Data Quality of DEIMOS-1 & UK-DMC2 Imagery for the Monitoring of 2011 US Crop Season

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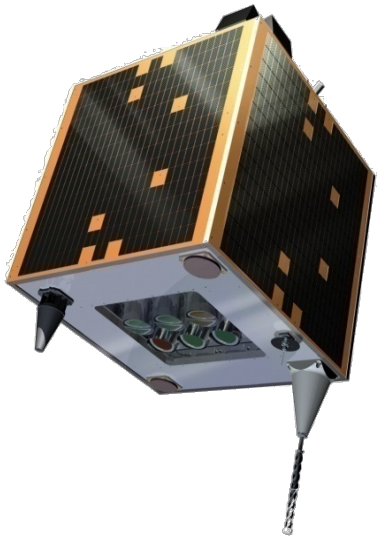
1 The DEIMOS-1 Earth Observation System

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
- Lifetime: 5 years nominal, >7 years expected

The Satellite

- Built by SSTL (UK)
- Mass: 100 Kg; Nadir-pointing platform
- 8-Gb on-board solid state recorder
- X-, S-band antennas for data transmission, TM/TC

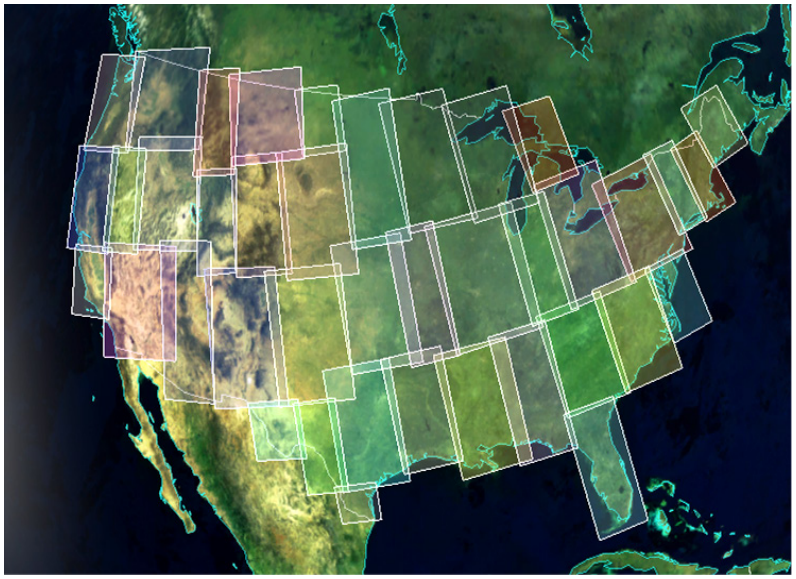


Ground Segment

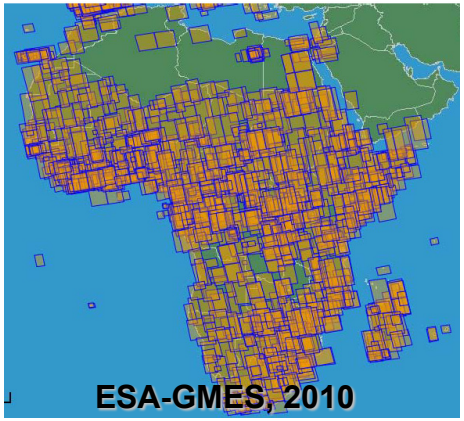
- The **2-station ground segment** is a key asset of the DEIMOS-1 system
- Svalbard (Norway) allows to **download data at each orbit**
- Boecillo (Spain) allows **4 further contacts each day**
- Weekly data volume: 120Gb
- ELECNOR DEIMOS premises in Boecillo have a control centre integrated with the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

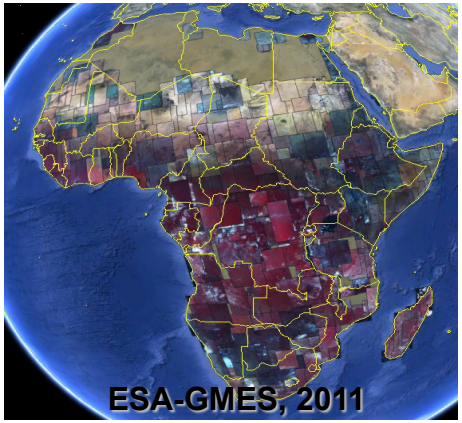
Payload & System Capacity

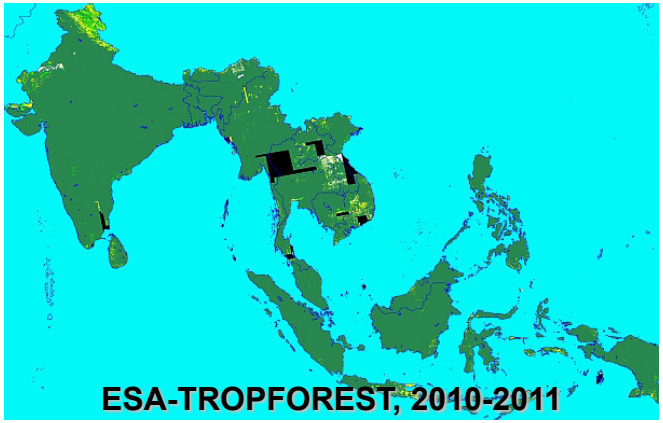
- **Combination of high spatial and temporal resolution**
- Dual-bank pushbroom CCD, 3 cameras per bank
- Spatial resolution of **22m** GSD at 10 bits
- The wide **>620-km swath** allows to have a high frequency of observation of any given point on Earth
- **Three bands (R,G,NIR)** similar to Landsat to assure continuity with existing tools and harmonization with historical data
- DEIMOS-1 **wide swath** (620 km) combined with **data download at each orbit** assures a high revisit frequency for any given point on Earth
- Typically, 2-3 images per day over the US (~1 million km^2 per day)
- **Complete coverage of the US every 2 weeks**
- **Worldwide capacity >5 million km^2 per day**

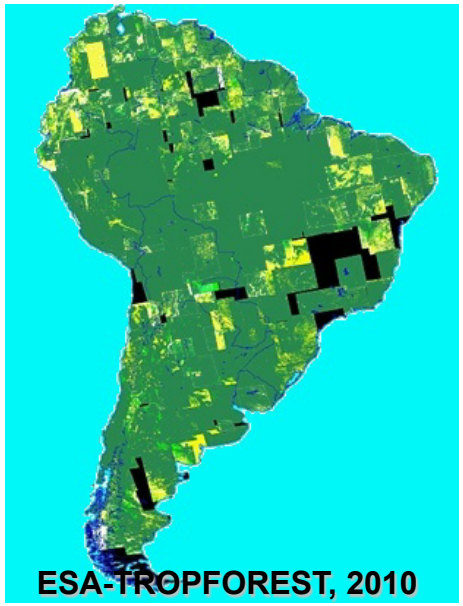


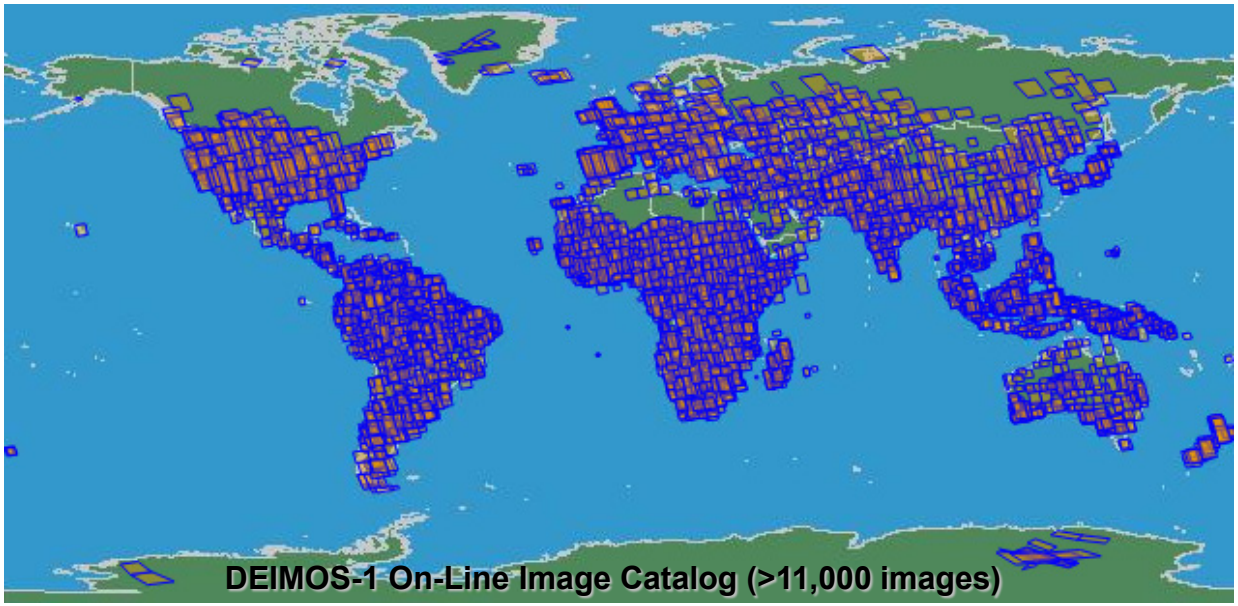
Worldwide Coverage











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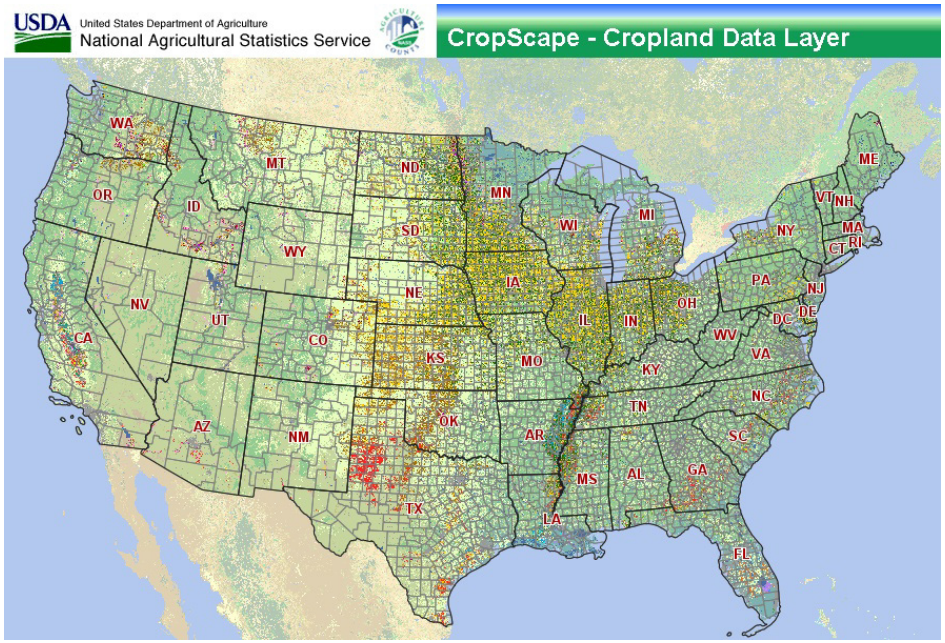
2 2011 US Crop Season Monitoring Campaign

US 2011 Crop Campaign

- ELECNOR DEIMOS IMAGING has been the **data provider** for the USDA contract for the provision of satellite imagery for the **US 2011 Crop Season**, awarded to Astrium GEO-Information Services North America
- ELECNOR DEIMOS IMAGING provided **DEIMOS-1** data, complemented with data from its twin DMCii satellite **UK-DMC2** (around 80% of all delivered data is from DEIMOS-1, with 20% from UK-DMC2)

Main contract requirements:

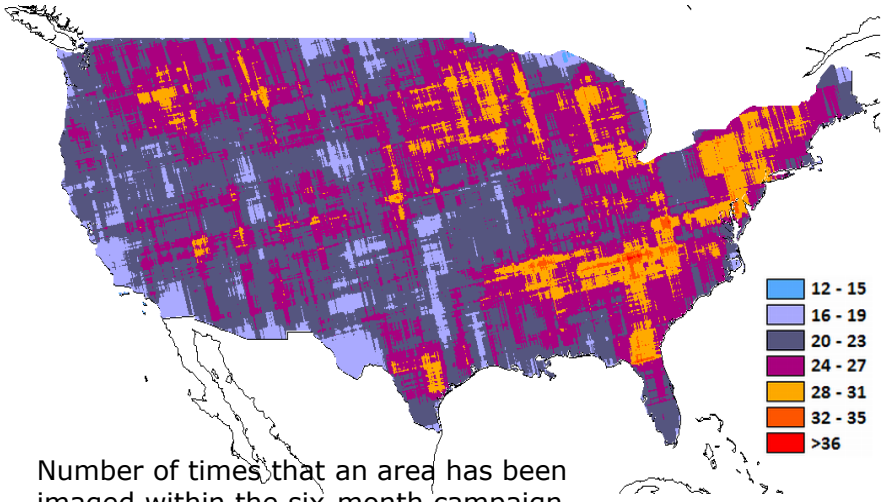
- One complete coverage of CONUS **every 15 days** from May to October 2011, **70% cloud-free** & with **daily acquisitions**
- All data shall be delivered, **orthorectified, within 72 hr** from acquisition
- All data shall be orthorectified with **<1 pixel GSD accuracy**



Main Outcomes

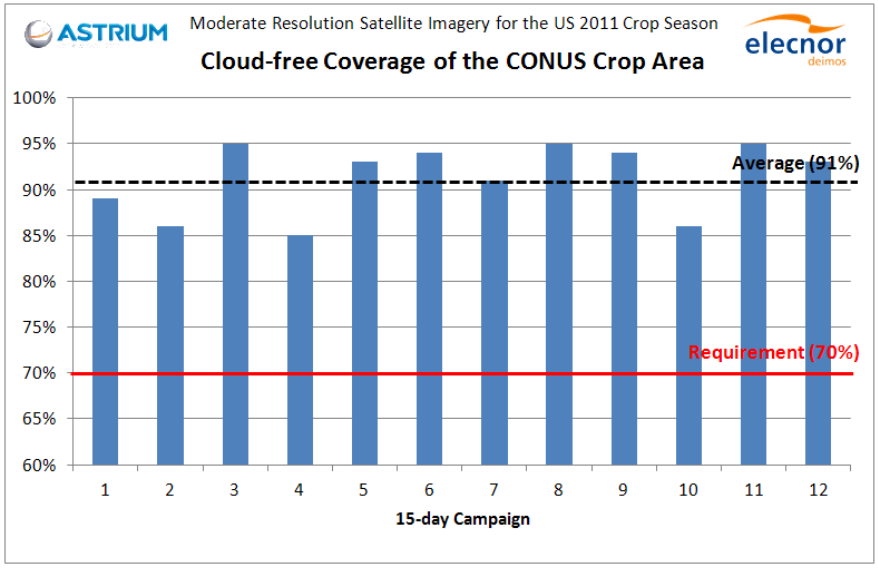
- All requirements have been met (and exceeded)
- More than 186 MKm^2 have been delivered (equivalent to 23 times the area of the Lower 48), of which **150 MKm^2 cloud-free**
- Cloud-free coverage requirements (>70%) greatly exceeded, with averages ~90%
- 99.5% of images delivered, ortho, in less than 72hr from acquisition
- **Average delivery time** of the orthorectified images: **32 hours from acquisition** (including weekends and holidays)

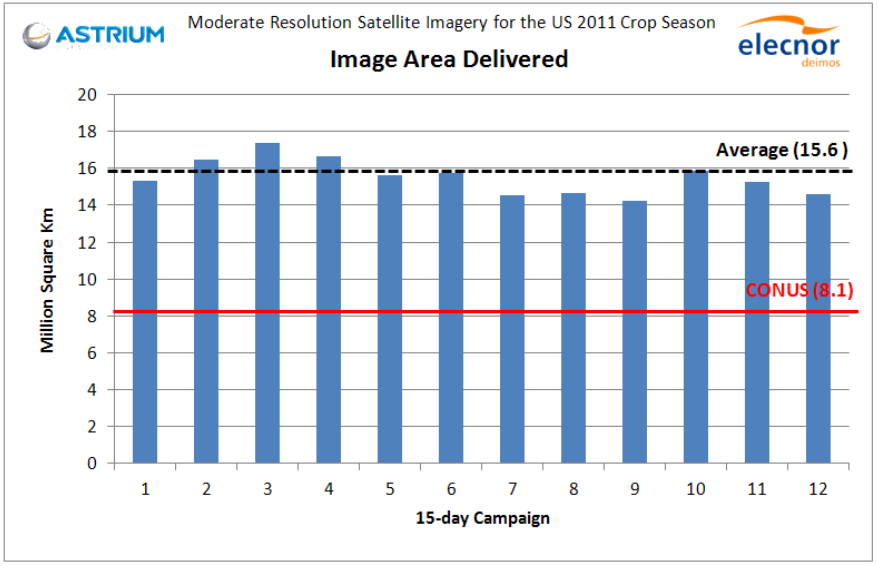
	DEIMOS-1	UK-DMC2	Total
Acquired images	1,052	549	1,578
Delivered images	962	500	1,462
Delivered images < 72h	959	494	1,454
Delivered Km2	146,879,759	39,156,063	186,035,822
Cloud-free Km2	117,852,981	32,785,188	150,638,170
Cloud-free Km2 (%)	78.2%	21.8%	100%
Average delivery time (h)	29.0	40.2	32.5

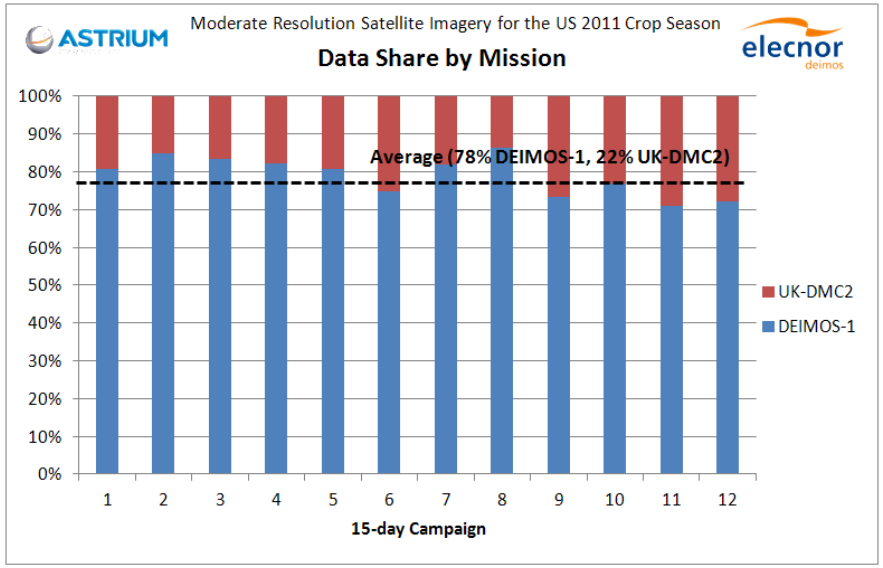


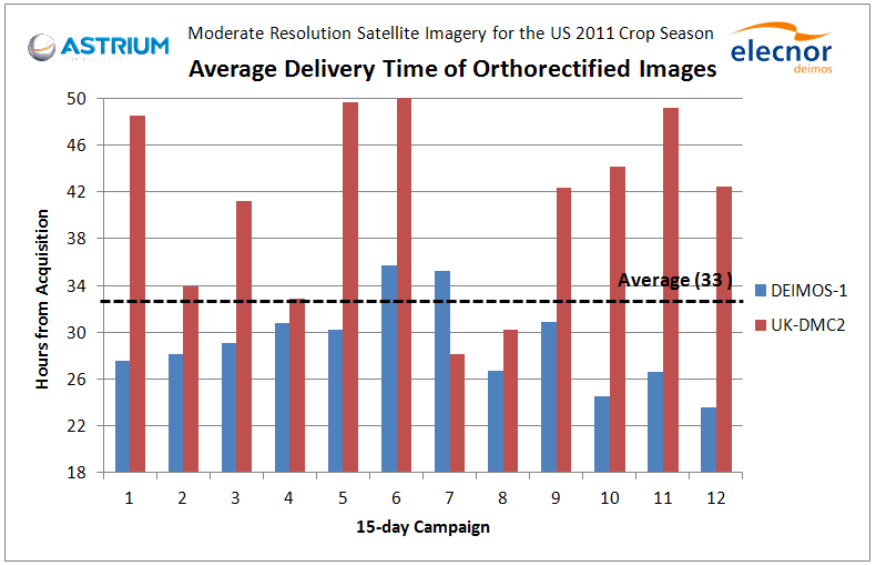
Number of times that an area has been imaged within the six-month campaign

Main Outcomes



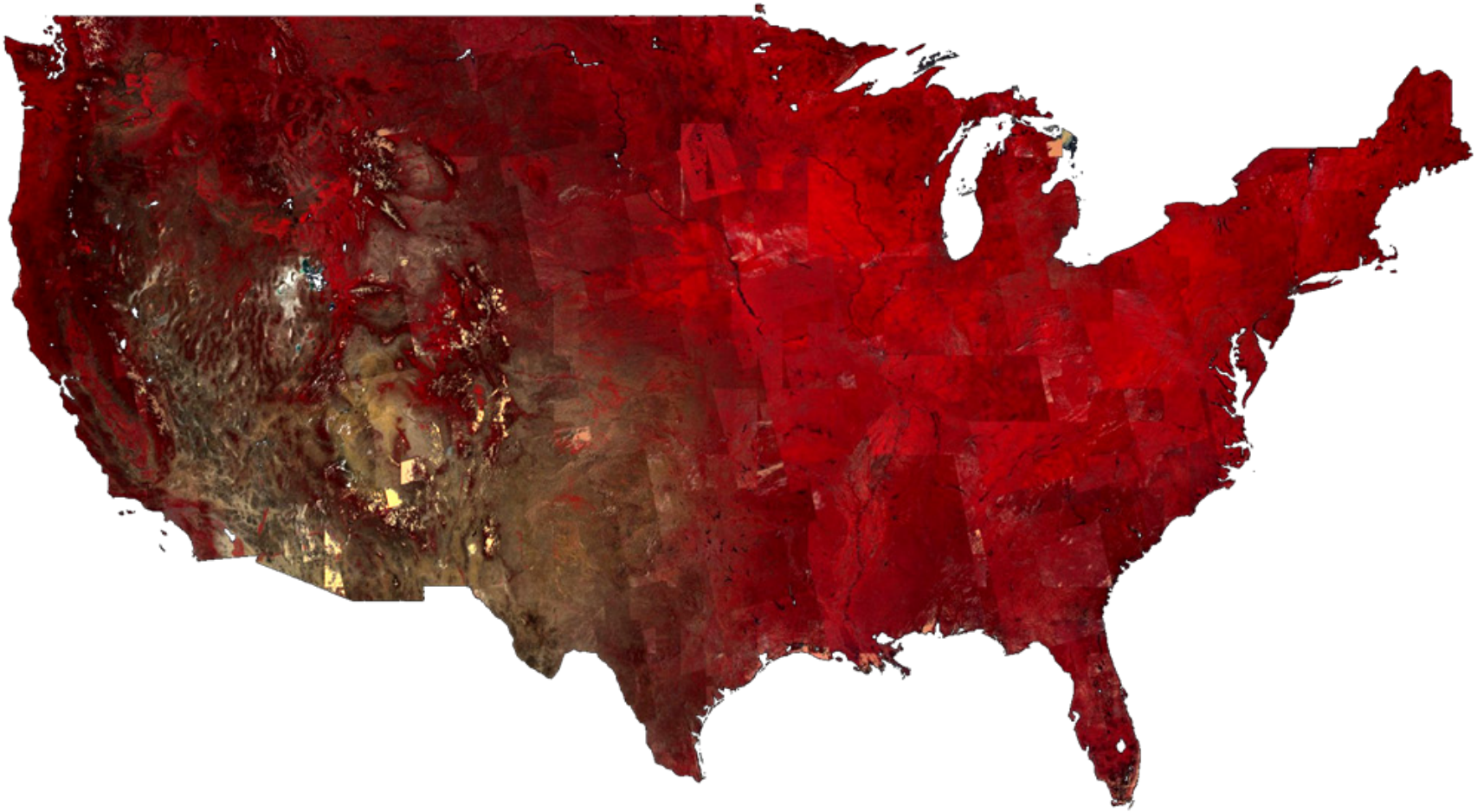






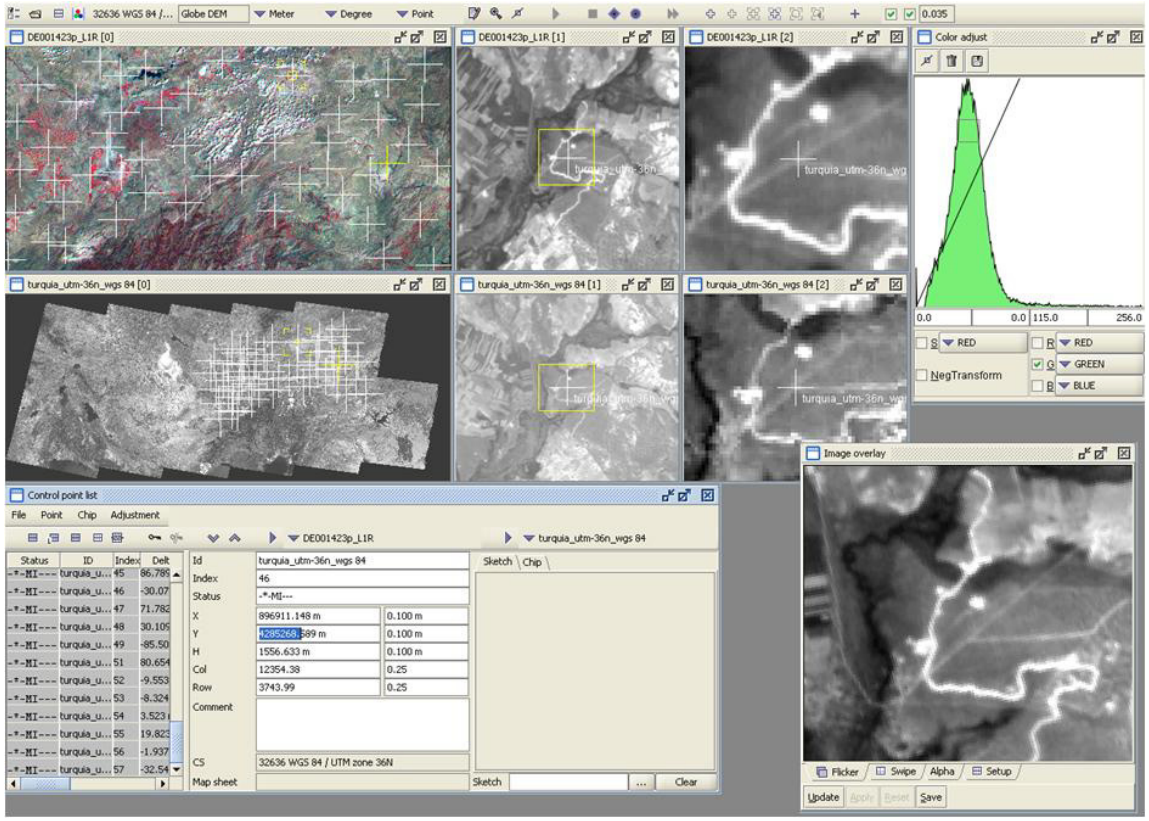
Main Outcomes

- **Example of monthly (July) coverage mosaic: 96% cloud-free**



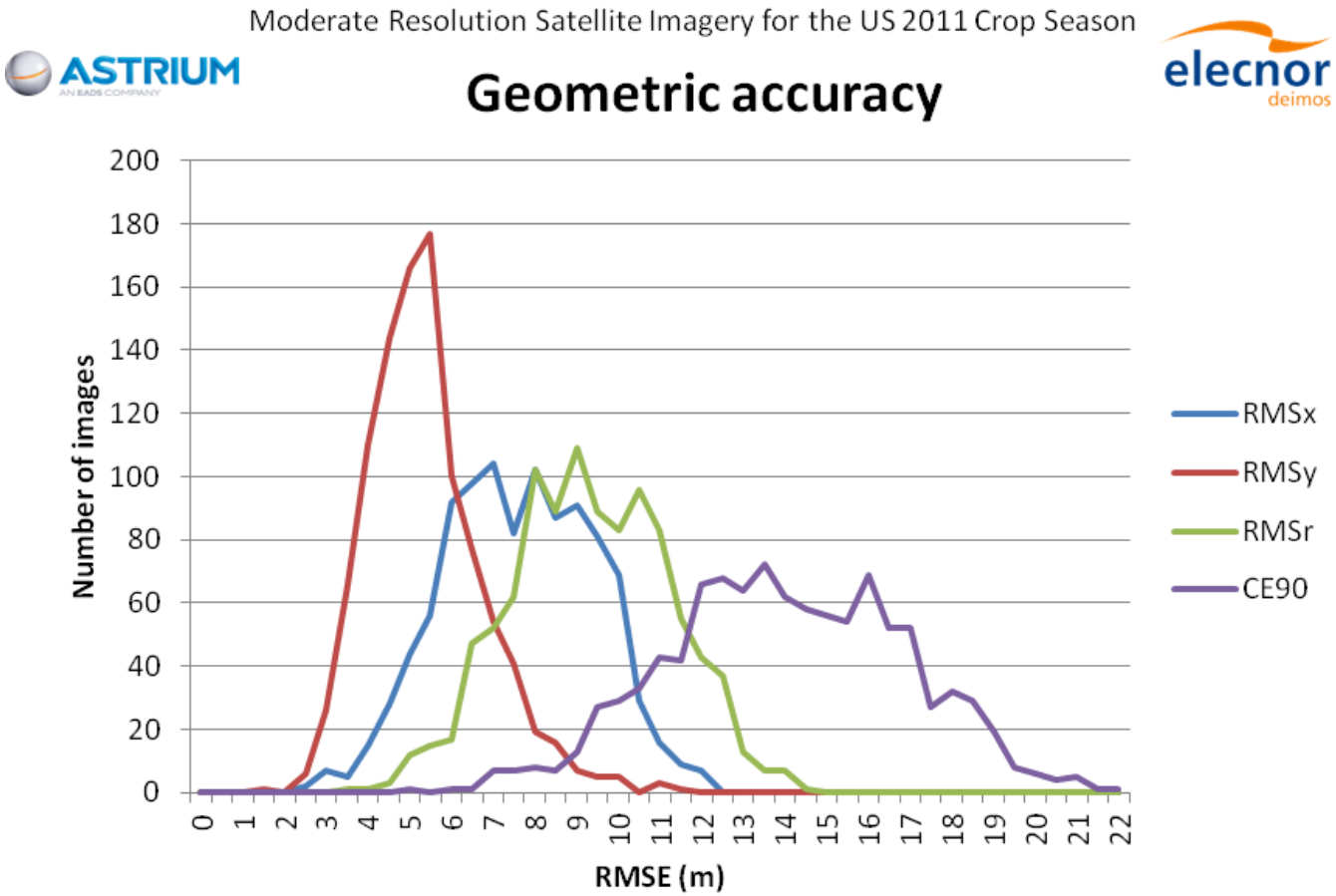
Geolocalization

- **GLS2000** is used as the reference dataset, together with **SRTM v3** DEM
- The orthorectification chain is improved through the generation of **mosaics** from GLS2000 reference data, in order to streamline GCP collection and processing
- **Validation of geometric quality** is performed on every image to assure that CE90% is below pixel resolution



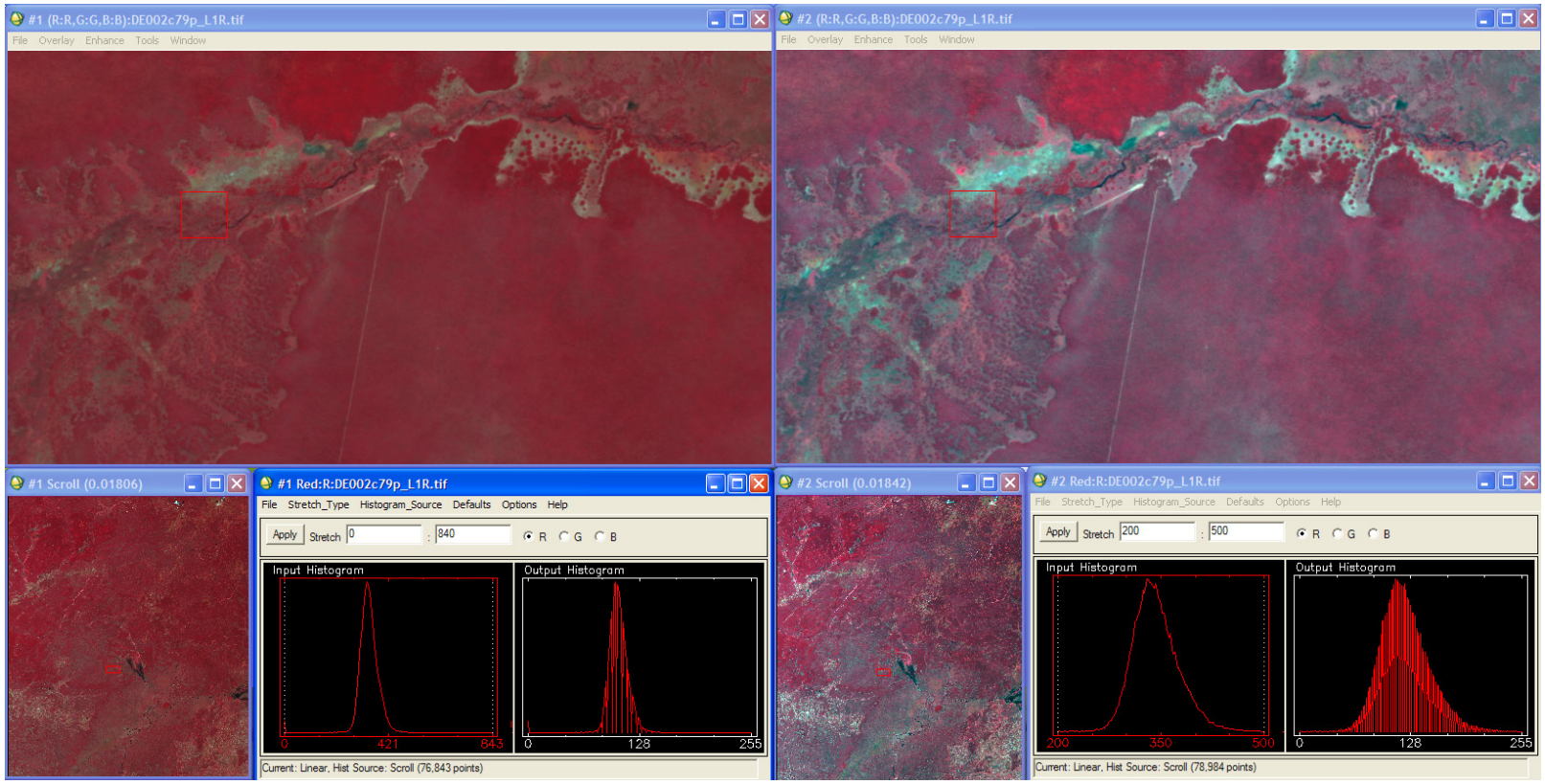
Geolocalization

- **Sub-pixel accuracy has been achieved on 100% of delivered images, with average RMSE near ½ pixel (~10m)** w.r.t. Landsat reference dataset
- 99.5% of all images delivered, orthorectified, within 72 hours from acquisition



Radiometric Optimization

- **A radiometric optimization is applied before the delivery of each image**
- The 10-bit histograms are analyzed, and optimally scaled to 8-bit images
- Optimization is computed by defining a minimum and maximum value of useful data within the scene, in order to obtain more contrast while maintaining radiometric quality in 8-bit images



Calibration

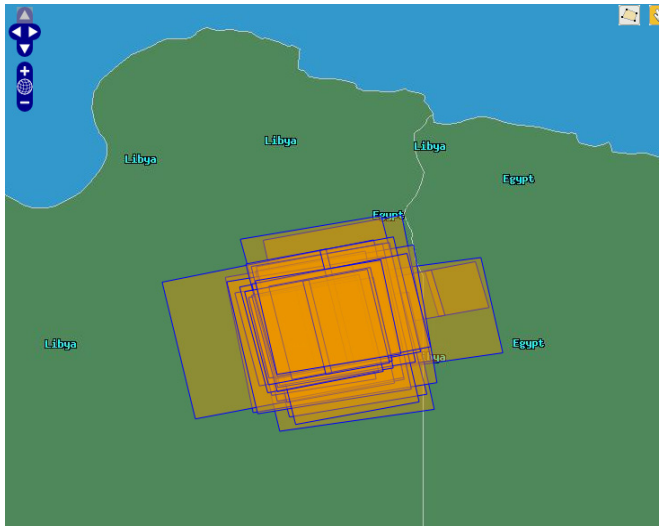
- **Dynamic on-board calibration**: on-board control of gain parameters (rescaling from 14 to 10 bits) as a function of the type of the target, to optimize the radiometric resolution of the data

- **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 Libya-4, Dome-C)
  - **Cross-calibration with the "gold standard" Landsat 7** (Libya-4, 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 internal activities at ELECNOR DEIMOS**

Landsat-7 Cross-Calibration

- **Libya-4** CEOS pseudo-invariant site
- Two acquisitions per month (> 40 so far)
- 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.
- Performed by Steve Mackin's team (DMCii) together with other DMC satellites



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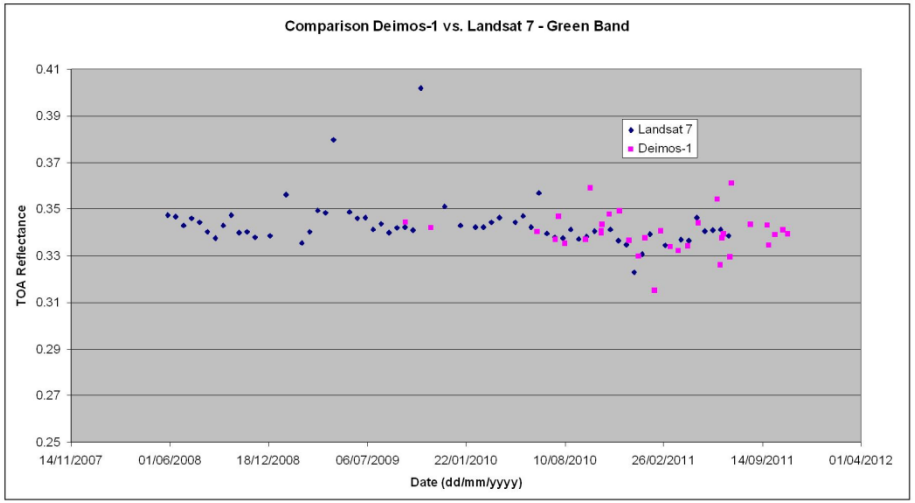
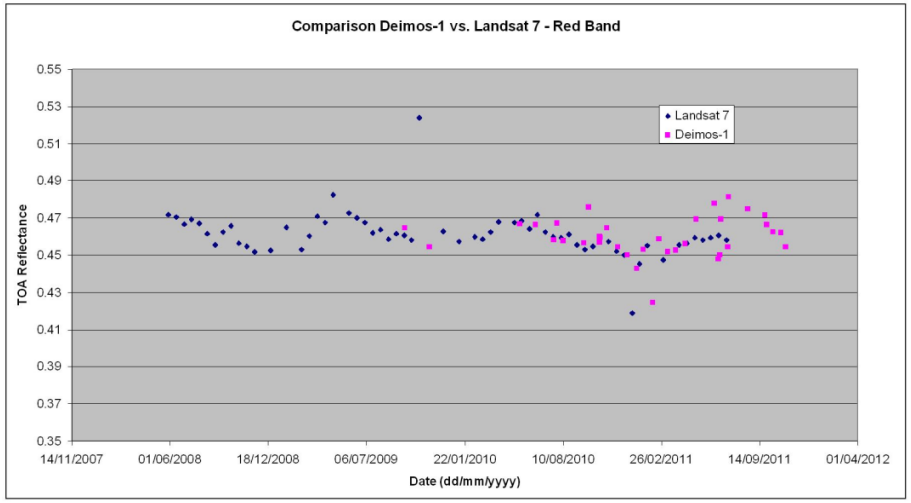
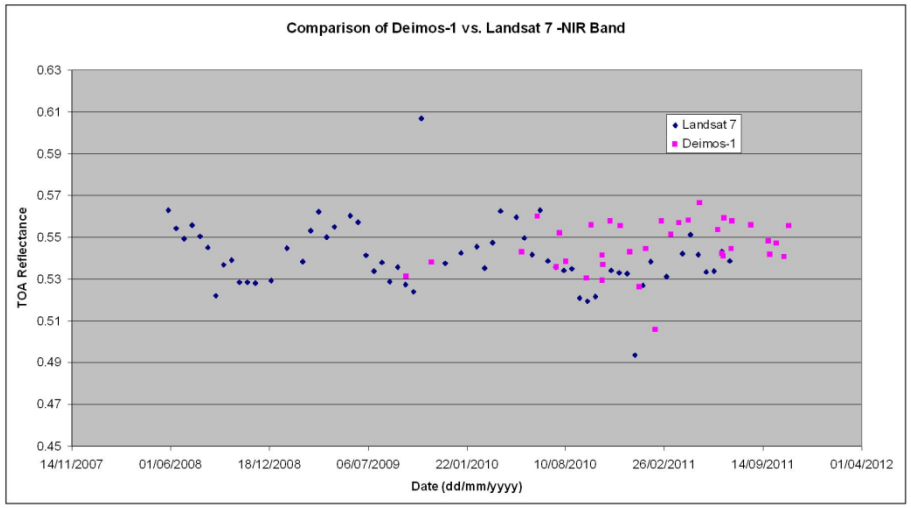
Landsat-7 Cross-Calibration Methodology

- No need of nadir-only acquisitions, thanks to DMCii's BRDF model of the site
- Data processed to **radiance** using the current coefficients
- Data converted to **TOA reflectance** (radiance varies a lot during the year)
- **Removal of the seasonal component** through a fitted sinusoid
- View angle (to fixed target in the centre of the scene) determined for each image
- Data output from last two steps plotted to derive a relationship between view angle and de-trended TOA reflectance
- Fit the data with one or two independent linear functions (typically two linears, one for the S-Bank and one for the P-Bank), to **remove the view angle effects** and greatly reduce scatter
- Plot the corrected view angle against the Landsat-7 data, compare mean values
- The mean values provide a **multiplicative correction** to determine how much the coefficients need to be changed to align the data with Landsat-7

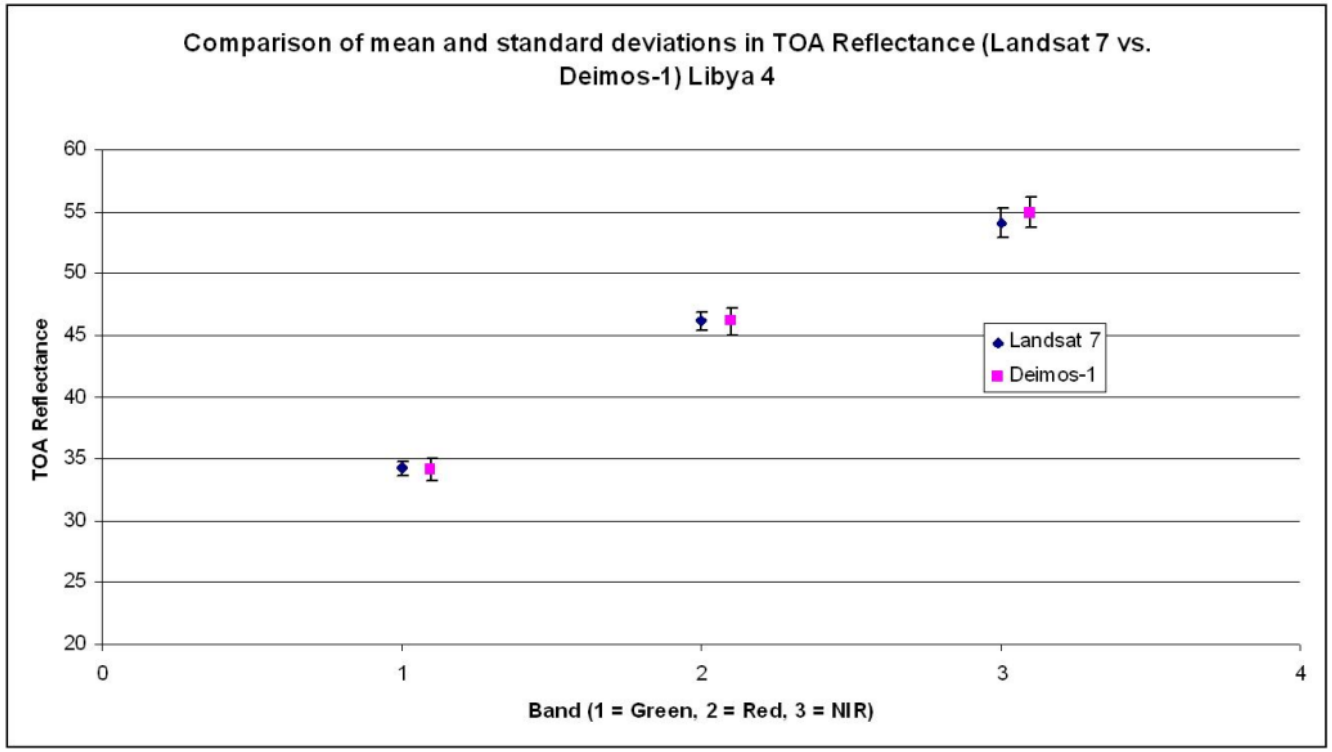
Latest Results (including the 2011 US Crop Monitoring campaign)







Calibration



Band	TOA Reflectance				Calibration Accuracy
	Landsat 7		DEIMOS-1		
	Mean	Deviation	Mean	Deviation	
Green	34.18%	0.56%	34.09%	0.87%	**3.7%**
Red	46.11%	0.72%	46.12%	1.10%	**3.5%**
NIR	54.05%	1.17%	54.83%	1.23%	**4.9%**

Synthetic Blue Band

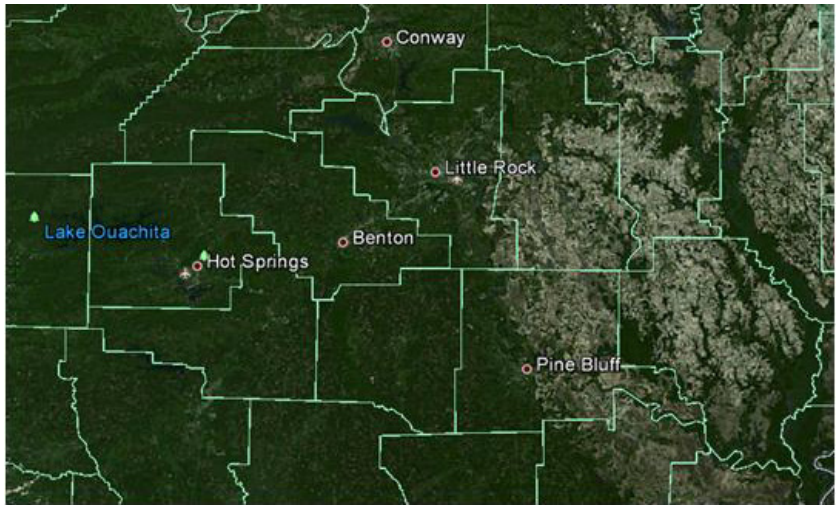
- A **Synthetic Blue band** can be computed from a combination of the other three available bands to provide **natural color images**
- This data can be especially **useful for crisis & disaster management**, and in all cases where the users are not remote sensing specialists, but need to extract quickly the most relevant information from the images
- Literature shows that there is a high correlation between the reflectivity of the visible bands and the blue band
- Using the similarity with Landsat 2, 3 and 4 bands, we have looked for an **empiric law to create a synthetic blue band that adjusts to Landsat data**
- Reflectivity is dependant of Sun-Zenith angle of each pixels, so for large swaths like DEIMOS-1, this effect shall be properly accounted for and compensated
- The study was performed over Spain, covering all seasons, and used Landsat data corrected with MODIS to account for historical phenology deviations
- Even if we looked for correlations with R,G, and NIR bands, the best correlations were found with only the Green and NIR bands, using this linear formula:

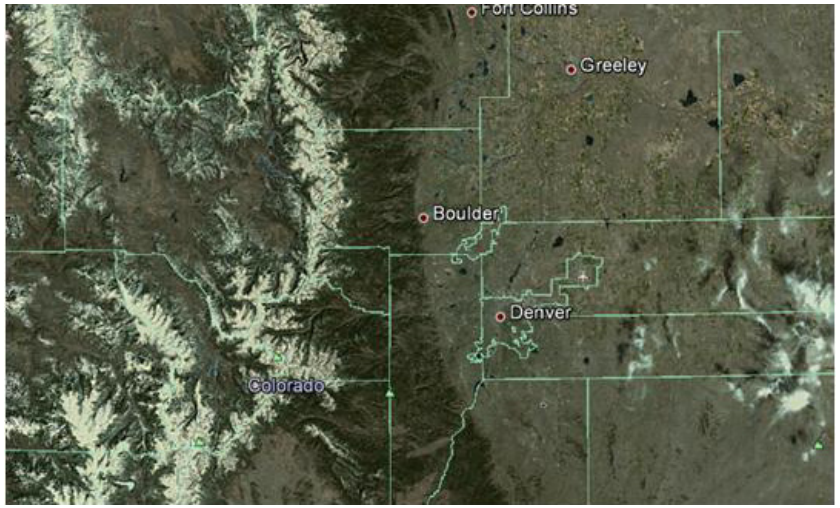
$$\textbf{Blue} = \textbf{a} \cdot \textbf{Green} - \textbf{b} \cdot \textbf{NIR} + \textbf{c}$$

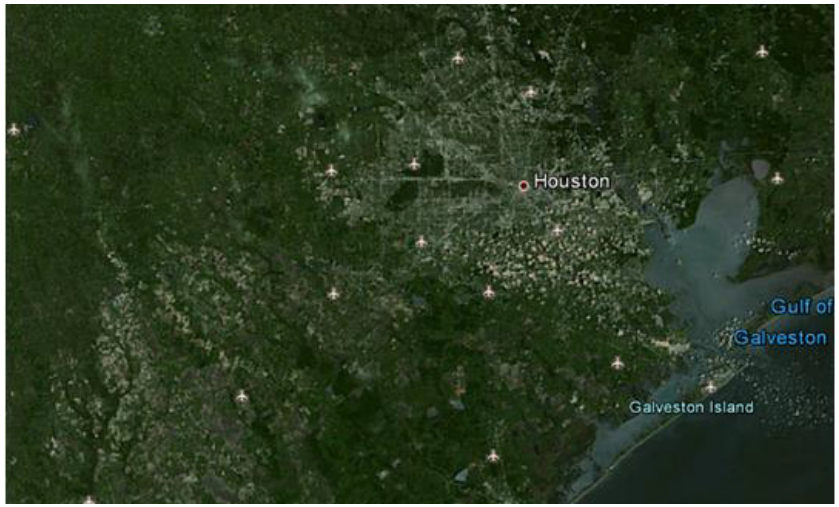
- With this formula, water surfaces still have an excess of red that is corrected with a proper gamma correction on the red band

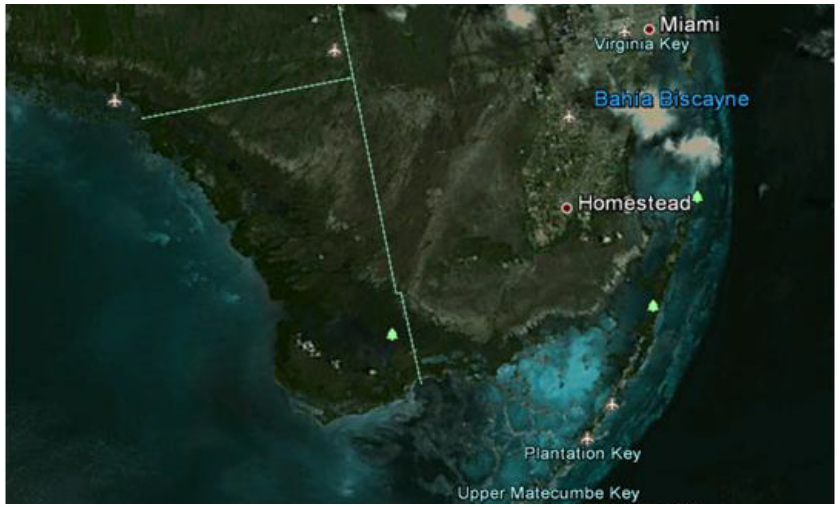
Synthetic Blue Band

- **Examples of DEIMOS-1 natural color images with synthetic blue band**







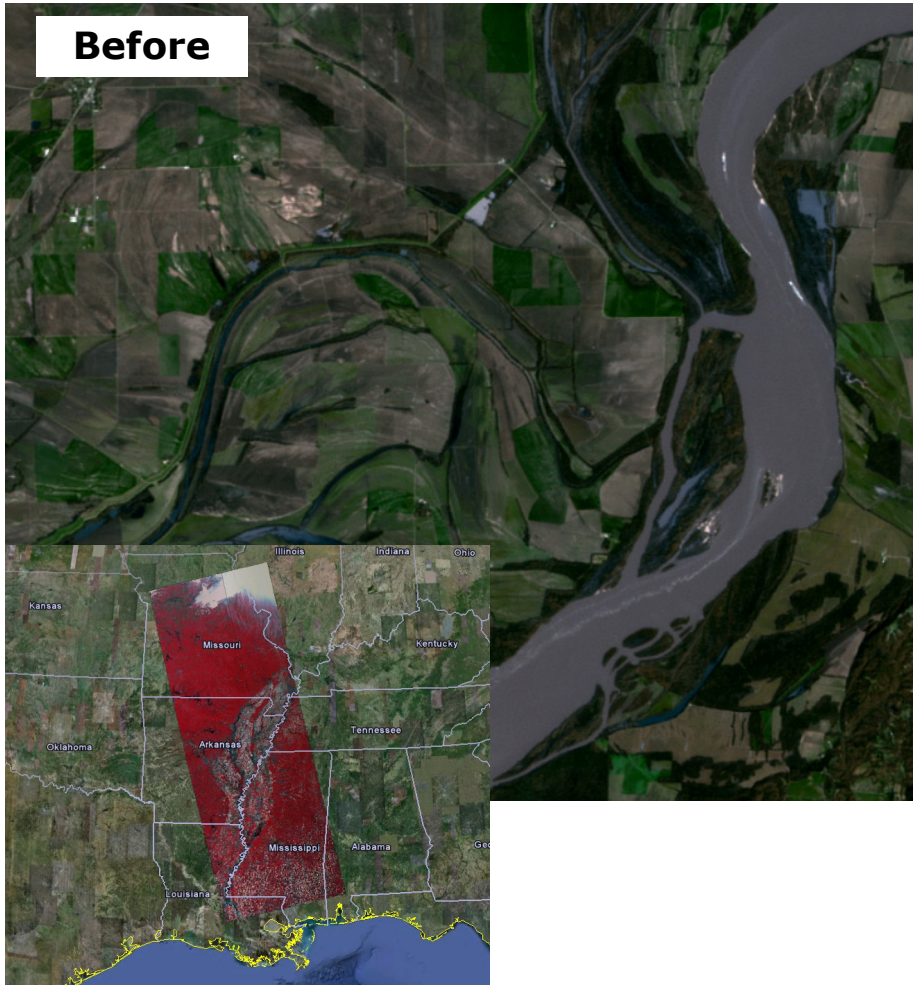


Synthetic Blue Band

- **Natural color mosaic of CONUS using DEIMOS-1 data from June 2011**

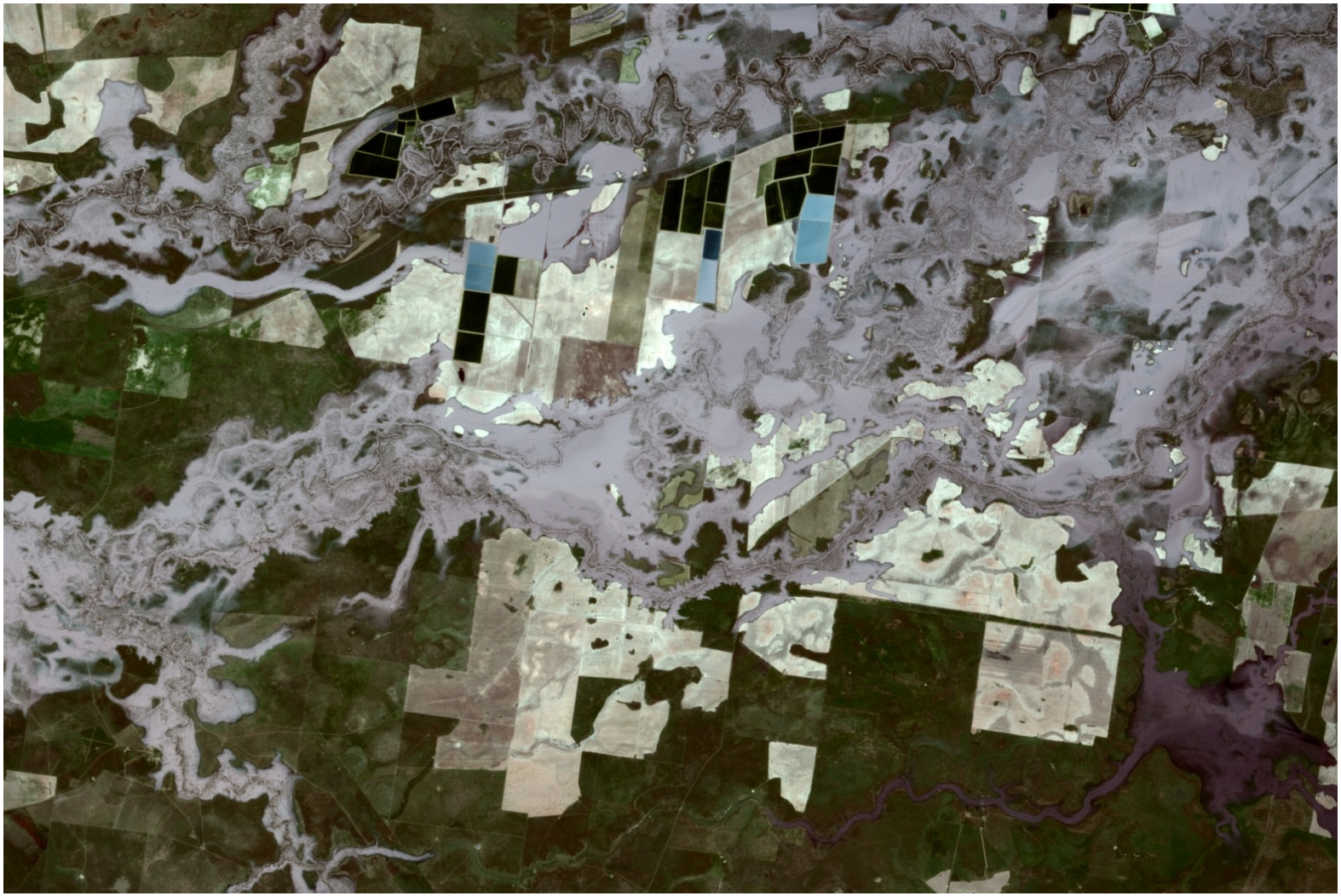
Support to Crisis Management

- **Mississippi floods** near Memphis (May 2011)



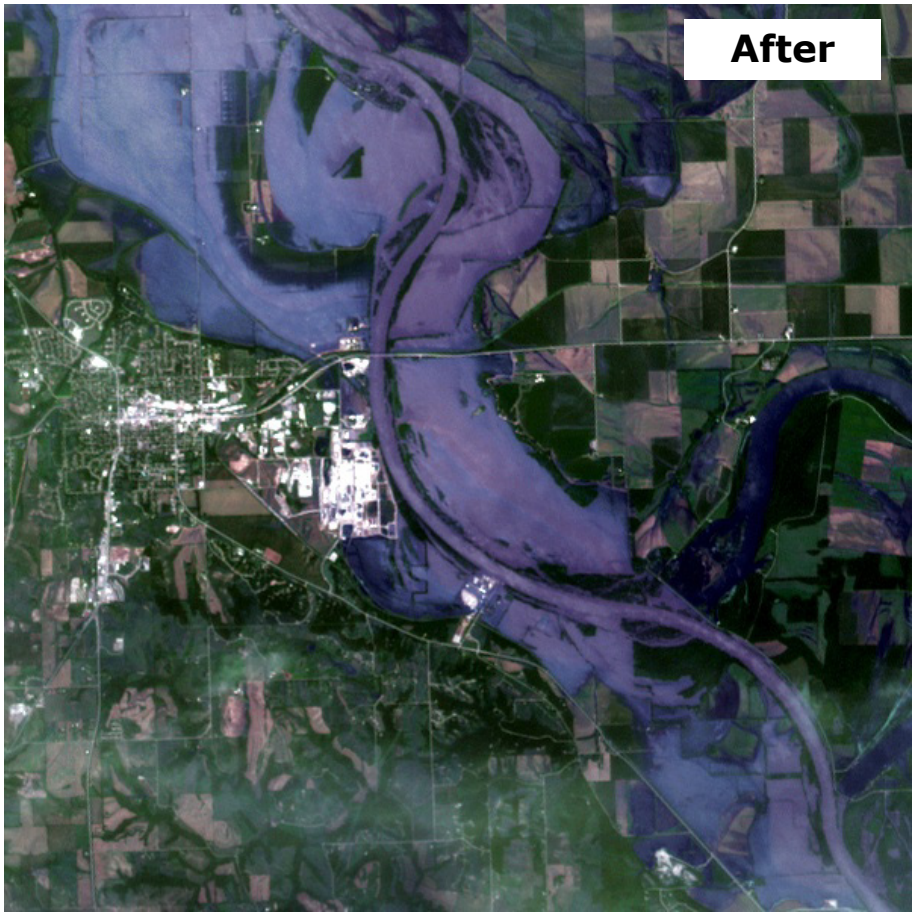
Support to Crisis Management

- **New South Wales floods** in Australia (February 2012)



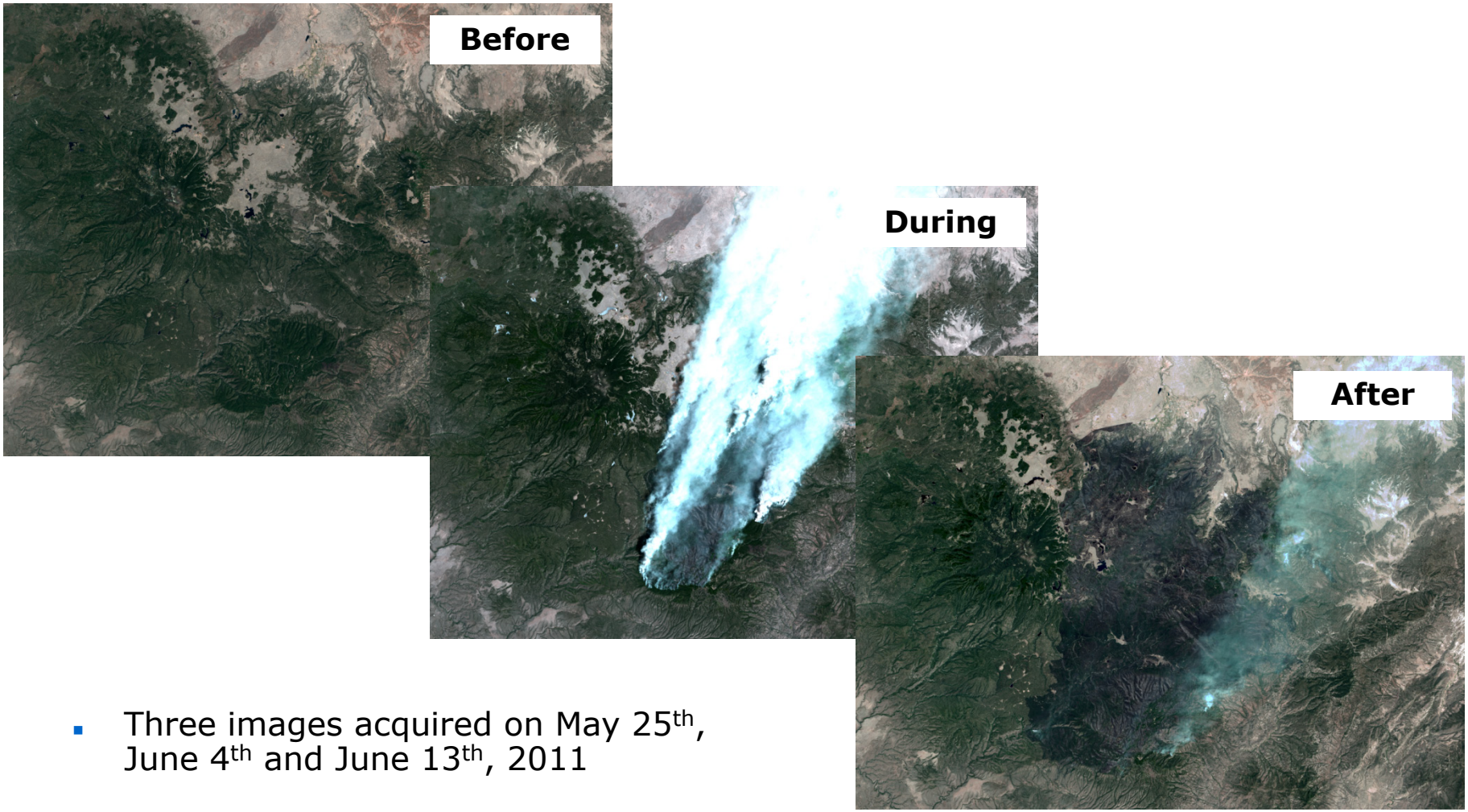
Support to Crisis Management

- **Missouri floods** near the Fort Calhoun nuclear plant, Nebraska (June 2011)



Support to Crisis Management

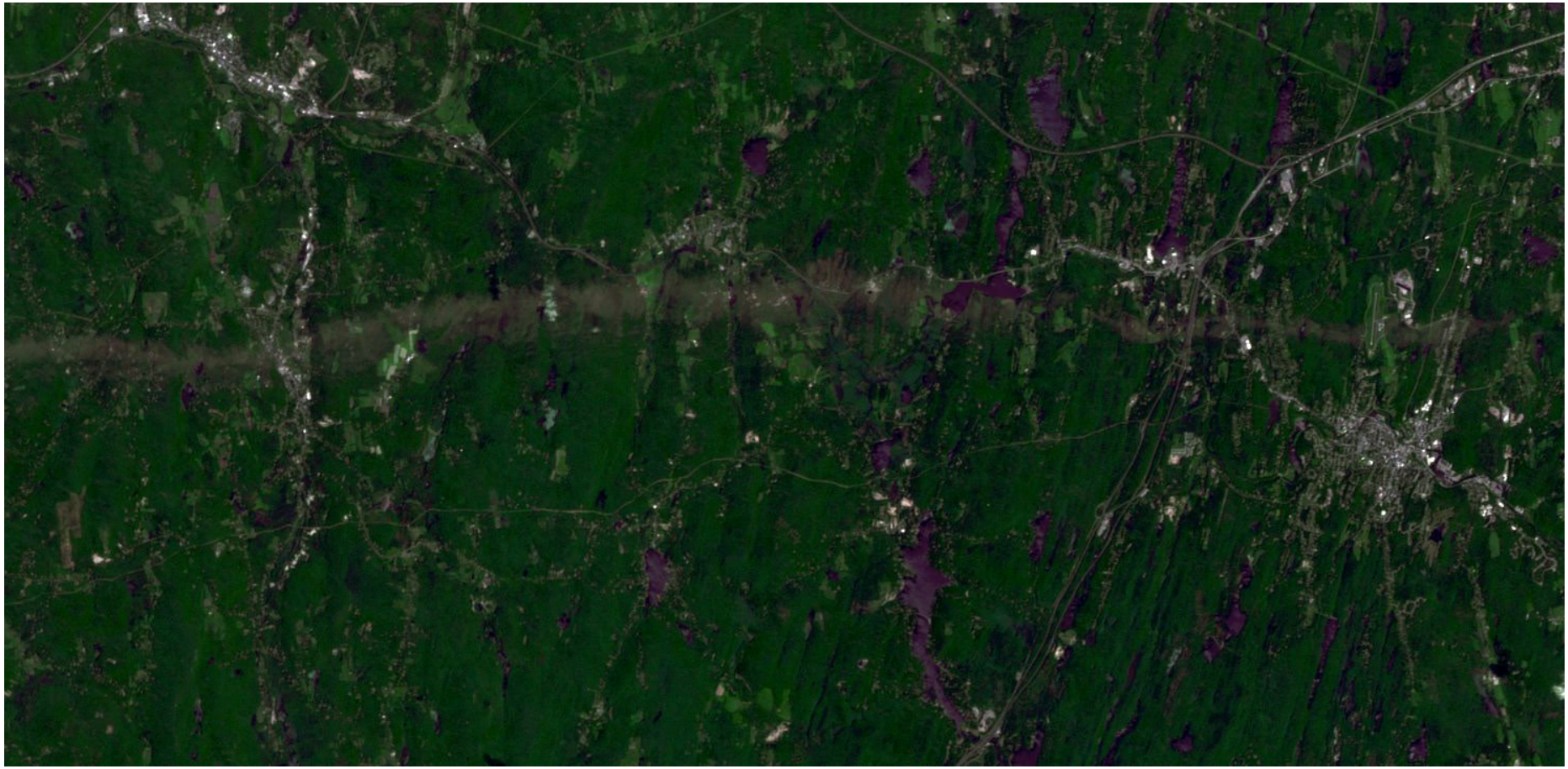
- Large **Arizona wildfires** (June 2011)



- Three images acquired on May 25th, June 4th and June 13th, 2011

Support to Crisis Management

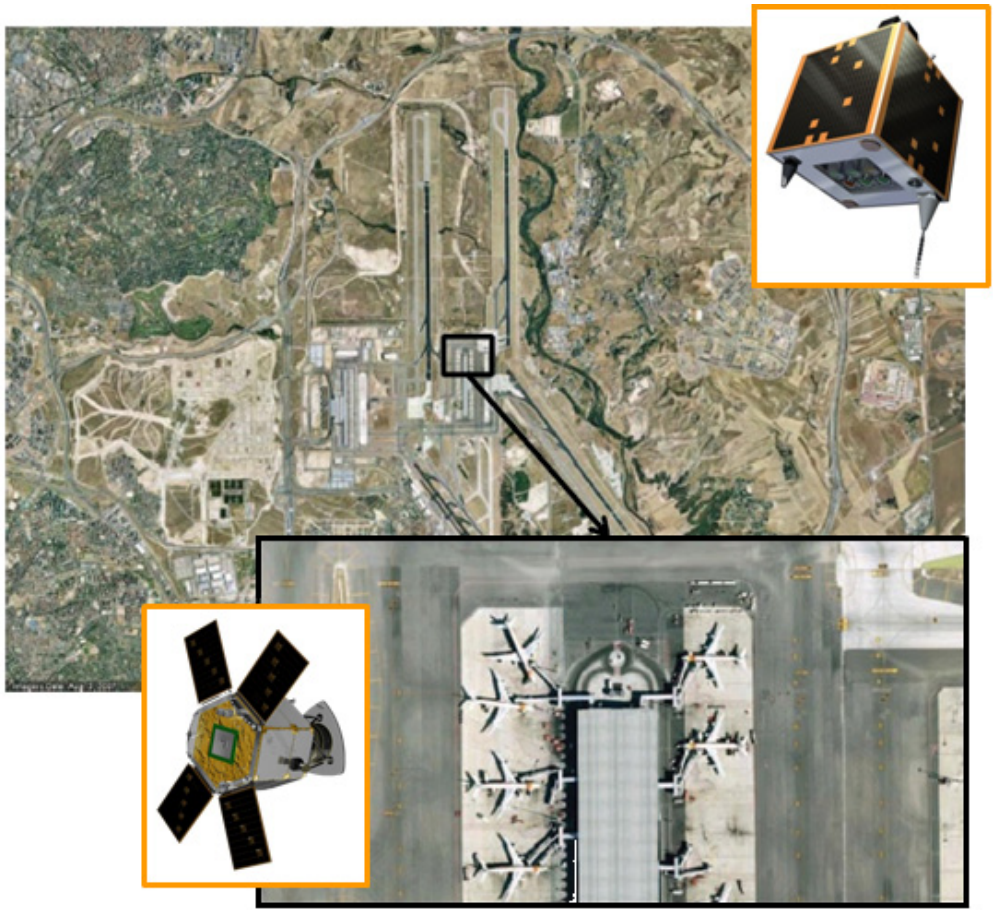
- **Tornado track** near Sturbridge, Massachusetts (May 2011)



3 DEIMOS EO System Evolution: DEIMOS-2

DEIMOS EO System Evolution

- ELECNOR DEIMOS' EO system will be upgraded in **Q4 2013** with the launch a **new satellite**, the **DEIMOS-2**
- **DEIMOS-2** will be a **multispectral optical** satellite with **very high resolution (1m Pan, 4m MS)**
- The DEIMOS-2 end-to-end system has been designed to provide a **cost-effective** and **highly responsive** service to cope with the increasing need of **fast access to very-high resolution imagery**
- Designed and built in cooperation with Satrec Initiative (South Korea), it will be integrated and tested in Spain, in new **ELECNOR DEIMOS SATELLITE SYSTEMS** premises currently under construction



Thank you!

Questions?

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