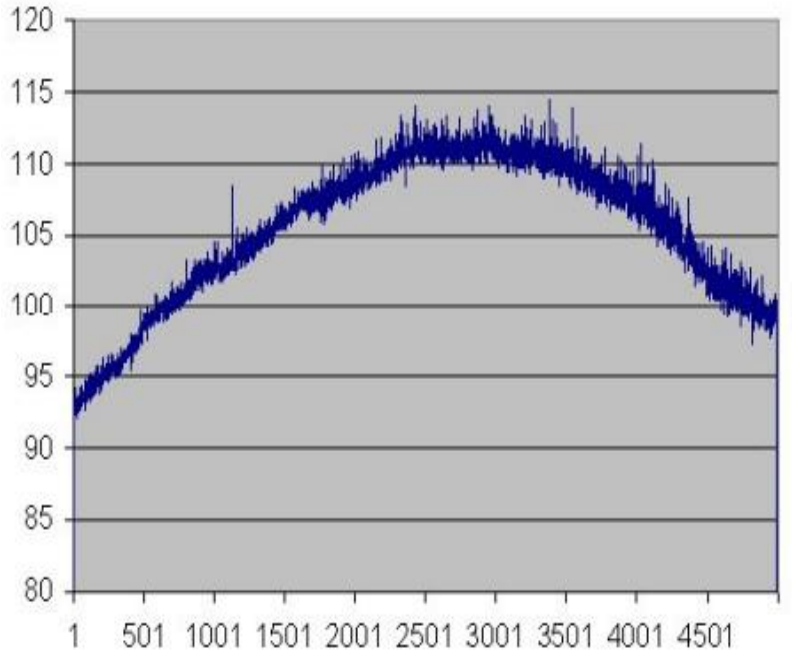
- The background signal is different for each detector, due to pixel-to-pixel variation in sensitivity
- The signal is also sensitive to a number of imaging parameters, which shall be optimized and fixed

Relative Calibration

- Asses the signal over a bright target
- With a ~300-km swath per bank a large and uniform area is required
- CEOS Landnet site **Dome-C** (Antarctica) is chosen
- Yearly calibration campaign



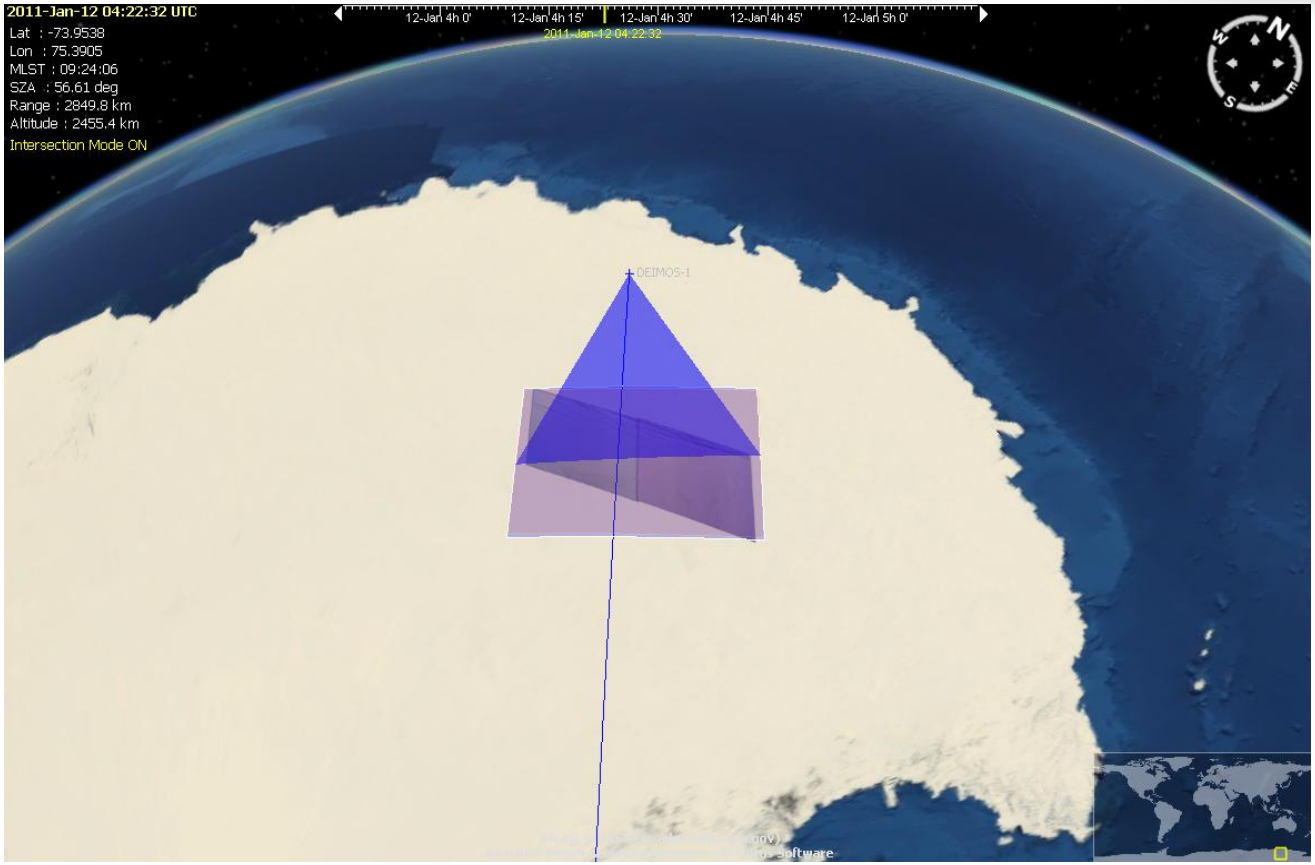
A very uniform white surface:
Deimos-1 image over Dome-C



(Source: Dr. S. Mackin, DMCii)

- Two effects are visible, in addition to the difference in response for each detector:
  - **Vignetting:** Intrinsic to the camera. Compensated by calibration coefficients
  - **Asymmetry:** The snow has a significant BRDF effect, and the ground is viewed under a changing solar angle across-track

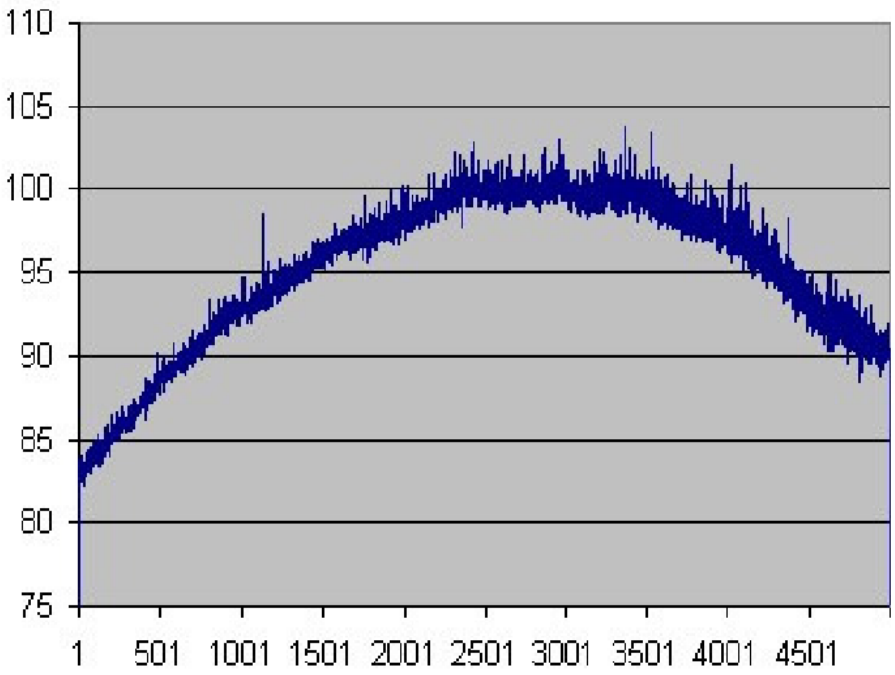
Relative Calibration



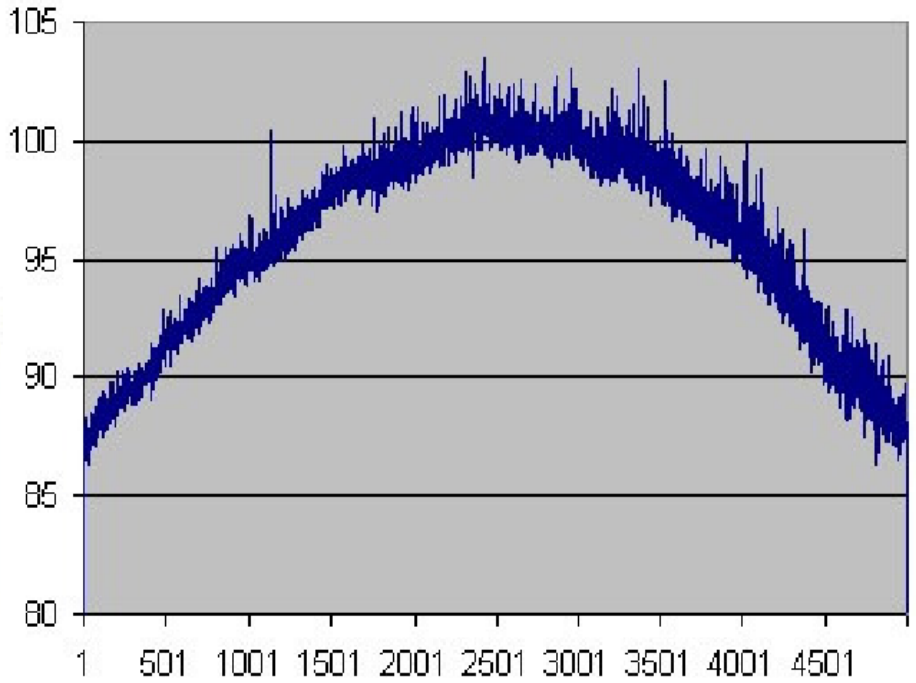
- To minimise the BRDF effect, we **turn the platform in yaw** so that the CCD is perpendicular to the Principal Plane. This maneouver has to be parametrized ad-hoc for each Dome-C capture.
- In the image above, we can see the nominal swath footprint in comparison with a dual bank image captured using the described techique.

Relative Calibration

Without Yaw Maneuver



With Yaw Maneuver



(Source: Dr. S. Mackin, DMCii)

- The asymmetry disappears on the right graph, which comes from a Dome-C image taken with the platform properly yawed. The left one was generated using an image captured with the platform in its nominal orientation.
- Once the effect of the BRDF is removed, we can characterize each detector with a gain and a bias, equalize their response, and consider the full array of detectors as a single one.
- Next step: Proceed with absolute calibration.

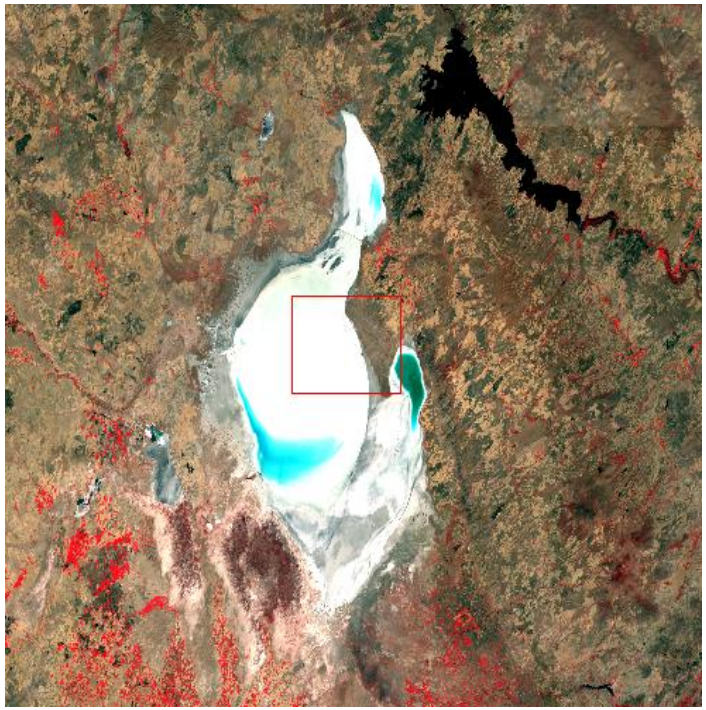
Relative Calibration

Before equalization process

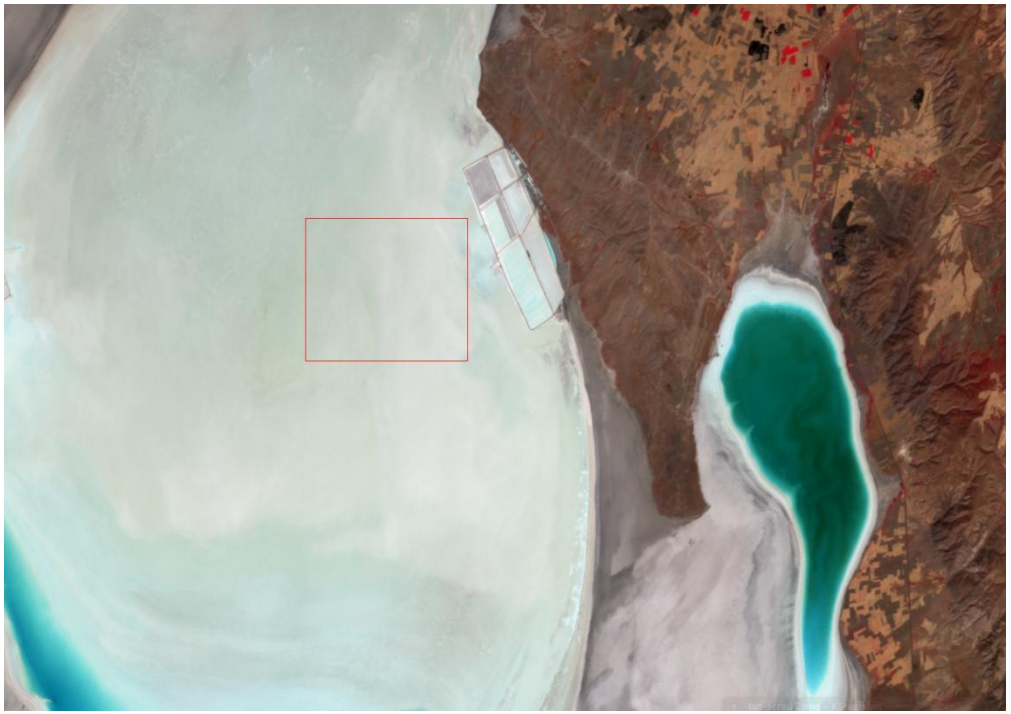
After equalization process

Absolute Calibration

- Now we have each array equalized, it's time to make them measure radiance.
- We startes with pre-launch absolute calibration parameters (launch on July 29th, 2009).
- **Vicarious calibration**: Adquisition of images of Tuz Gölü (Turkey), a CEOS Landnet site, coordinated with TÜBİTAK. TÜBİTAK performed ground and atmospheric measurements and generated atmospherically-corrected TOA radiance at the time of the satellite overpasses.



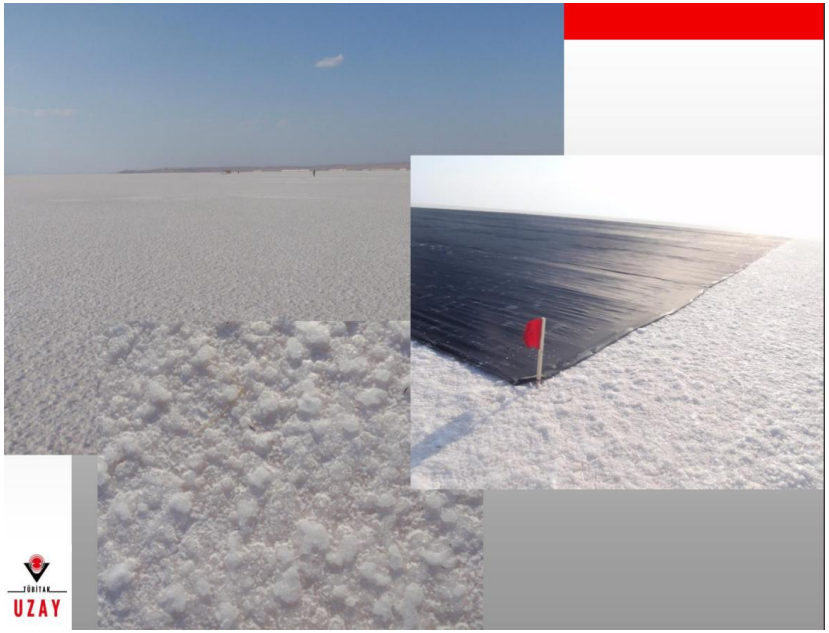
Deimos-1 image



Deimos-1 image

Absolute Calibration

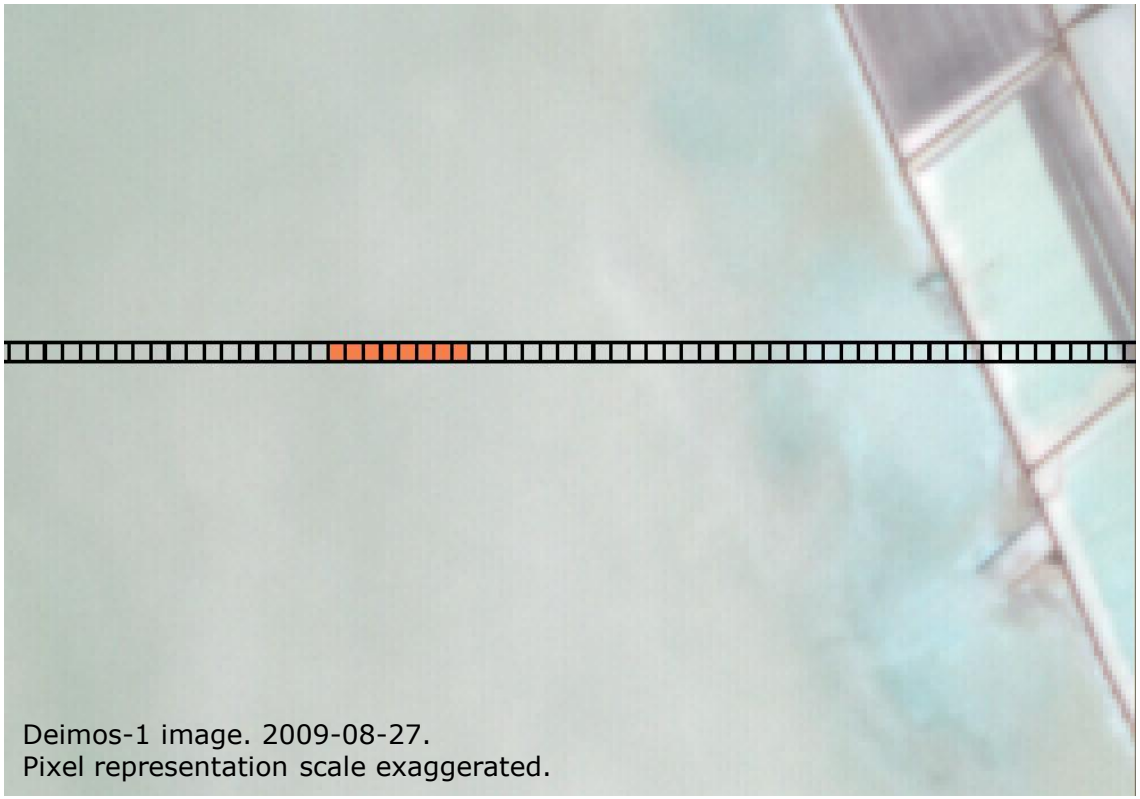
- TOA (Top of Atmosphere) radiance values were calculated using 6S (Second Simulation of a Satellite Signal in the Solar Spectrum) radiative transfer code.
- The collected parameters for 6S were:
  - Surface Reflectance
  - Geometrical Conditions: Acquisition month, day, solar zenith and solar azimuth angle at acquisition time, view zenith and azimuthal angle.
  - Atmospheric Model: Atmospheric Profile and Aerosol Model
  - Spectral Conditions
  - Target and Sensor Altitude



(Source: Tübitak)

Absolute Calibration

- With all linear arrays of detectors equalized, we need only a small, but very well measured, sample which spans to a few pixels to obtain the absolute calibration parameters for each band. These parameters will be extensible to the whole array.
- Main output: **absolute calibration uncertainty <5% on all bands**



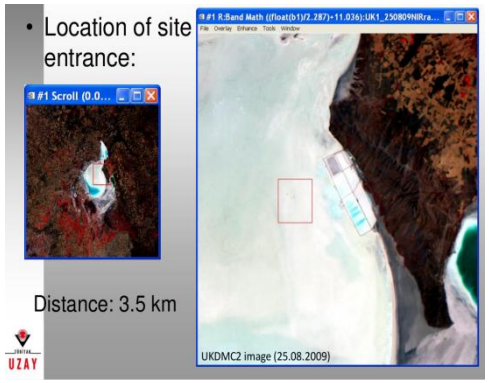
Deimos-1 image. 2009-08-27.
Pixel representation scale exaggerated.

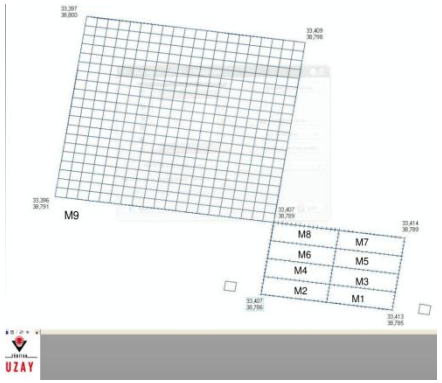
The first set of post-launch absolute calibration parameters was generated on 2009-10-23

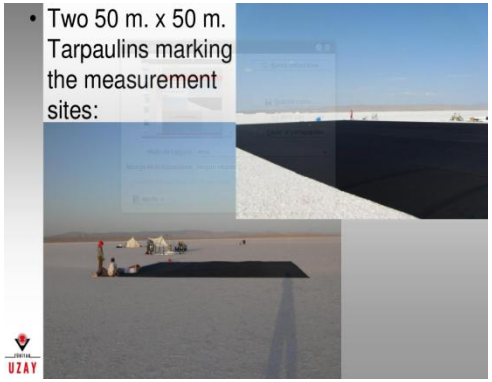
Cross-Calibration

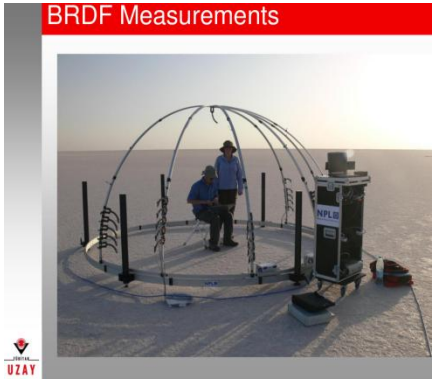
- August 2010 - CEOS Land Comparison campaign.
- Location: Tuz Gölü salt lake. Carried out by TÜBITAK.
- Sensors:

Institution	Optical sensor
CMA	FY3A/VIRR
CNES	SPOT4
	SPOT5
DMCII	Beijing1
	Deimos1
	UK-DMC2
ESA	ENVISAT/MERIS
	ENVISAT/AATSR
JAXA	ALOS/AVNIR-1
	ALOS/AVNIR-2
NASA	EO1/ Hyperion (primary) and ALI
	Terra/MODIS
USGS	Landsat5
	Landsat7
GISTDA	THEOS
DLR	RAPIDEYE_2
	RAPIDEYE_3
	RAPIDEYE_4
	RAPIDEYE_5



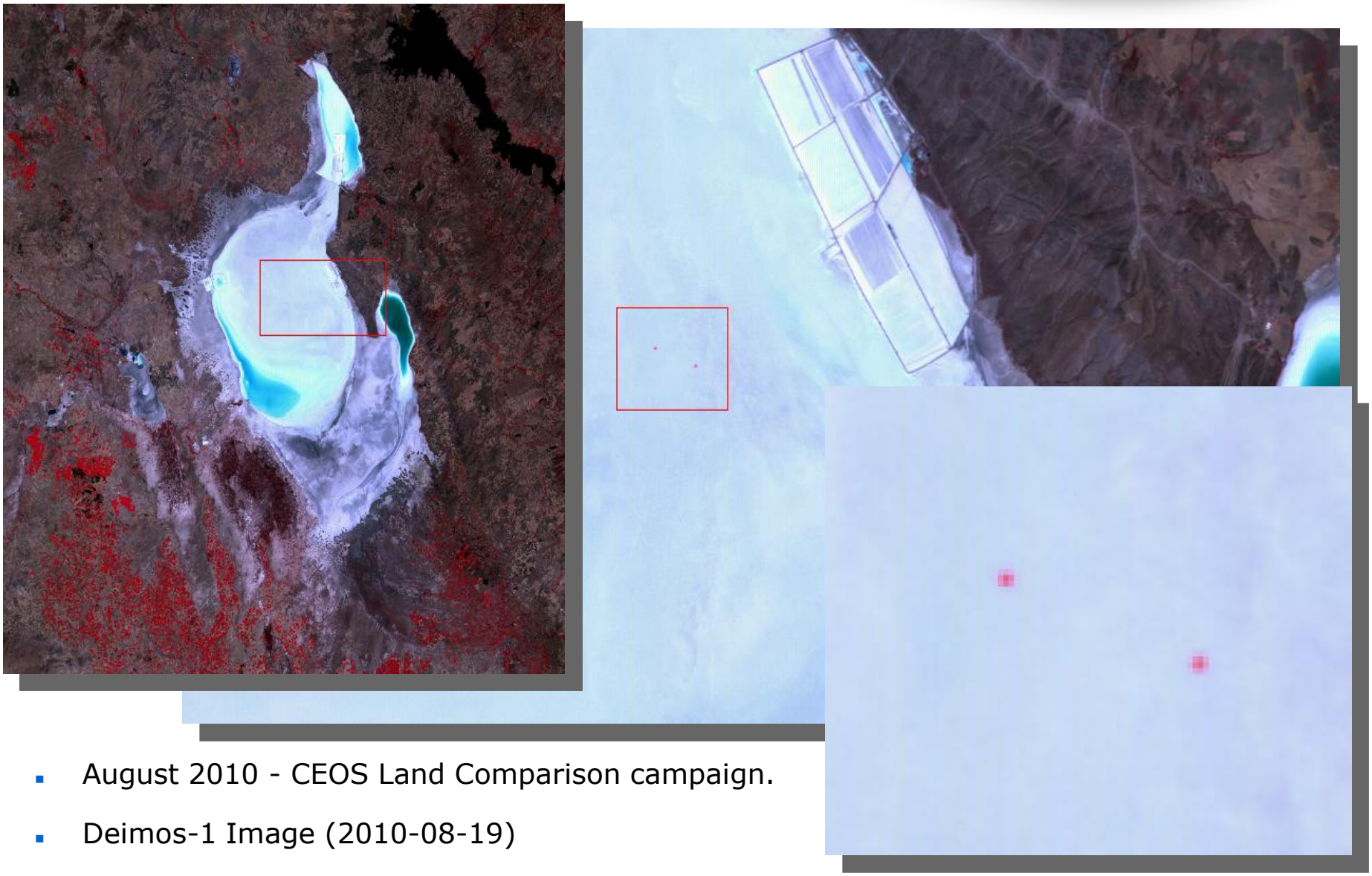






(Source: Tübitak)

Cross-Calibration

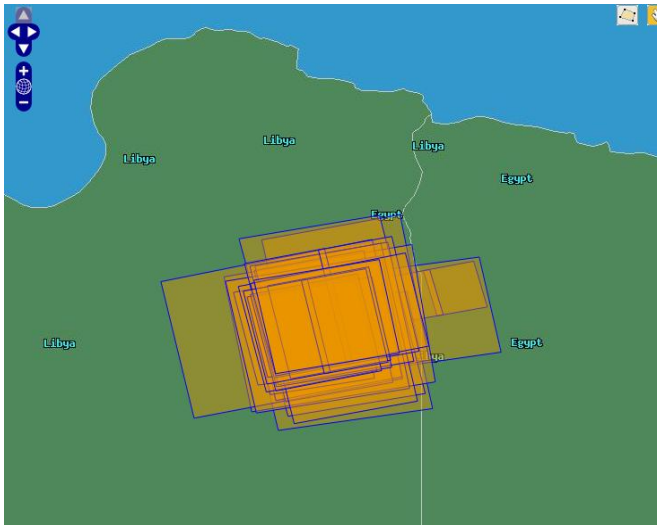


- August 2010 - CEOS Land Comparison campaign.
- Deimos-1 Image (2010-08-19)

3 Deimos-1 Validation

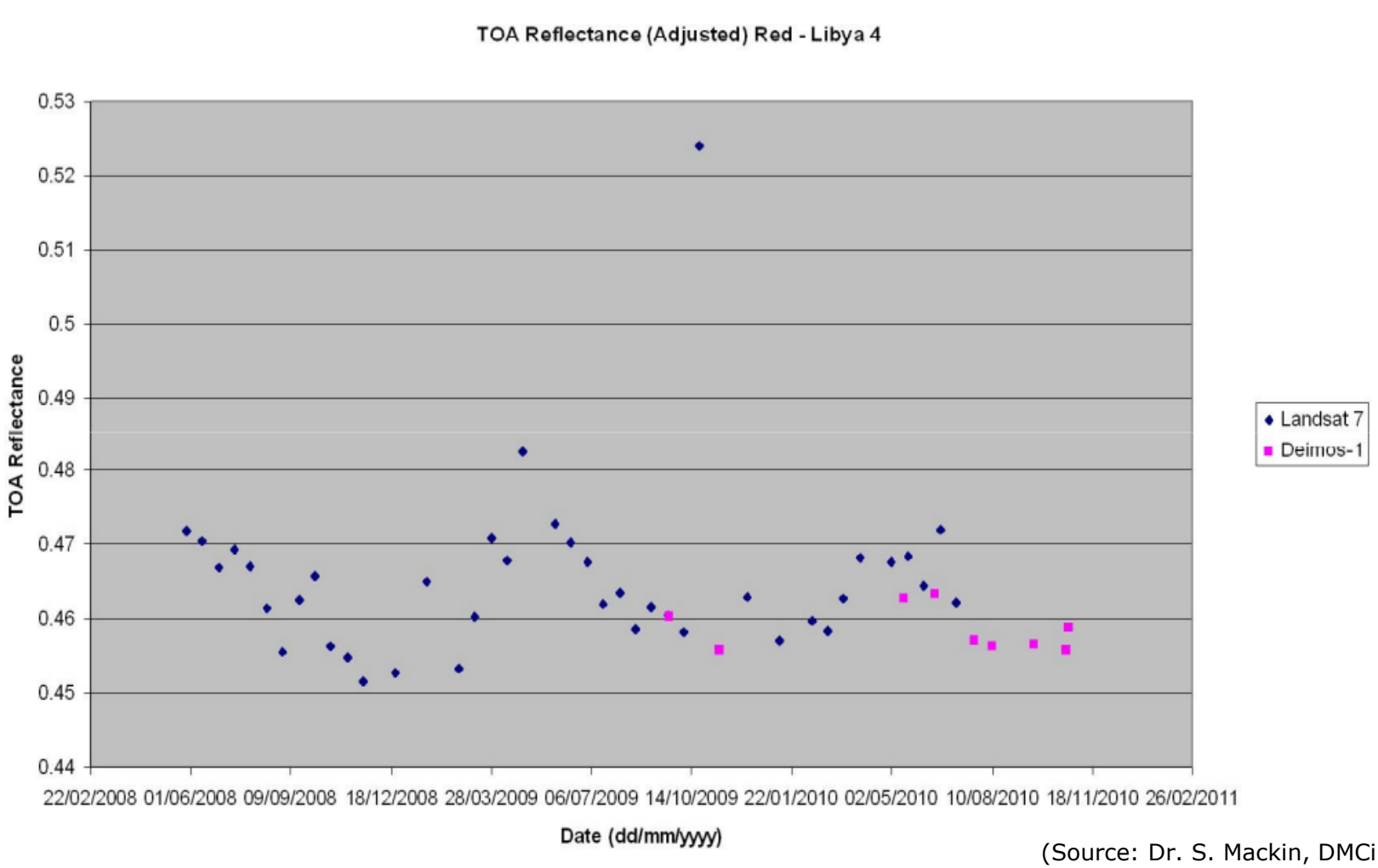
Validation with Landsat

- Libya 4 CEOS pseudo-invariant site
- Two acquisitions per month
- Monitoring:
  - Trend
  - Landsat 7 cross-calibration
  - Other DMC platforms cross-calibration
- Outputs are used as inputs to tune the calibration parameters. So this periodic acquisition is both a calibration and a validation techique.
- The trend monitoring gives us information about the sensors degradation. If a sensible deviation is found, a new calibration campaign would be scheduled.



Validation with Landsat

- Deimos-1 vs Landsat 7 cross-calibration results over Libya-4 (accuracy 1-2%)



(Source: Dr. S. Mackin, DMCii)

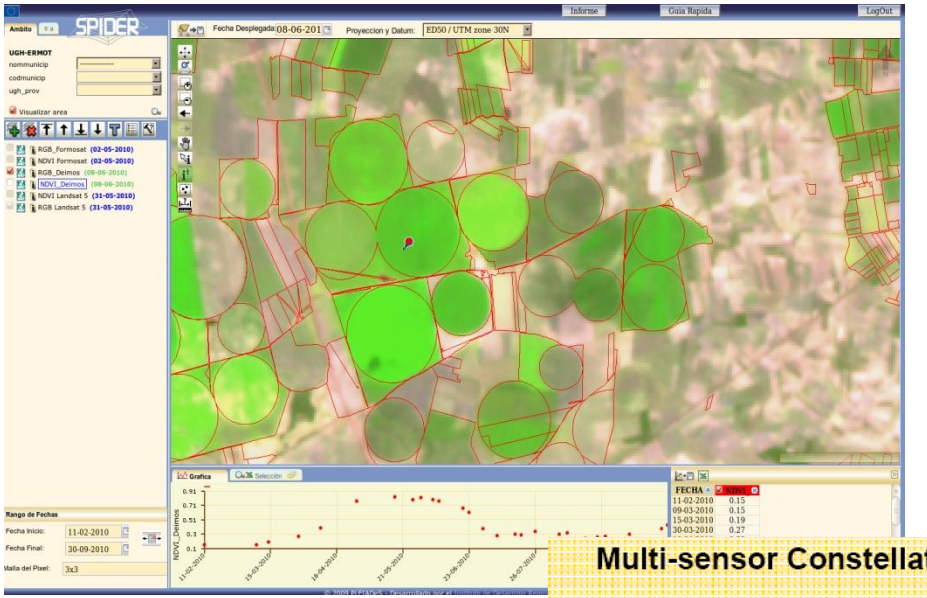
Validation with Landsat

- In addition to the calibration provided by DMCii, DEIMOS Imaging routinely performs cross-calibration with Landsat-7
- Cross-calibration check with Landsat-7 over Tuz Gölü (Turkey), a CEOS Landnet site. August 2009 => Good correlation

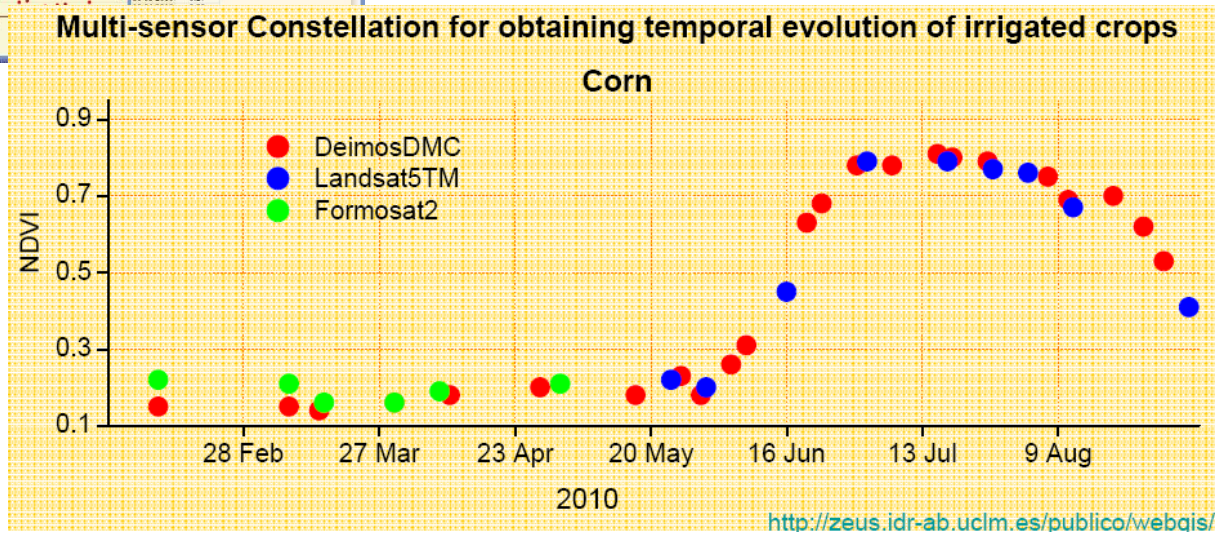
- Cross-calibration check with Landsat-7 over La Crau (France), a CEOS Landnet site. November 2009 => Good correlation

Validation with Landsat

- **Satellite Constellation for Crop Monitoring**: Formosat-2, Deimos-DMC and Landsat 5TM

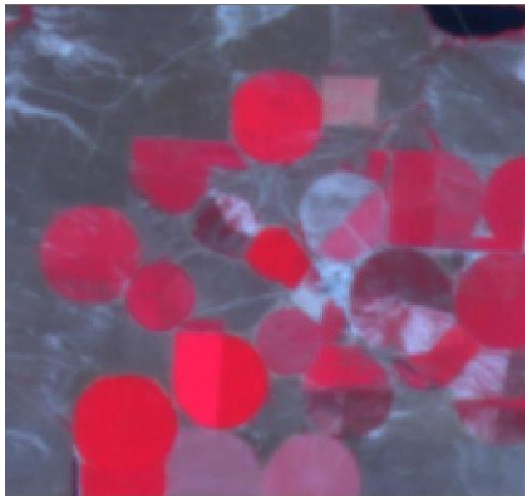


- Evolution of NDVI of an irrigated crop (maize) estimated from Deimos-DMC, Landsat 5TM and Formosat-2, during 2010.
- Temporal evolution of NDVI from several sensors can be observed through the SPIDER WebGIS system (EU PLEIADeS Project).

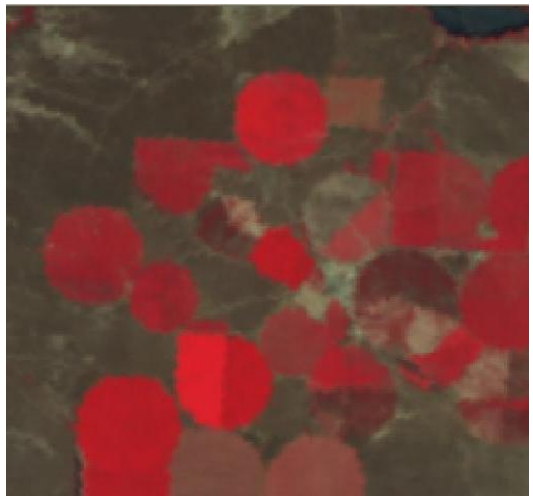


Validation with Landsat

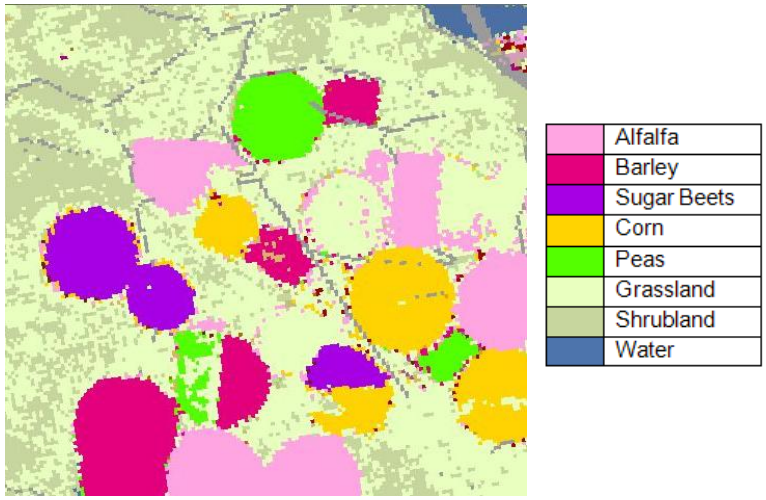
- **Comparative analysis of CDL with Deimos-1 and Landsat-5 TM** over Idaho



Deimos-1 (RGB=NIR,R,G)



Landsat-5 TM (RGB=4,3,2)



Operational CDL classification with Deimos-1 data

- Deimos-1 data can be **seamlessly used within normal procedures**
- Deimos-1 data can be **included in the normal NASS CDL process** (together with or instead of AWIFS, Landsat-5 and/or Landsat-7)
- The resulting **accuracy with Deimos-1 data is very similar** (within 1-3%) to the one obtained with **Landsat** (using all available bands)
- The improved spatial resolution allows to compensate almost completely the lack of a mid-infrared or thermal band

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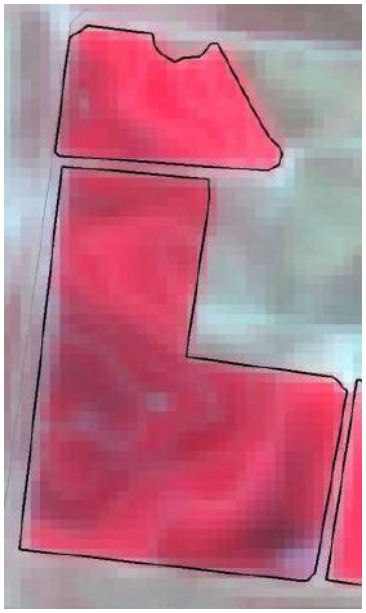
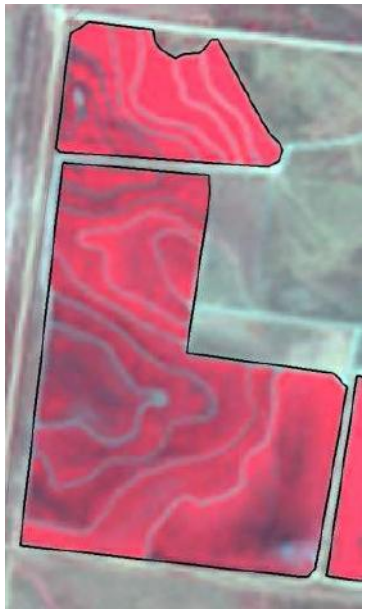
Validation with SPOT-5

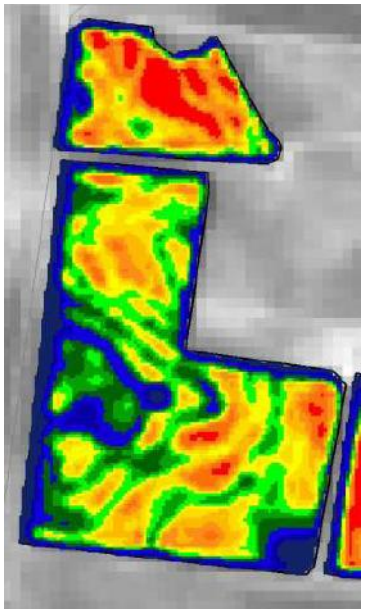
- **Comparative analysis of NDVI with Deimos-1 and Spot-5** (rice fields)



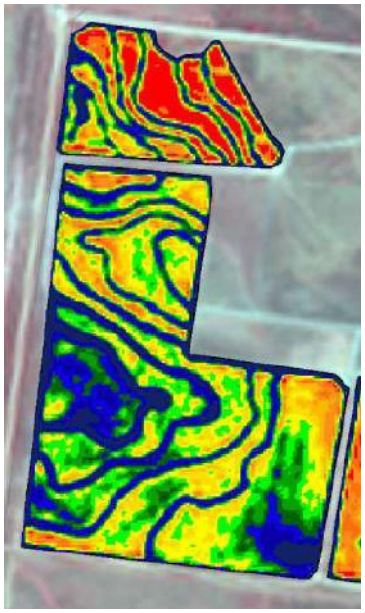
Deimos-1 (20m)



Spot 5 (10m)



Deimos-1 NDVI



Spot-5 NDVI

- In search of the **optimal imagery resolution**, matching to management scale
- SPOT-5 sees more in-field detail: needed for fields with contour variability
- BOTH sensors identify patterns of NDVI variability well
- Much larger swath on DEIMOS-1 assures higher revisit frequency and lower costs
- For most applications, **DEIMOS-1 data is a very cost-effective solution**

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4 Conclusions

Conclusions

- DEIMOS Imaging has been successfully operating DEIMOS-1 since July 2009
- DEIMOS-1 has an unmatched coverage capacity at 22-m resolution, thanks to:
  - Wide sensor swath (640 km)
  - 2-station ground segment that guarantees 20 data download slots per day
  - Advanced mission planning system that allows acquisitions optimization
- Calibration (both absolute and relative to Landsat) is considered top priority for DEIMOS-1
- DEIMOS-1 data is constantly calibrated according to CEOS guidelines and validated w.r.t. Landsat
- Results of absolute calibration are within 5% accuracy, and relative calibration with Landsat is within 1-2%
- DEIMOS-1 data can be seamlessly included in the nominal NASS CDL process, with a resulting accuracy very similar (within few %) to Landsat.

Deimos EO System Evolution

- DEIMOS Imaging EO system will be upgraded in 2013 with a new satellite
- DEIMOS-2 will be a small multispectral optical satellite with very high resolution (1m)
- It will be designed, integrated and tested in Spain, in new DEIMOS premises currently under construction
- The combined use of DEIMOS-1 (20 m) and DEIMOS-2 (1 m) will provide a wide range of capabilities for the generation of products in all optical imagery market segments

Thank you!

fabrizio.pirondini@deimos-imaging.com