Deimos-2
Post-launch radiometric calibration

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Contents

- **The DEIMOS-2 Earth Observation System**
- **DEIMOS-2 pre-launch radiometric characterization and calibration**
- **DEIMOS-2 post-launch radiometric characterization and calibration**
- **Results summary**

1 The DEIMOS-2 Earth Observation System

DEIMOS-2 EO System

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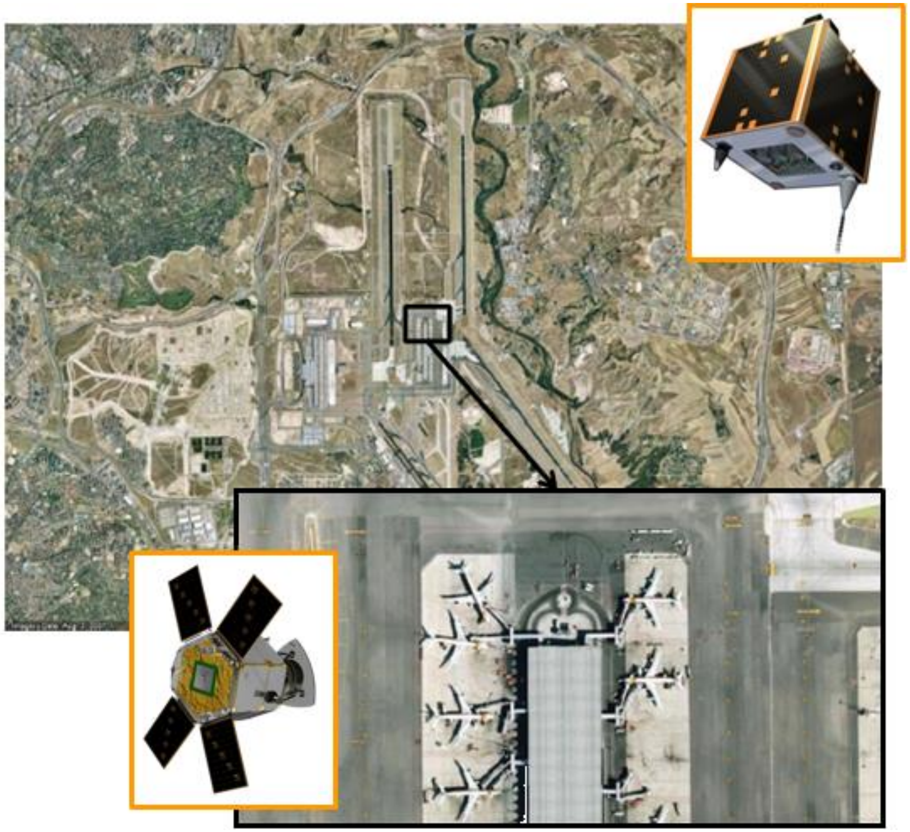
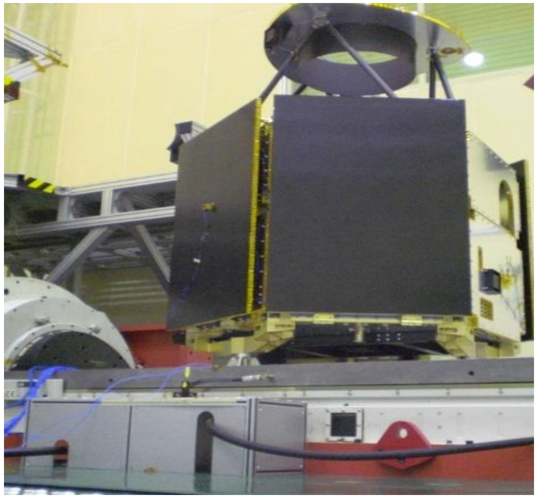
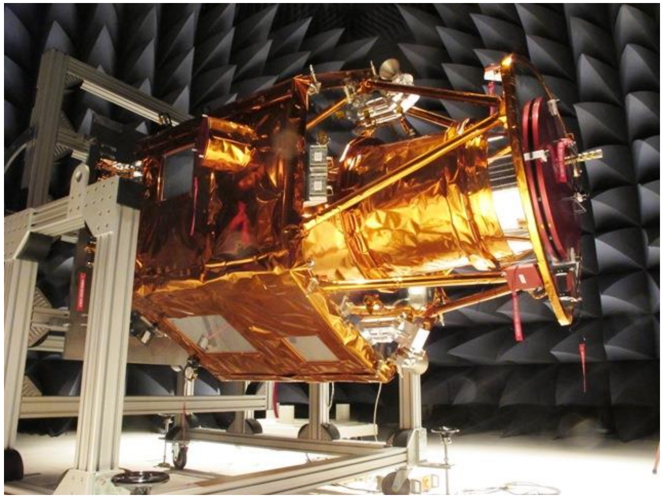
- **DEIMOS-1** (22m GSD, 3-band, 650 km swath), owned by ELECNOR DEIMOS, is the first Spanish Earth Observation satellite, launched in 2009
- ELECNOR DEIMOS' EO system has been upgraded in **2014** with the launch of a new satellite, the **DEIMOS-2**
- DEIMOS-2 is a **multispectral optical** satellite with **very high resolution**
- **Main product: pan-sharpened image, 0.75m @ Nadir**
- 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 by ELECNOR DEIMOS in cooperation with SATREC-i (South Korea). It has been integrated and tested in the new **ELECNOR DEIMOS Satellite Systems**' premises in Puertollano (Spain)

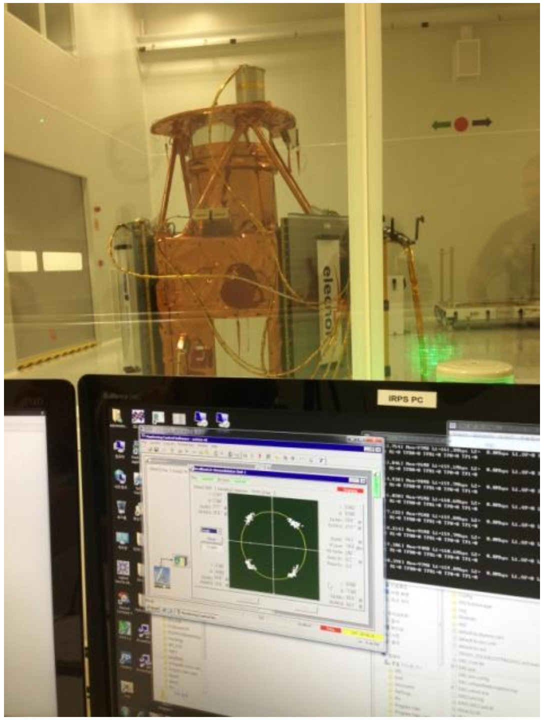


DEIMOS-2 EO System

- Built by ELECNOR DEIMOS in collaboration with SATREC-i (South Korea).
- Proven design with **significant heritage** (Dubaisat-1, Dubaisat-2)
- Nominal lifetime **>7 years**
- Mass: 310 Kg
- **Agile platform** (±45º across-track)
- High-performance AOCS for pointing accuracy & stability
- Xenon gas engines for orbit maintenance







DEIMOS-2 EO System

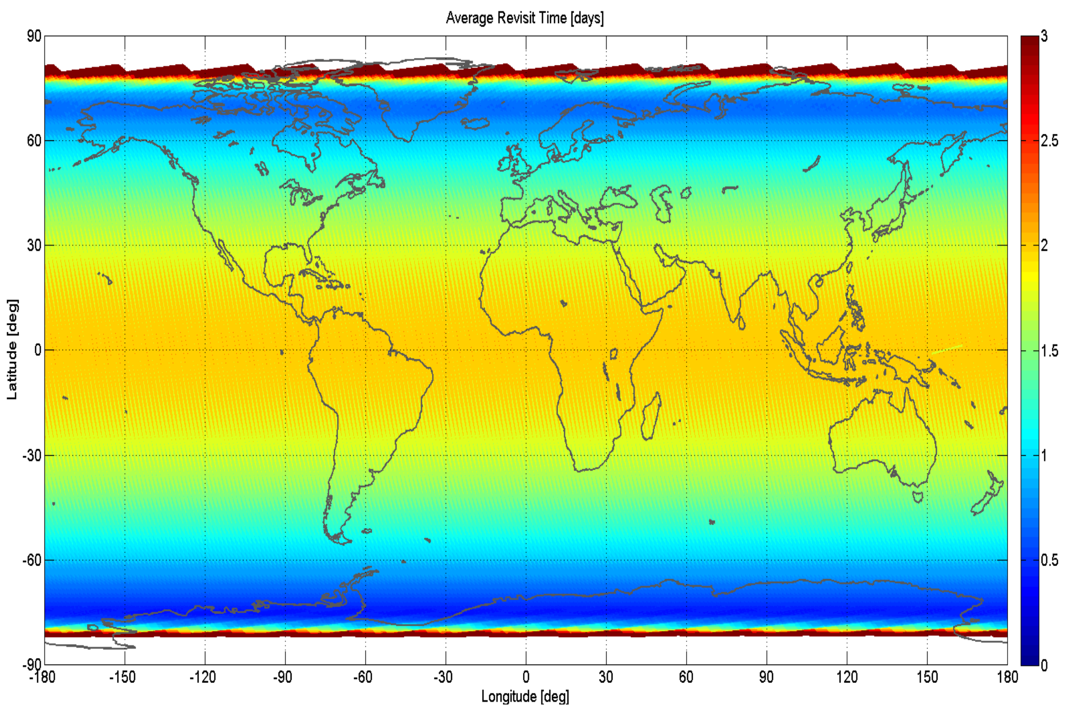
- **Orbit type**: Sun-synchronous, LTAN 10:30, ~620 km nominal altitude
- **Orbit determination**: via GPS, with metric accuracy
- **Orbit information** availability to users: with telemetry and on-ground POD

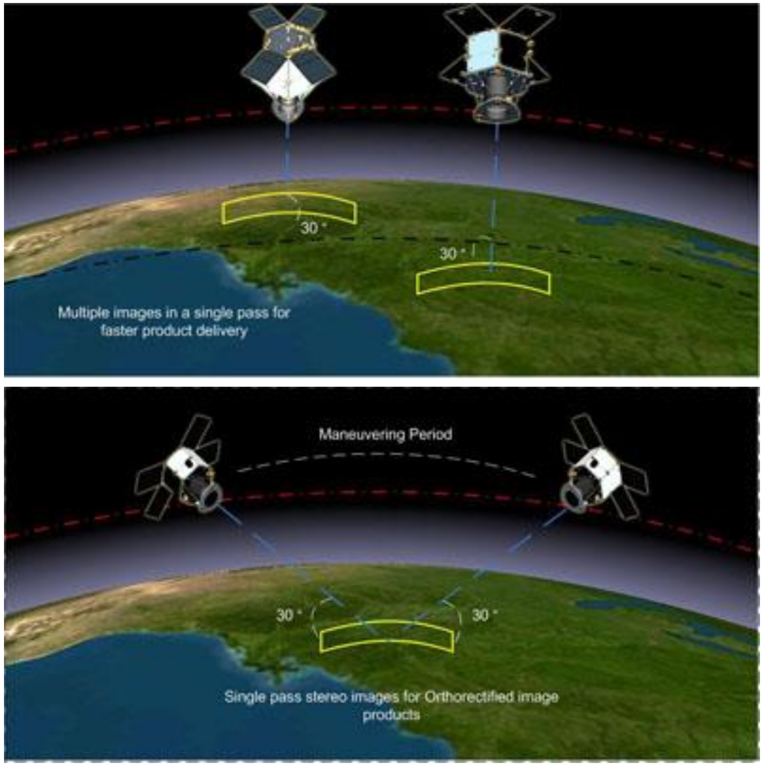
- **Viewing angle**: nominal ±30º, emergency ±45º
- **Geolocation accuracy**: ~100 m without GCPs

- **OBDH**:
- On-board recording (256 Gb, equivalent to 1,400km-long strip)
- Image data lossless compression, encryption, CCSDS encoding during transmission
- Solid state X band transmitter, with 160 Mbps download rate
- ±90°one-axis steerable X-band antenna

DEIMOS-2 EO System

- **System Capacity**: Up to 150,000 Km^2/day
- Global average revisit time: 2 days (±45º ACT)
- Average revisit time at 45º Lat: 1 day (±45º ACT)





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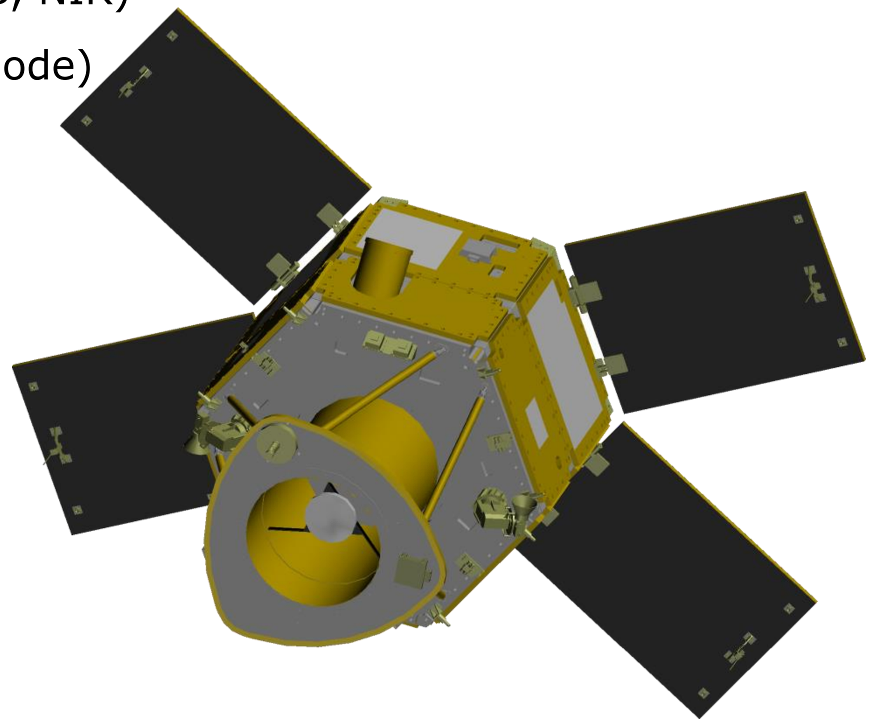
HiRAIS Payload

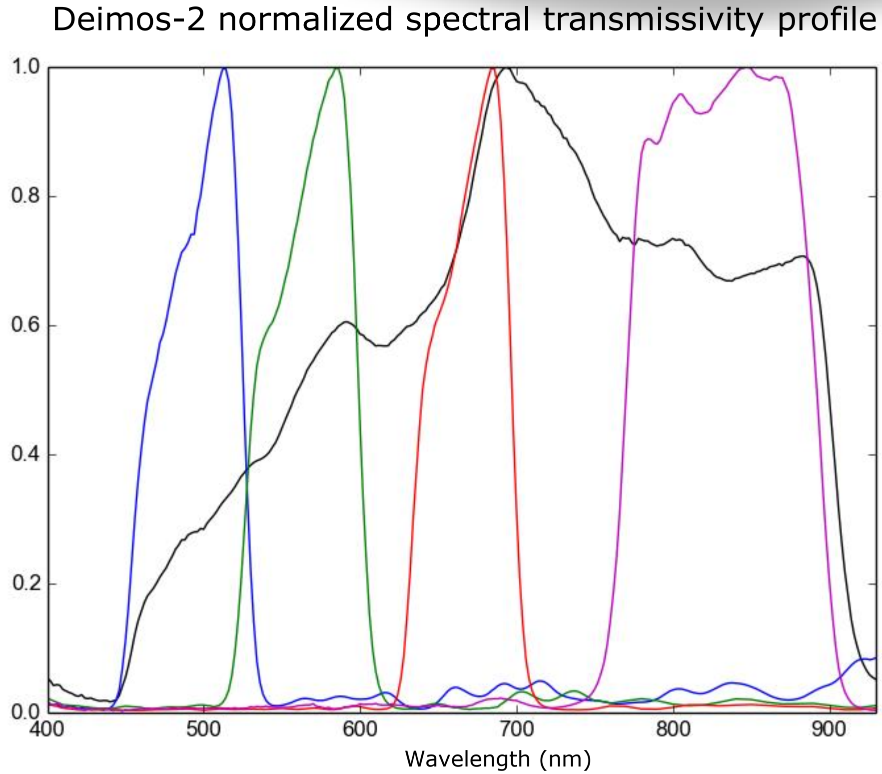
- Pan/Multispectral high-res camera
- 40 cm Korsch 4-mirror telescope (5.75 m focal length, 1.2º FoV)
- **GSD** @ Nadir: 1.0m Pan, 4.0m MS
- **Pan** (450-900 nm) **+ 4 bands** (R,G,B, NIR)
- **12 km swath** (24 km in wide area mode)
- Capacity for stereo-pair acquisitions
- Radiometric resolution 10 bits
- TDI sensor steps:
  - PAN : 6, 12, 24, 48
  - Blue, Green : 4, 8, 16
  - Red, NIR : 2, 4, 8

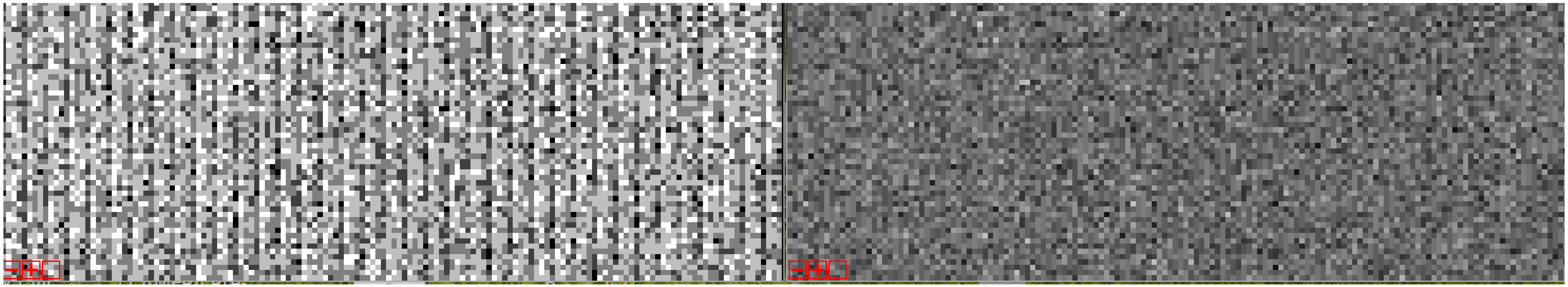


2 Deimos-2 pre-launch radiometric characterization and calibration

Deimos-2 pre-launch radiometric characterization

- Spectral transmissivity profiles
- Dark Signal
- Pixel response non uniformity
- Signal-to-noise ratio
- Pixel saturation levels
- MTF
- Radiometric model development





PRNU correction. PAN band

3 Deimos-2 post-launch radiometric characterization and calibration

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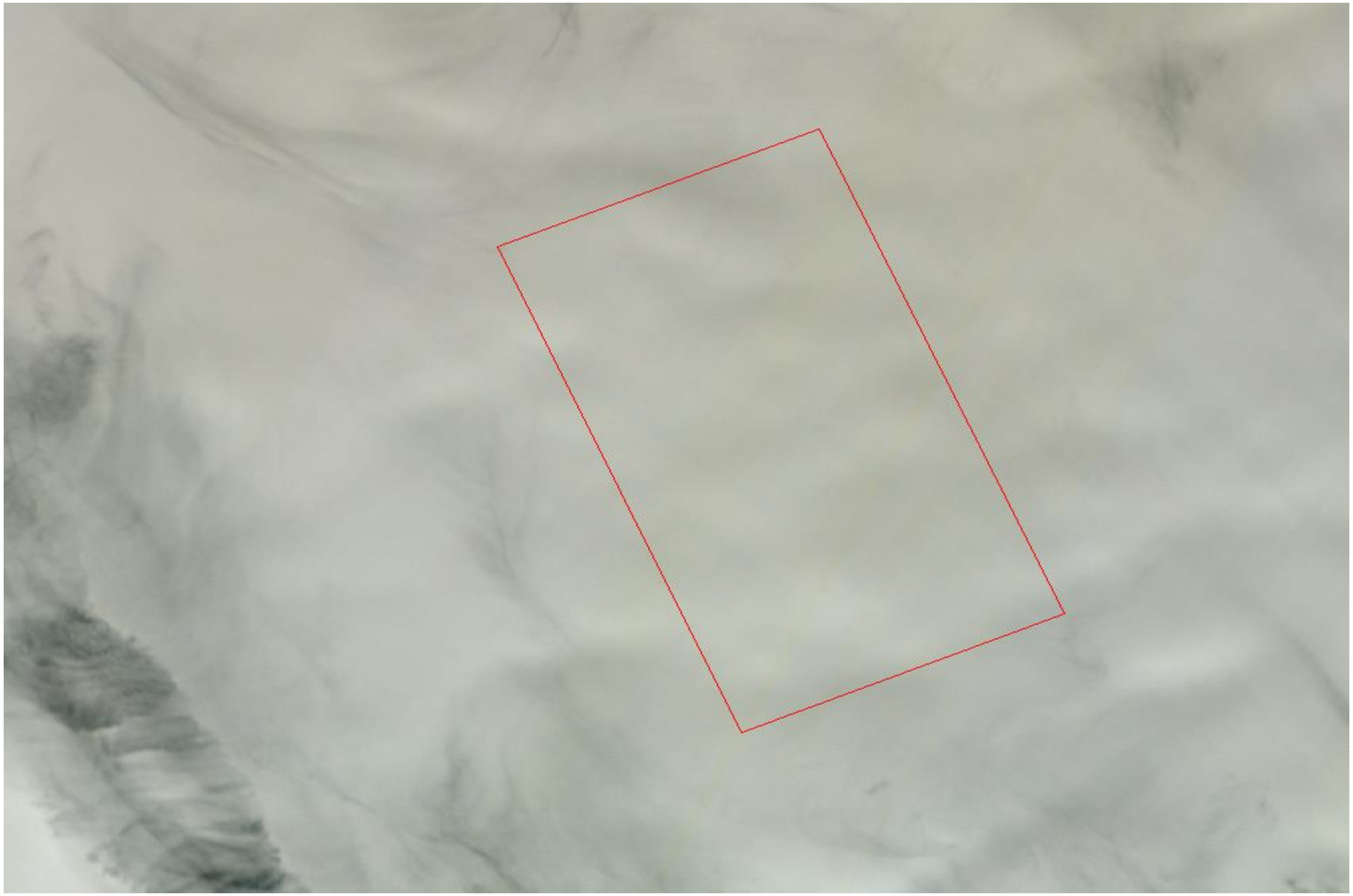
Sensor Characterization

- DSNU
  - Using acquisitions during eclipse over the North Pacific, where light sources (natural or anthropogenic) are unlikely
- PRNU
  - Greenland (Launched on June the 19th 2014. Dome-C unavailable at that time)
  - Dome-C (Antarctica)
- MTF
  - Stennis Space Flight Centre (USA)
  - Salon de Provence (France)
  - Baotou (China)

Greenland I

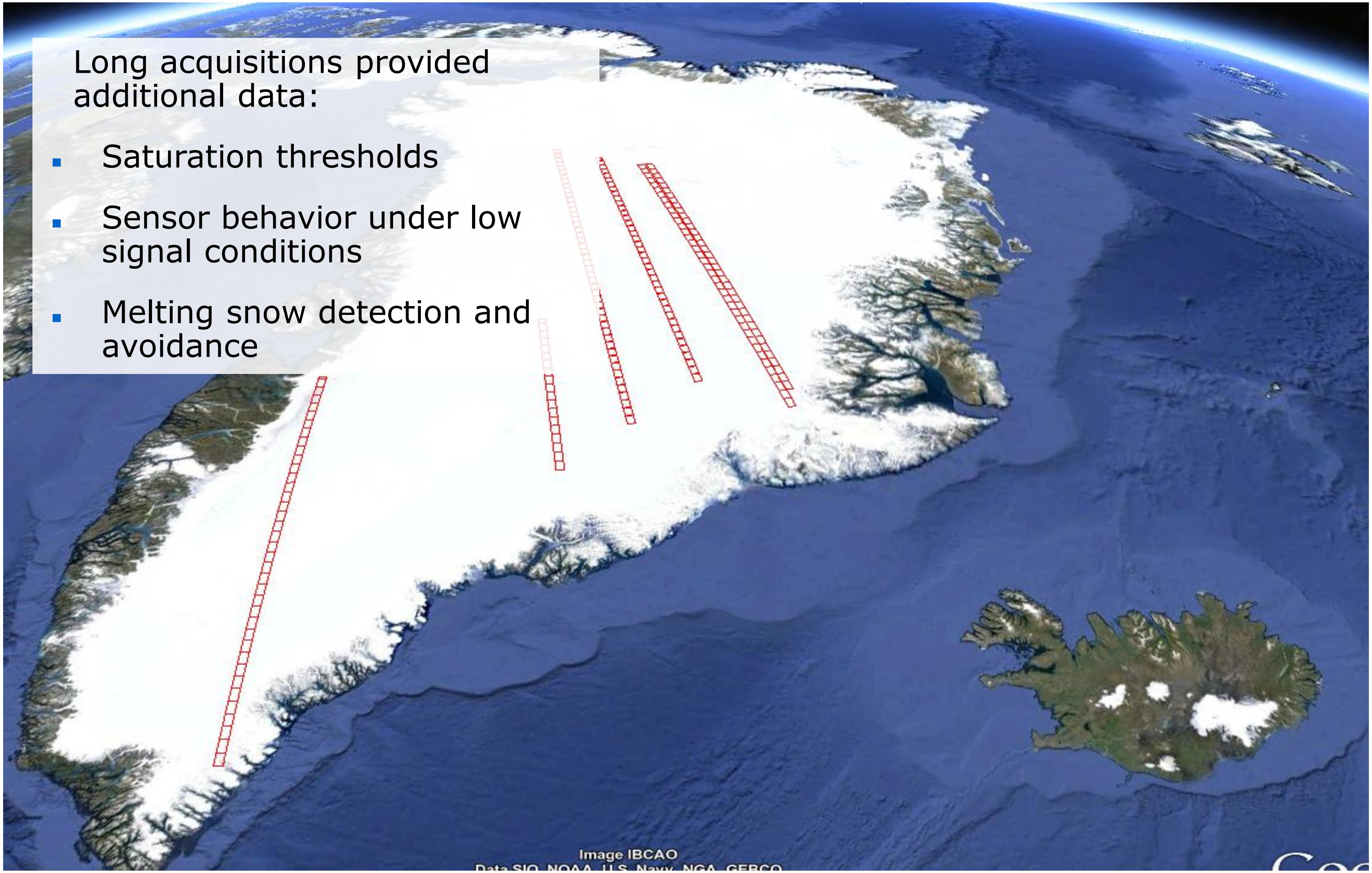
Using Landsat-8 OLI's recent data to find suitable target candidates in Greenland



Greenland II

Long acquisitions provided additional data:

- Saturation thresholds
- Sensor behavior under low signal conditions
- Melting snow detection and avoidance



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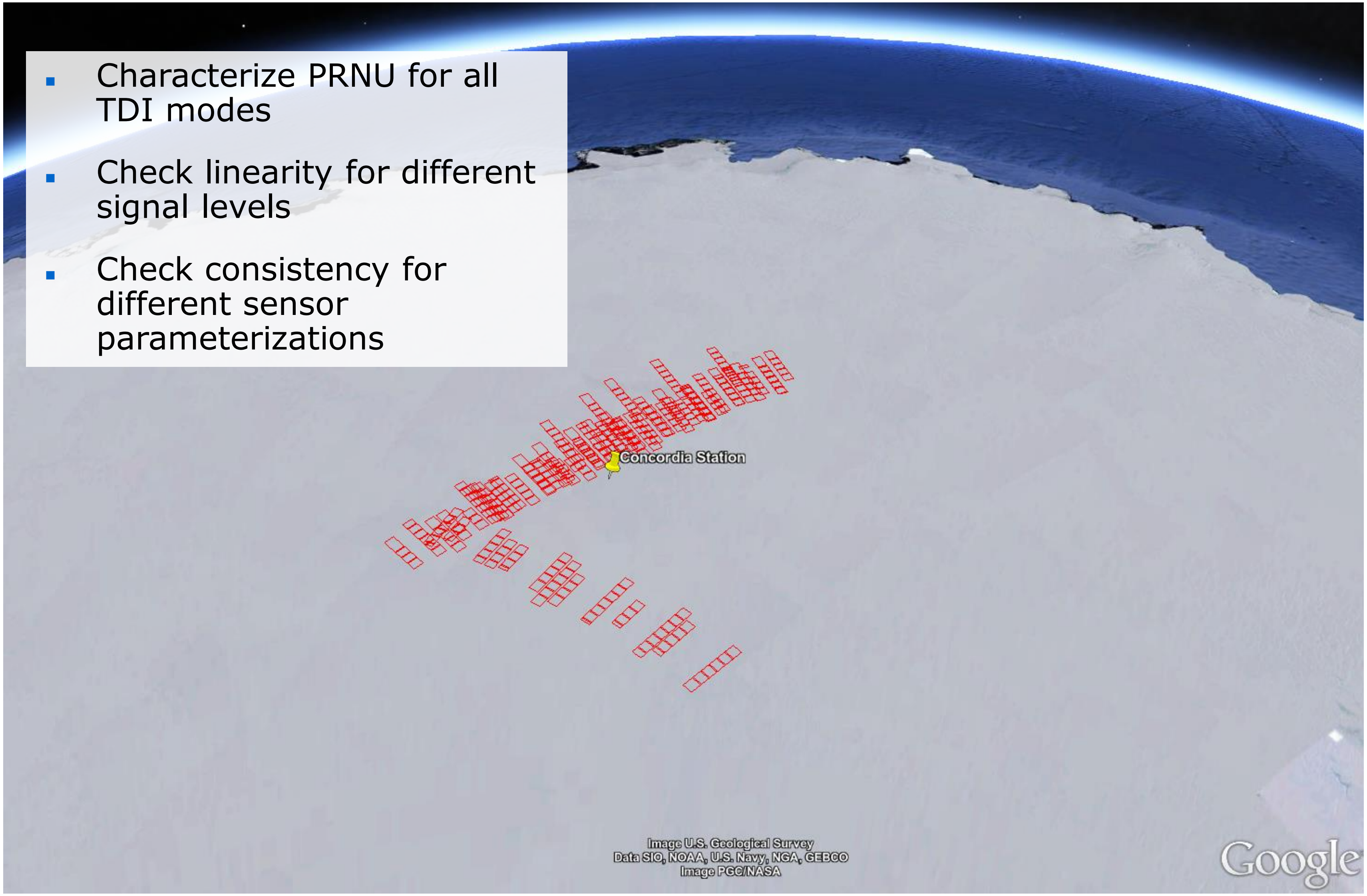
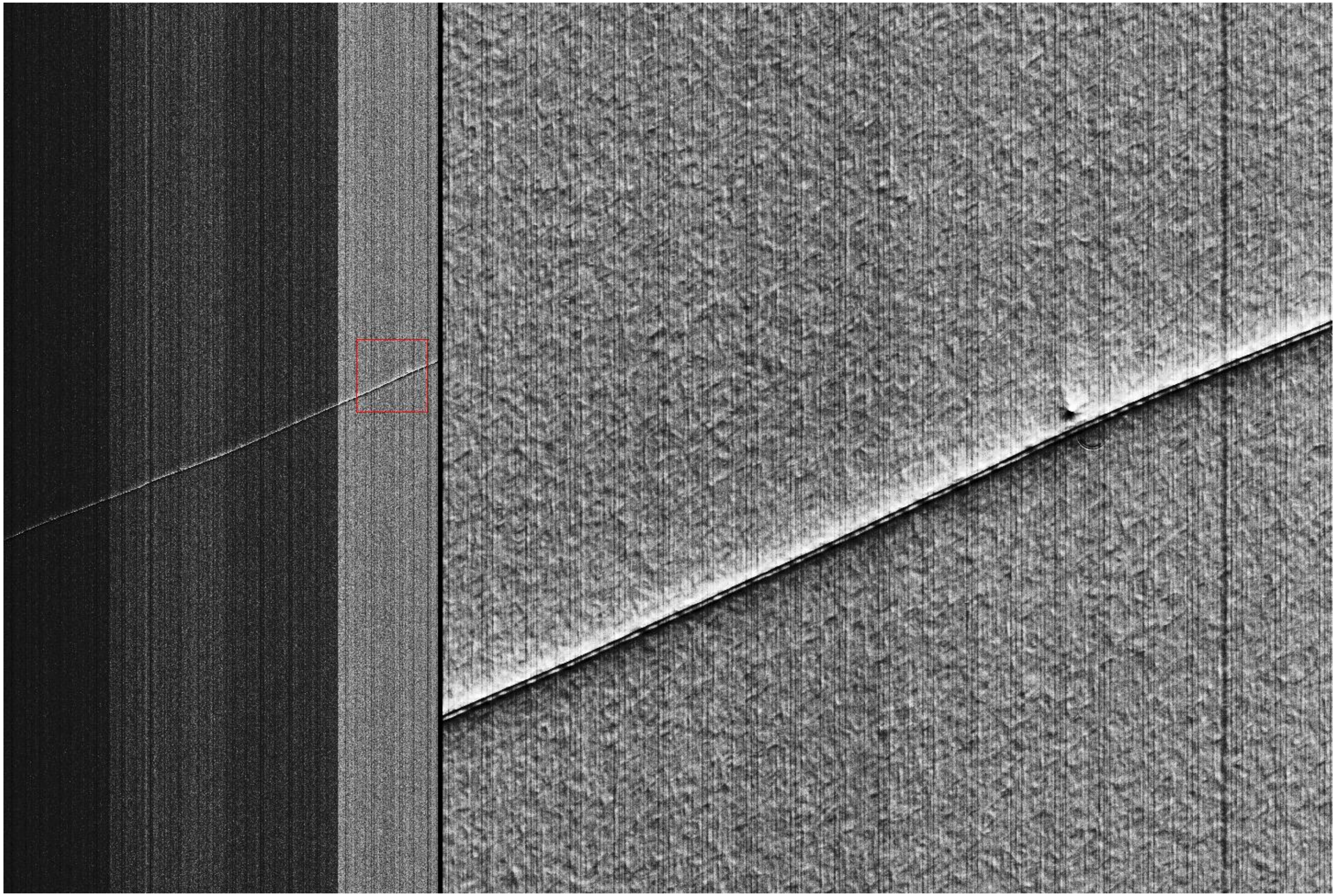
Dome-C I

- Characterize PRNU for all TDI modes
- Check linearity for different signal levels
- Check consistency for different sensor parameterizations



Dome-C II

Sample before radiometric correction



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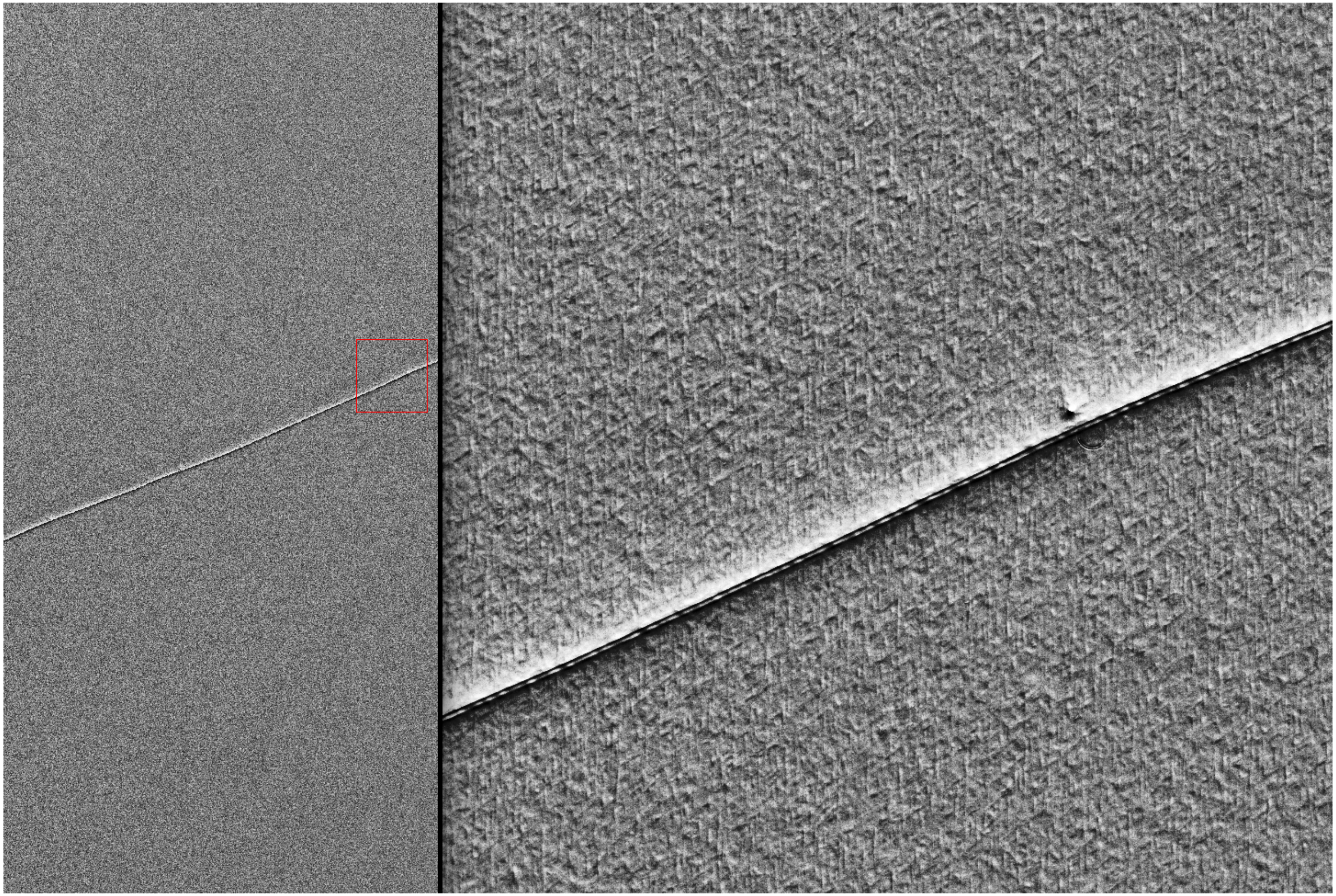
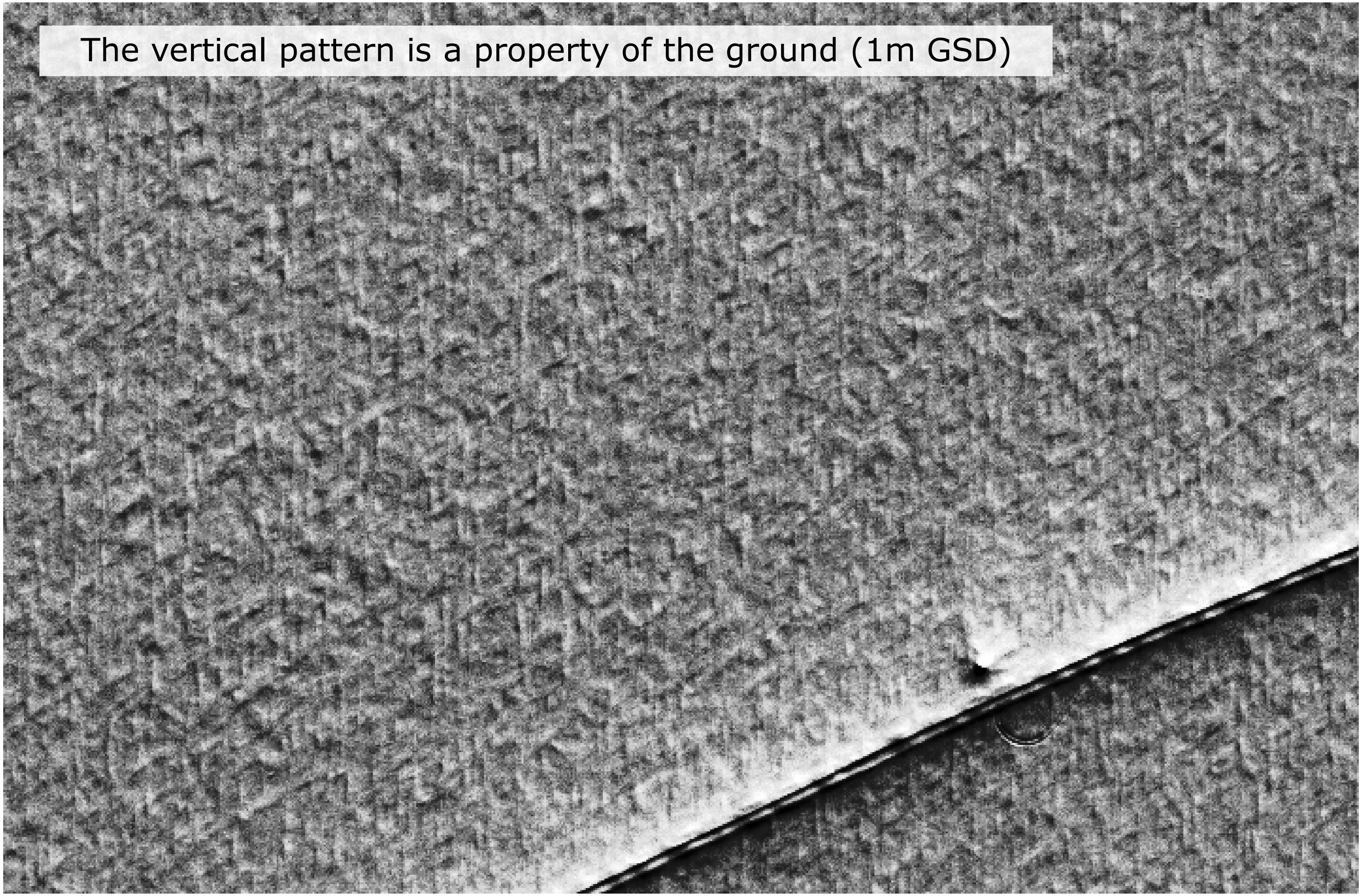
Dome-C III

Sample after radiometric correction



Dome-C IV



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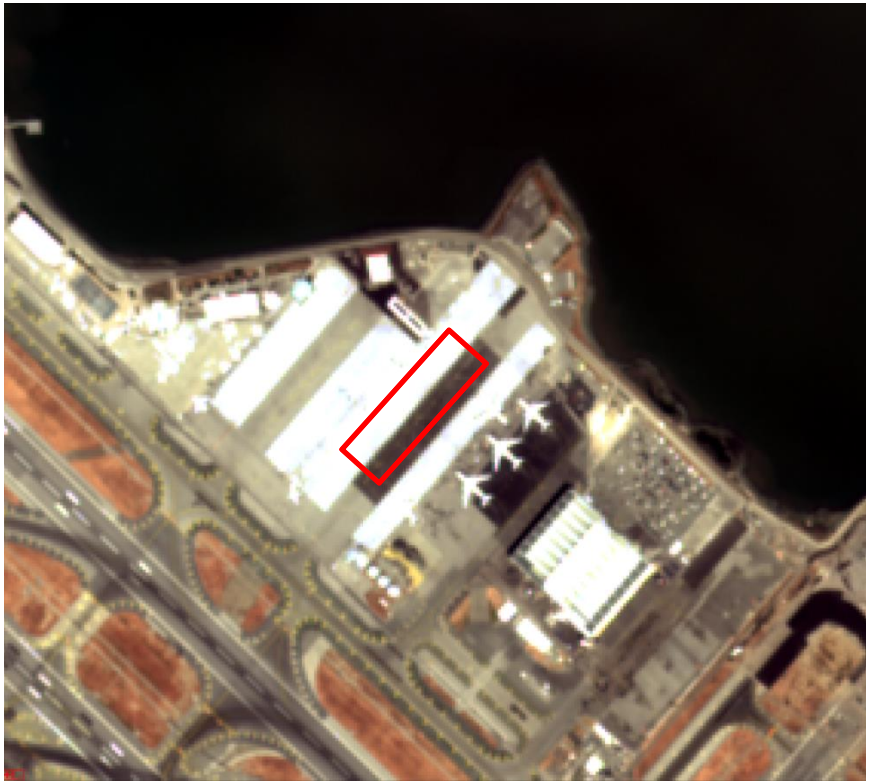
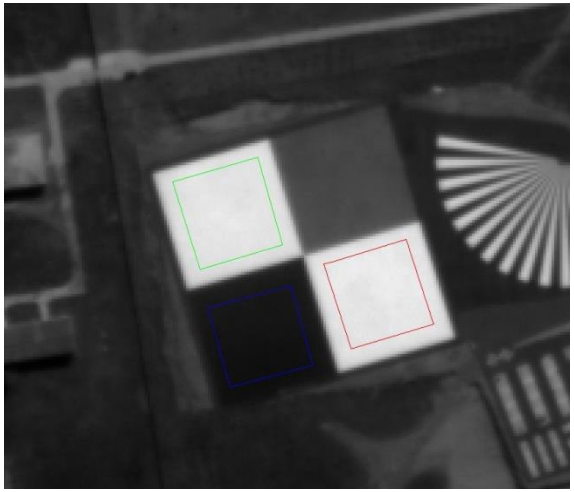
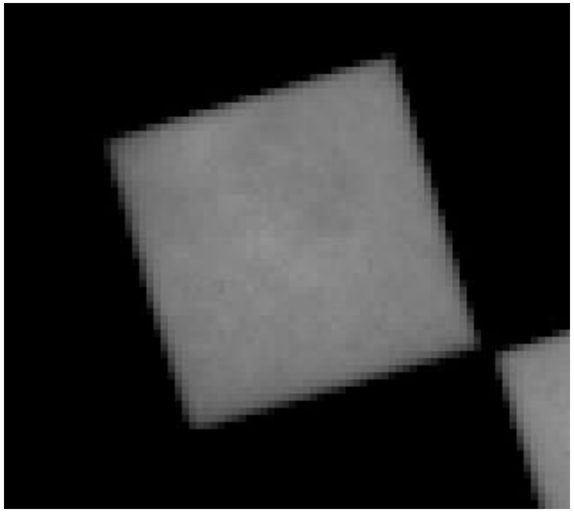
MTF & SNR measurements

- Stennis Space Center (USA), Salon de Provence (France) and Baotou (China) targets were acquired for the panchromatic band
- Baotou was chosen as the best target
- Artificial structures were used for the MS bands







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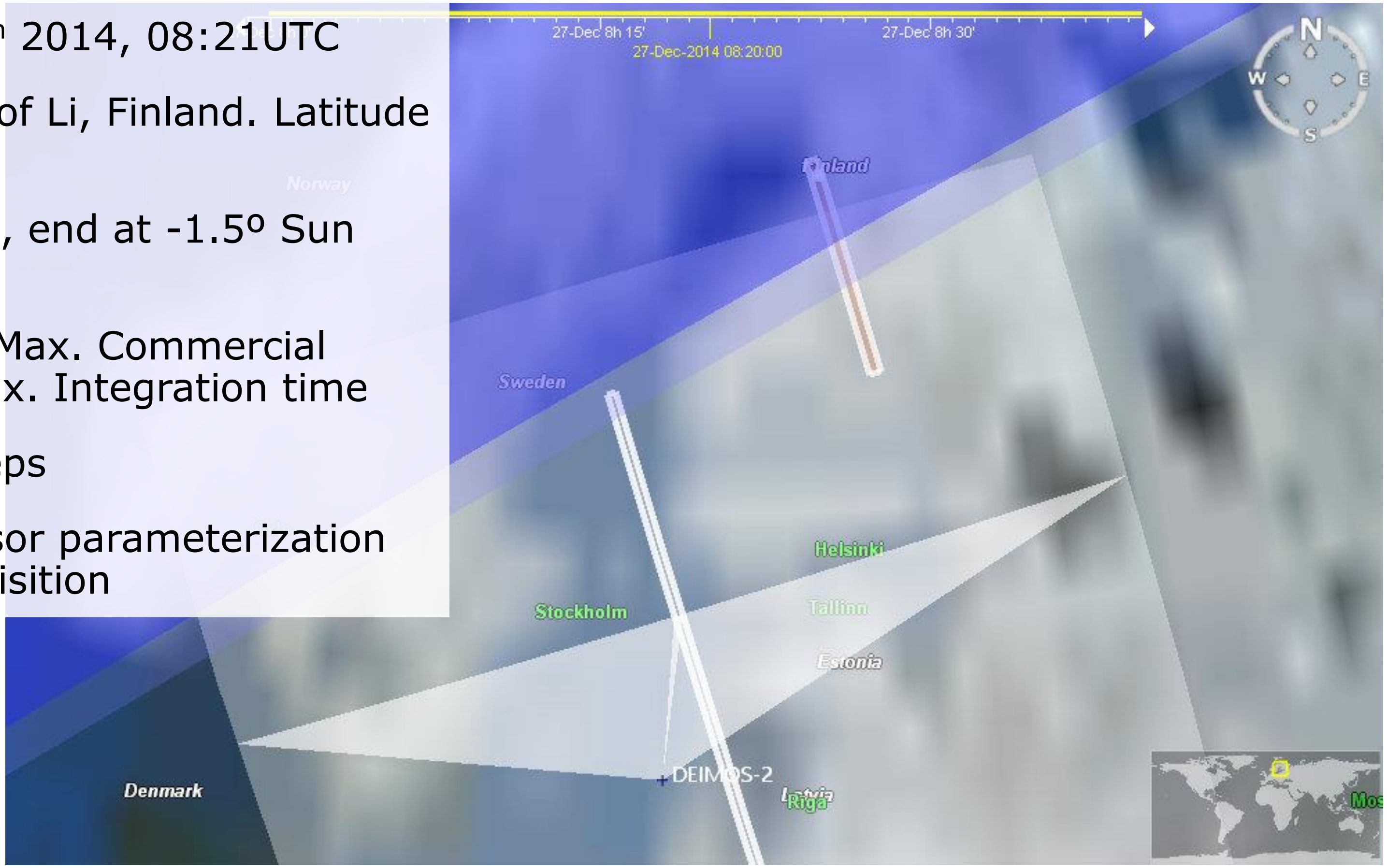
Looking for the limits: Twilight I

Is it possible to acquire a usable image during the civil twilight?

Acquisition setup:

- Dec. the 27th 2014, 08:21UTC
- Target: City of Li, Finland. Latitude 65.34º
- Start at 1.5º, end at -1.5º Sun elevation
- Roll at 30º (Max. Commercial limit) => Max. Integration time
- Max. TDI steps
- Specific sensor parameterization for this acquisition



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Looking for the limits: Twilight II

- Li city. Panchromatic band
- Acquired at -1.5º Sun elevation
- GSD 1.34m
- Noisy, but ground features clearly visible
- Worst SNR in the panchromatic band (18:1)

Absolute calibration I

Deimos-2

- No onboard calibration devices
- No reference sensor

We have to rely either on hyperspectral data over PICS targets and vicarious calibration

- EO1/Hyperion chosen as reference
- Libya-4 is the primary PICS
- Tuz Golu, Danhuang, Dolan Springs, Frenchman Flat, Ivanpah Playa, Railroad Valley, La Crau, Negev among others CEOS and non-CEOS sites have been used to assess the calibration methodology
- A vicarious campaign would be most solid way to validate the calibration methodology. Foreseen for 2015.

Absolute calibration II

EO1/Hyperion

- Hyperspectral sensor: 220 bands (from 400 to 2.500 nm)
- Spatial resolution: 30m
- Swath: 7.5 km
- Capable of pointing over one adjacent WRS
- Operator: NASA / GSFC
- Launch date: 21 November 2000
- Design lifetime: 1 year

Credit: NASA

Credit: NASA

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Absolute calibration III

Methodology

- As simple as possible
- Cross-calibrate Deimos-2 vs. EO1/Hyperion, **TOA radiance vs. TOA radiance**
- Build a spectral model of **Libya-4** using a long series of EO1/Hyperion data
  - Remove Lambert's law, Earth-Sun distance effects and seasonal trend
  - **NO atmospheric correction**. Would the atmospheric correction using a standard i.e. constant atmosphere model improve the measurements?
  - The atmosphere influence is considered an accidental error (i.e. noise), and being so, it is diminished through repeated measurements. The validity of this assumption can be reviewed after the model is built
- Perform acquisitions with Deimos-2
  - Remove Lambert's law, Earth-Sun distance effects and seasonal trend
  - Calibrate against the model

The seasonal trend removal was based on the work of Nischal Mishra, Dennis Helder, Amit Angal, Jason Choi and Xiaoxiong Xiong. Absolute Calibration of Optical Satellite Sensors Using Libya 4 Pseudo Invariant Calibration Site. Remote Sensing. 12 February 2014.

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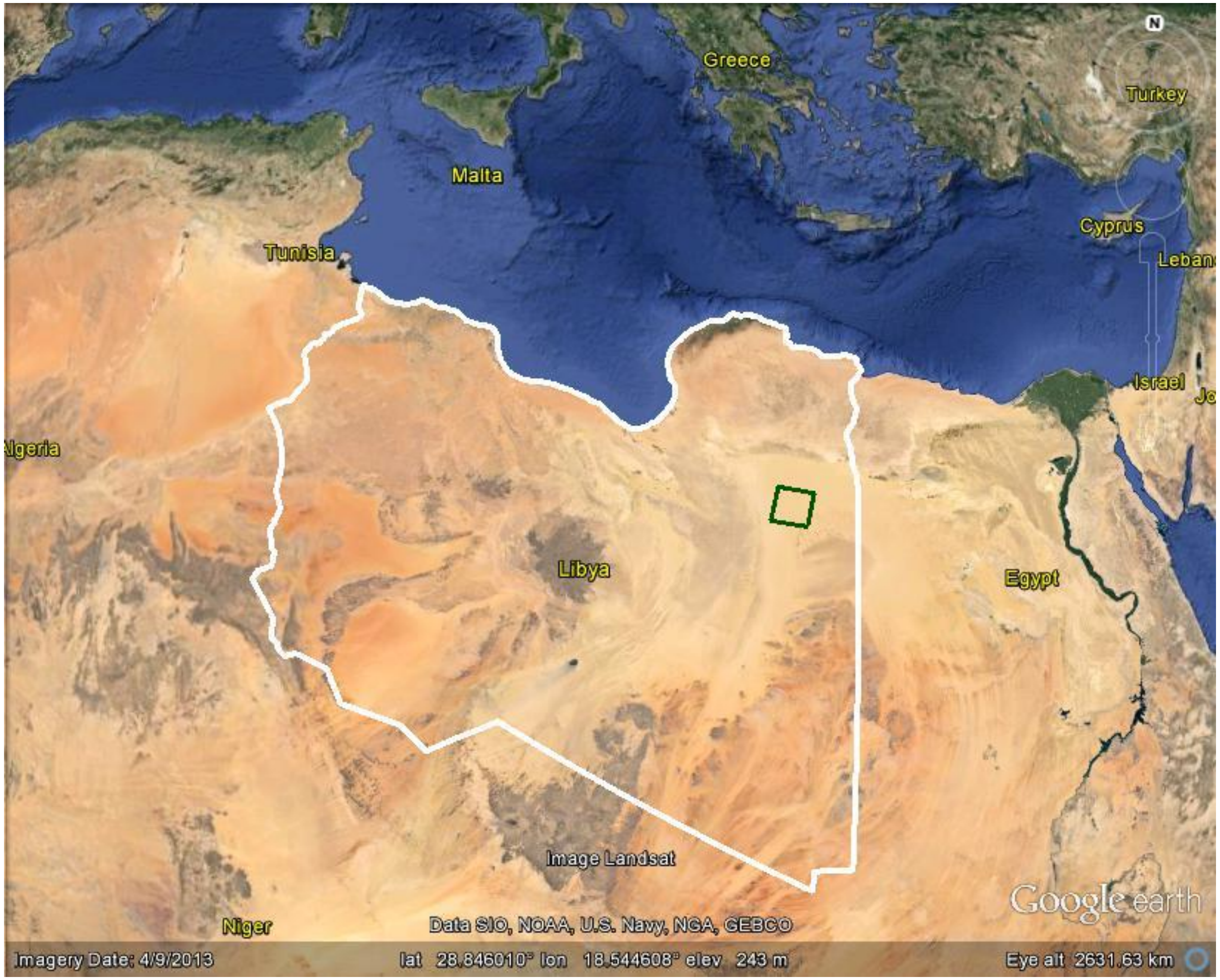
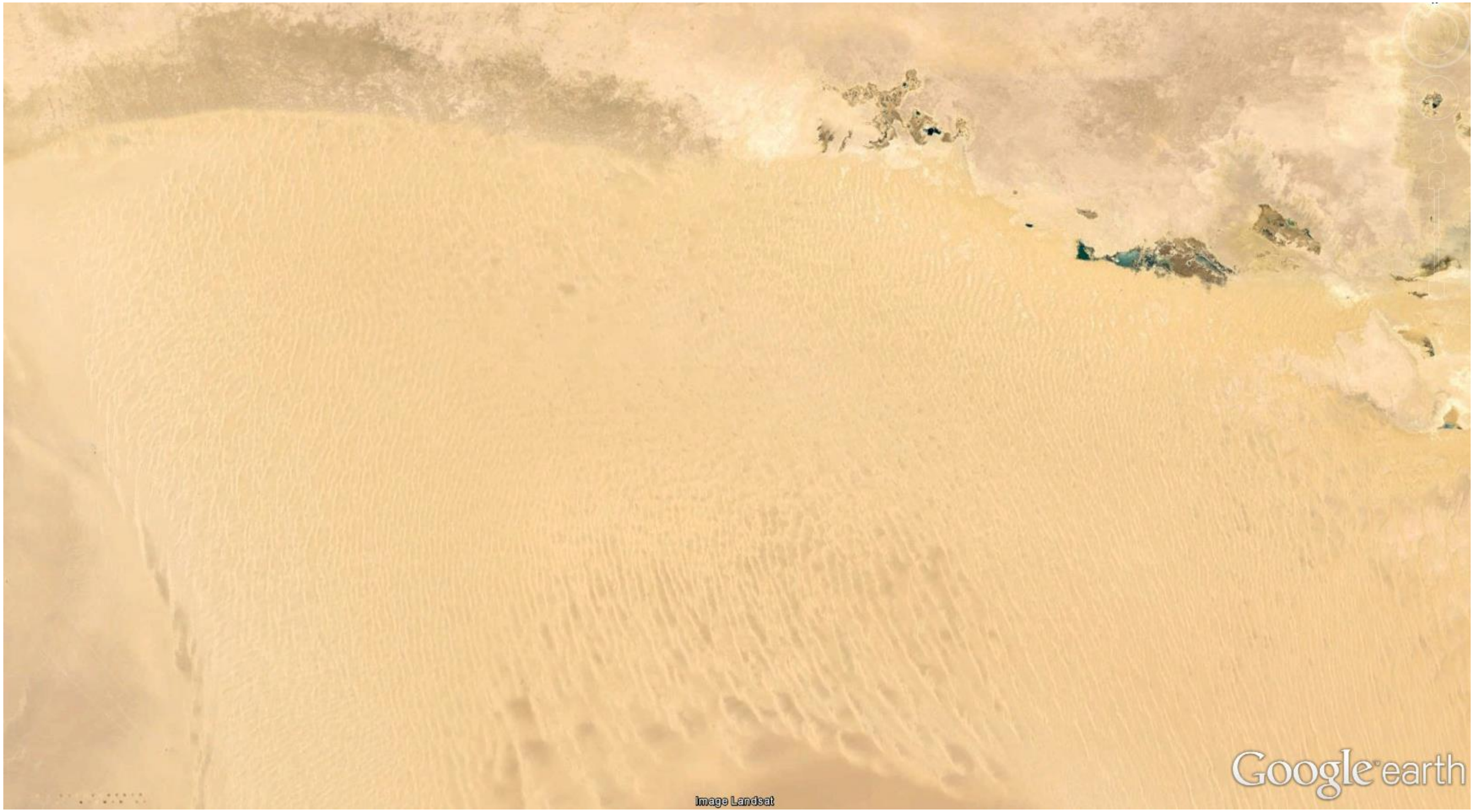
Absolute calibration IV

Where is Libya-4?



Absolute calibration IV

Where is Libya-4?



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Absolute calibration IV

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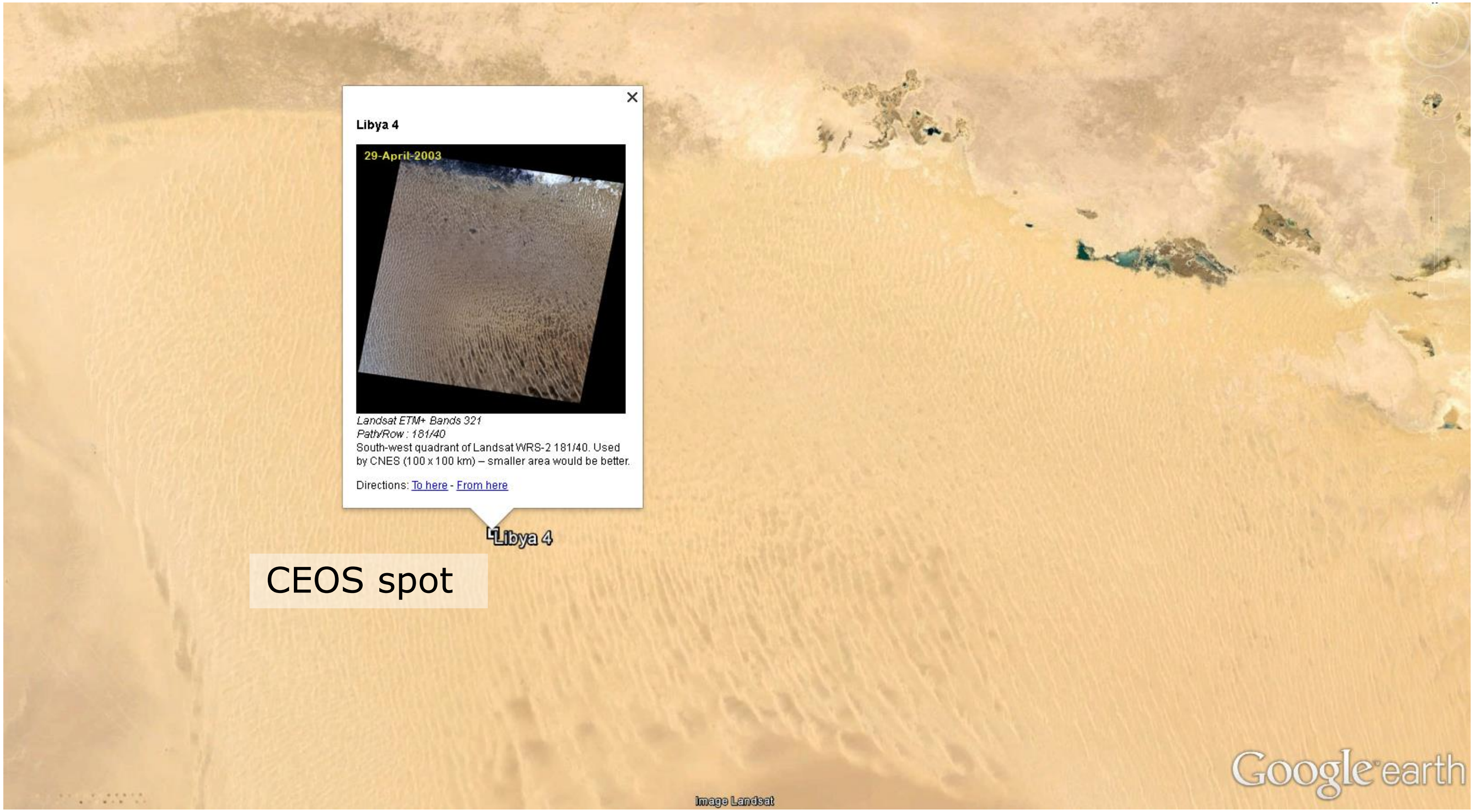

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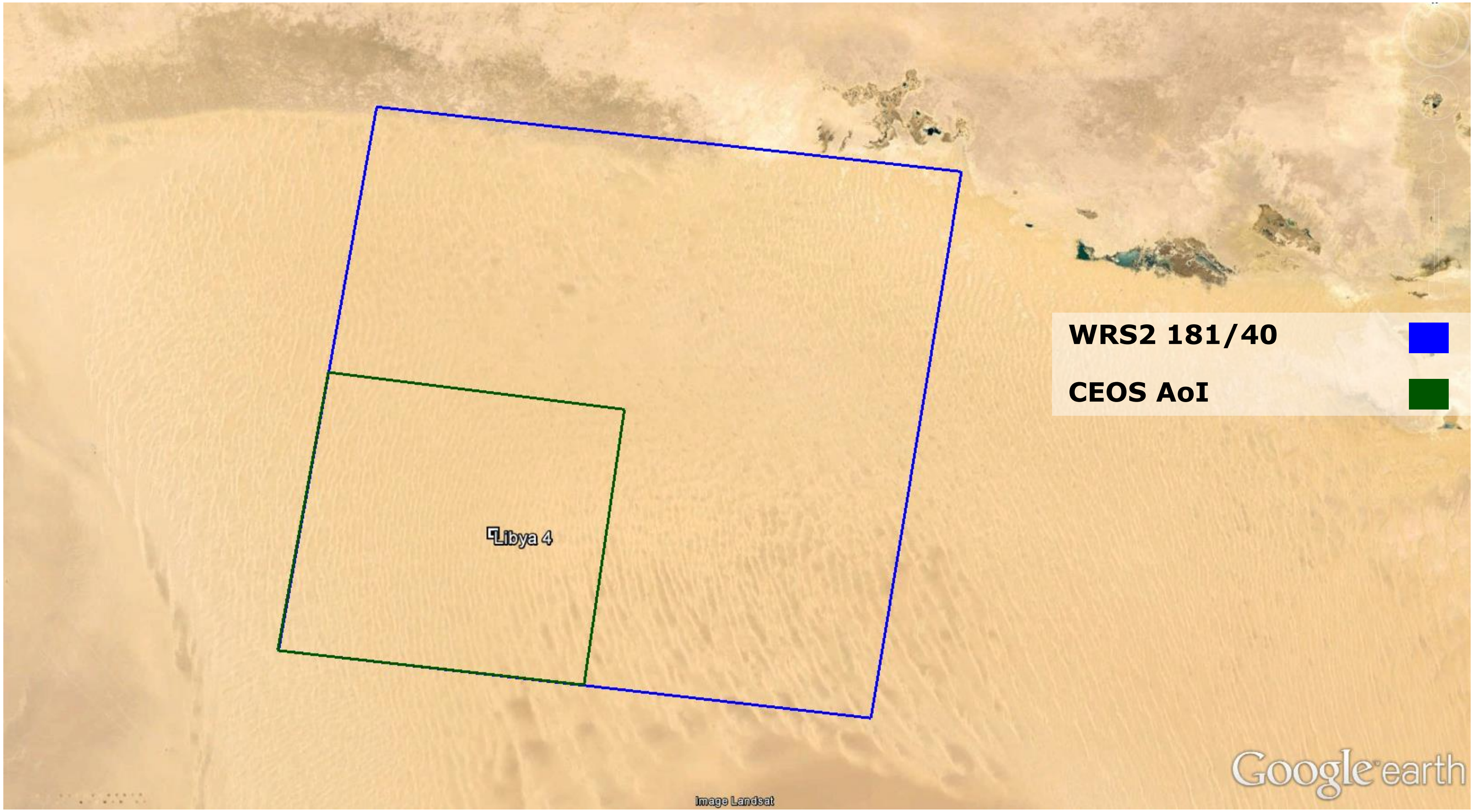

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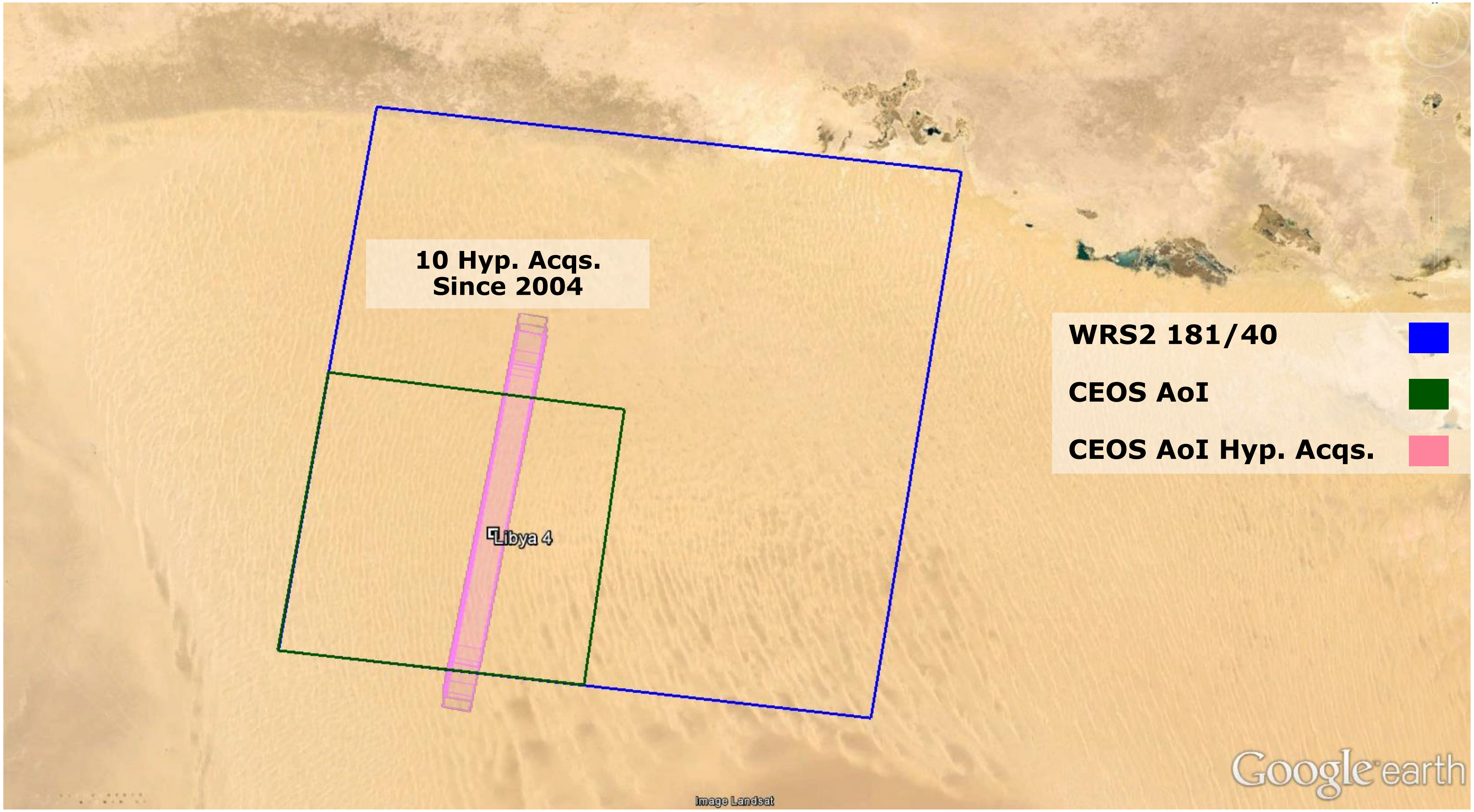

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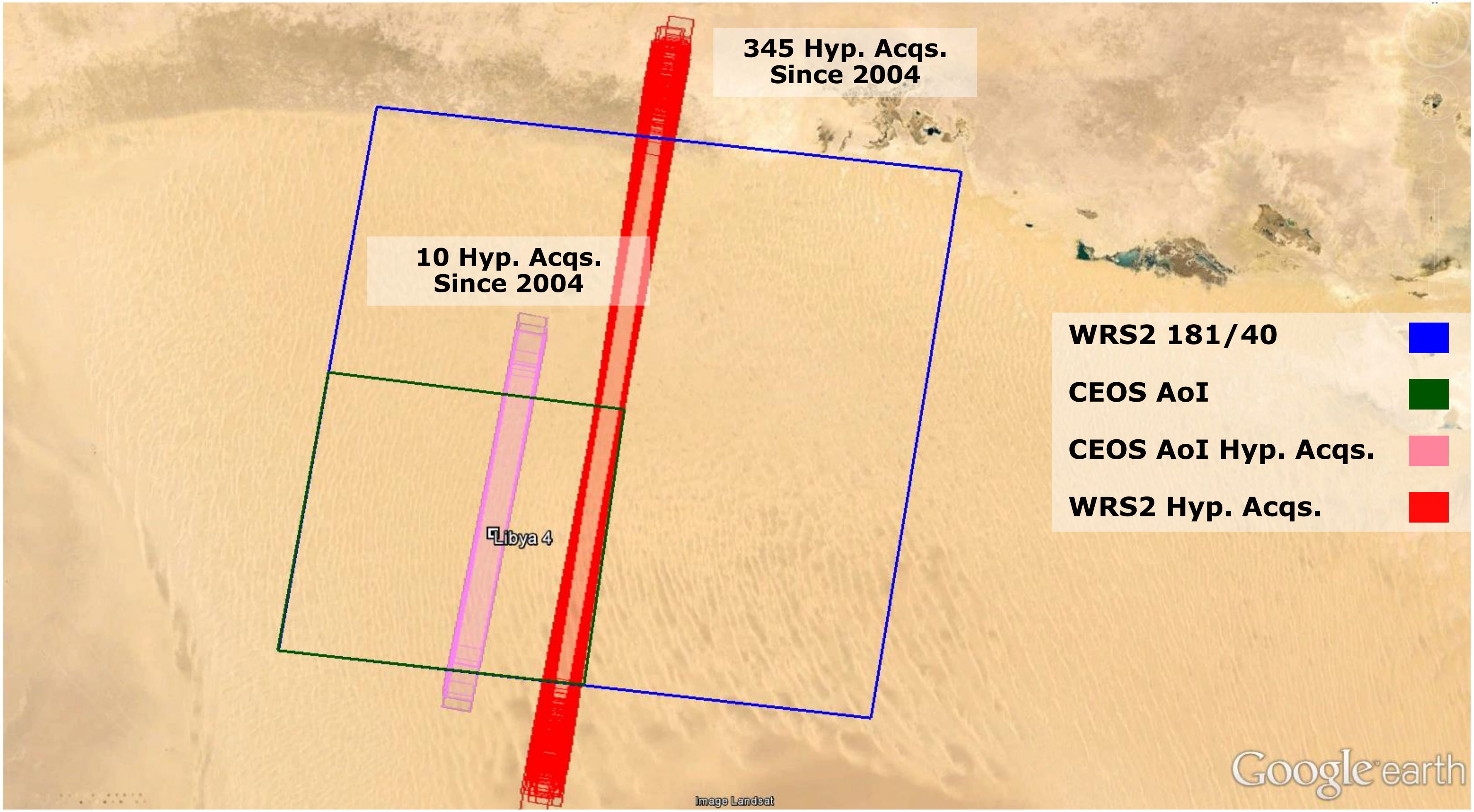

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Absolute calibration IV

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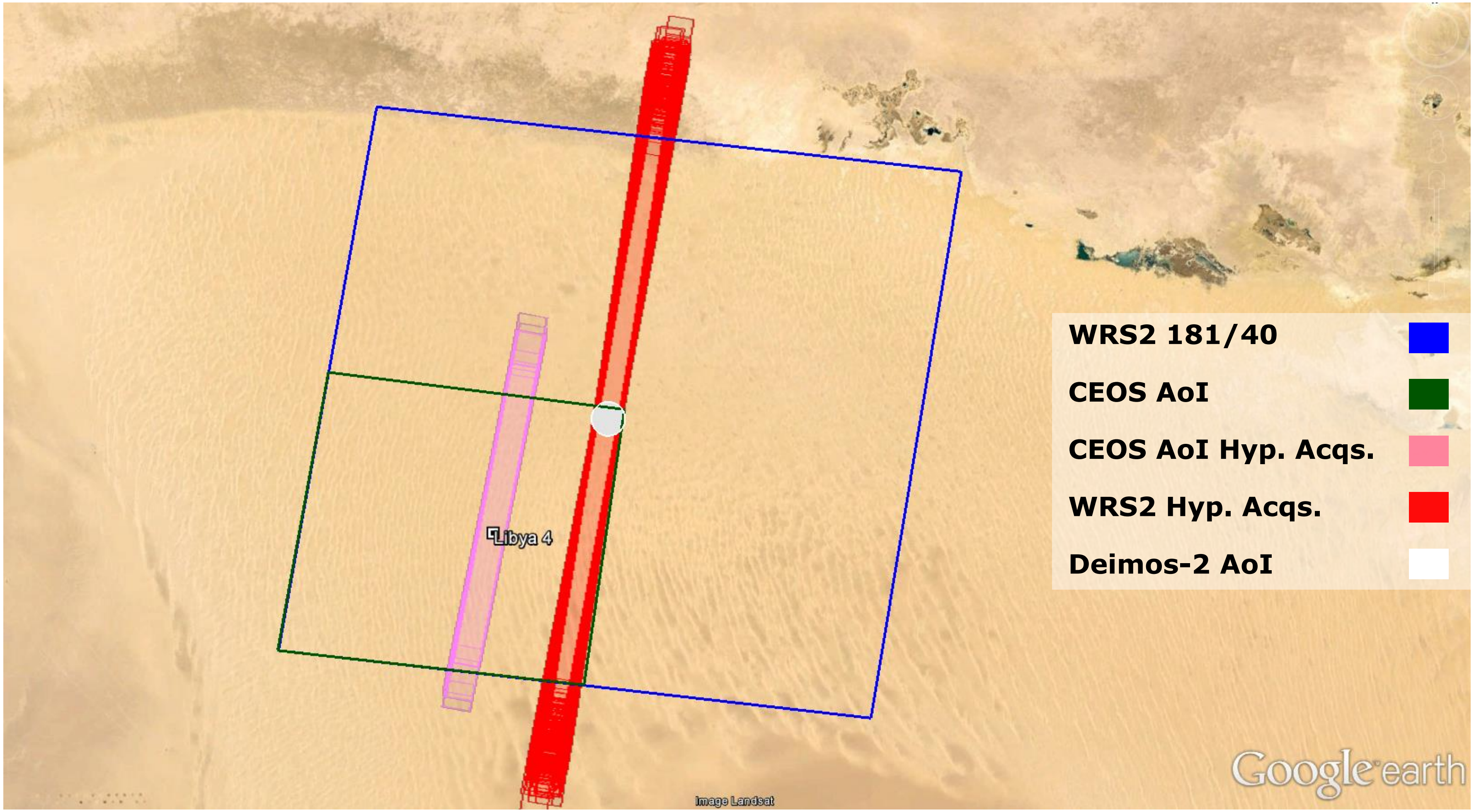

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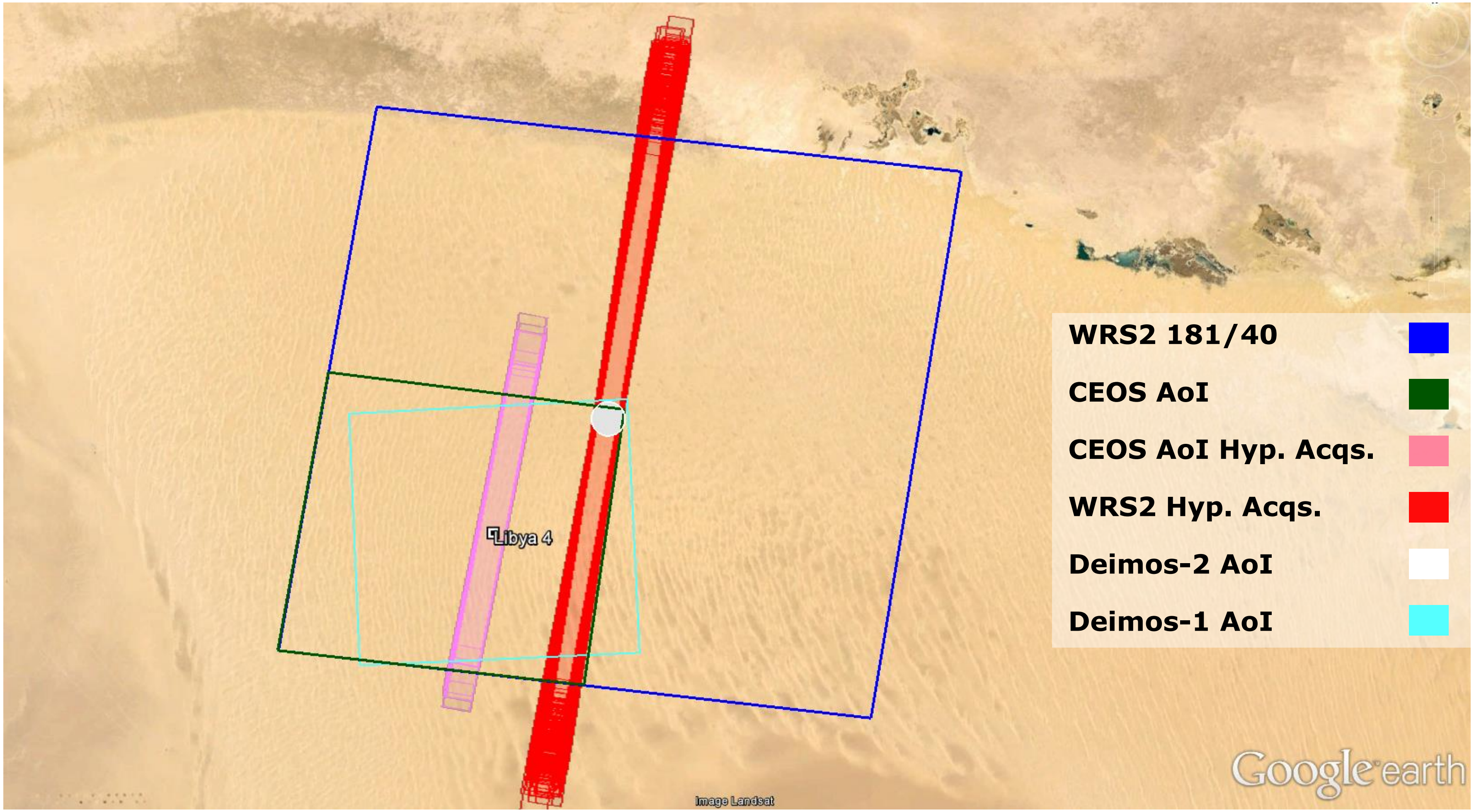
Absolute calibration IV

Where is Libya-4?



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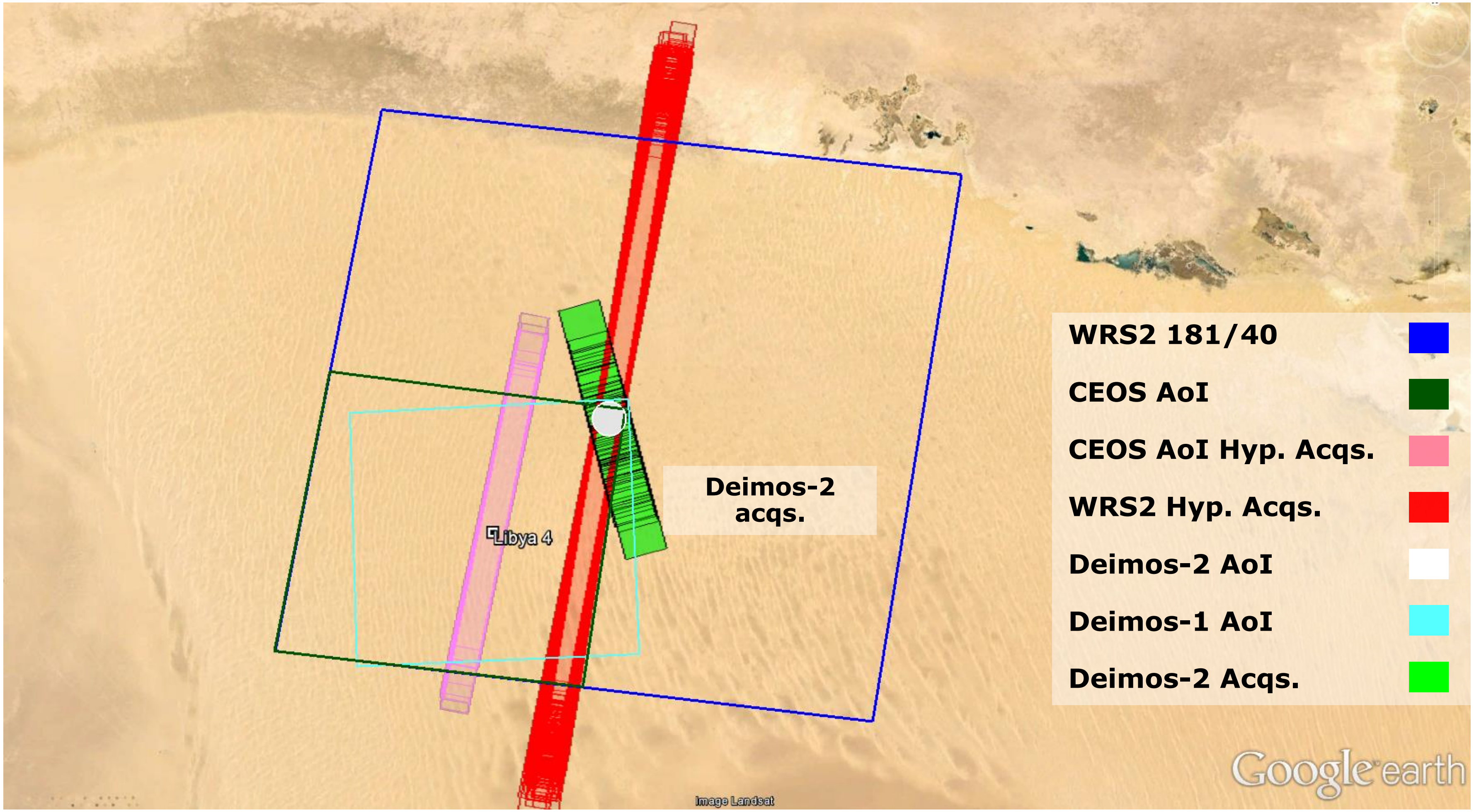
Absolute calibration IV

Where is Libya-4?



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Absolute calibration V

Hyperion data filtering

From January 26 2004 to October 10 2014 there are **345** Hyperion acquisitions in the Deimos-2 AoI

- **Spatial uniformity filtering**
  - Crop the Hyperion datasets using the Deimos-2 AoI
  - Automatic analysis of the spatial uniformity of each band in the Deimos-2 spectral range. If a single band fails the whole dataset is discarded
  - Visual inspection
  - **286** Hyperion datasets remaining
- **Viewing angle, time** and **spectral** consistency filtering
  - The three parameters were analyzed together
  - Viewing angle distribution
  - Yearly evolution
  - Full series uniformity
  - **100** Hyperion datasets ready for site modelling

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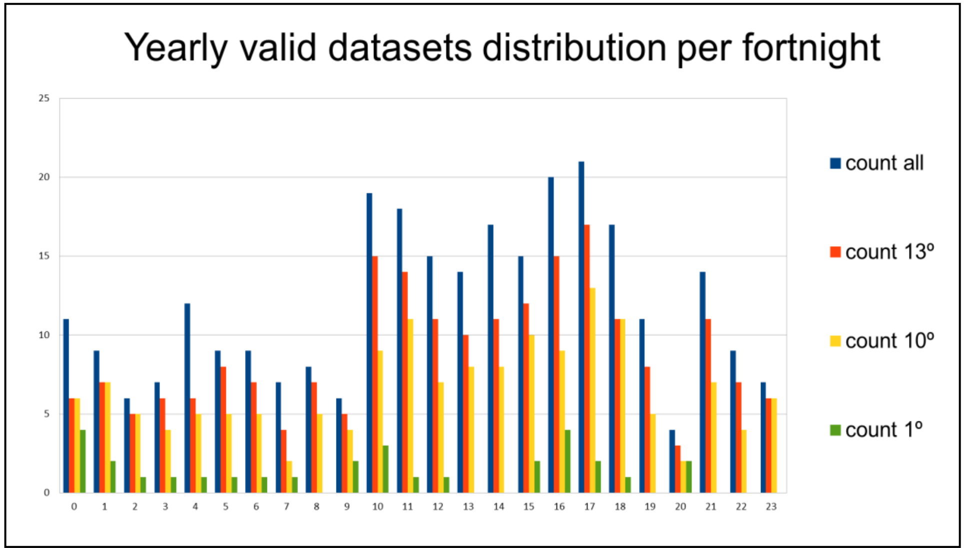
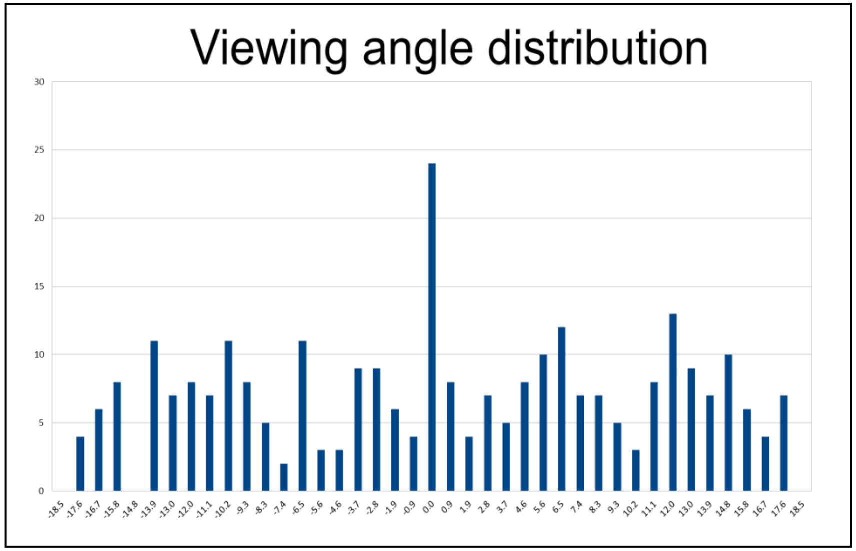
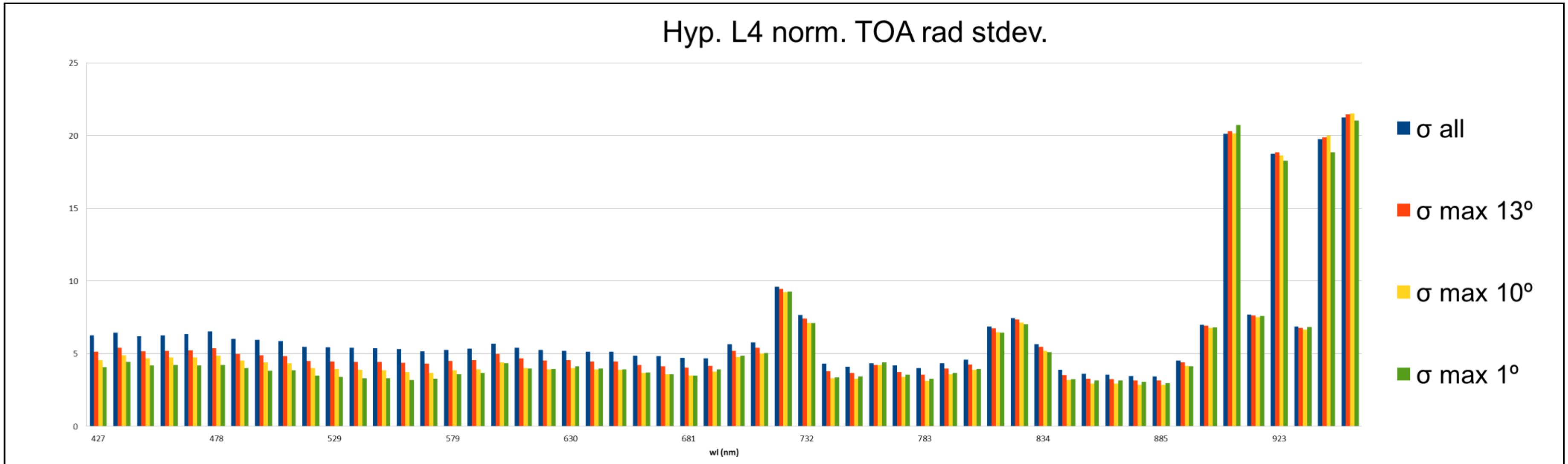
Absolute calibration VI – Hyperion data filtering







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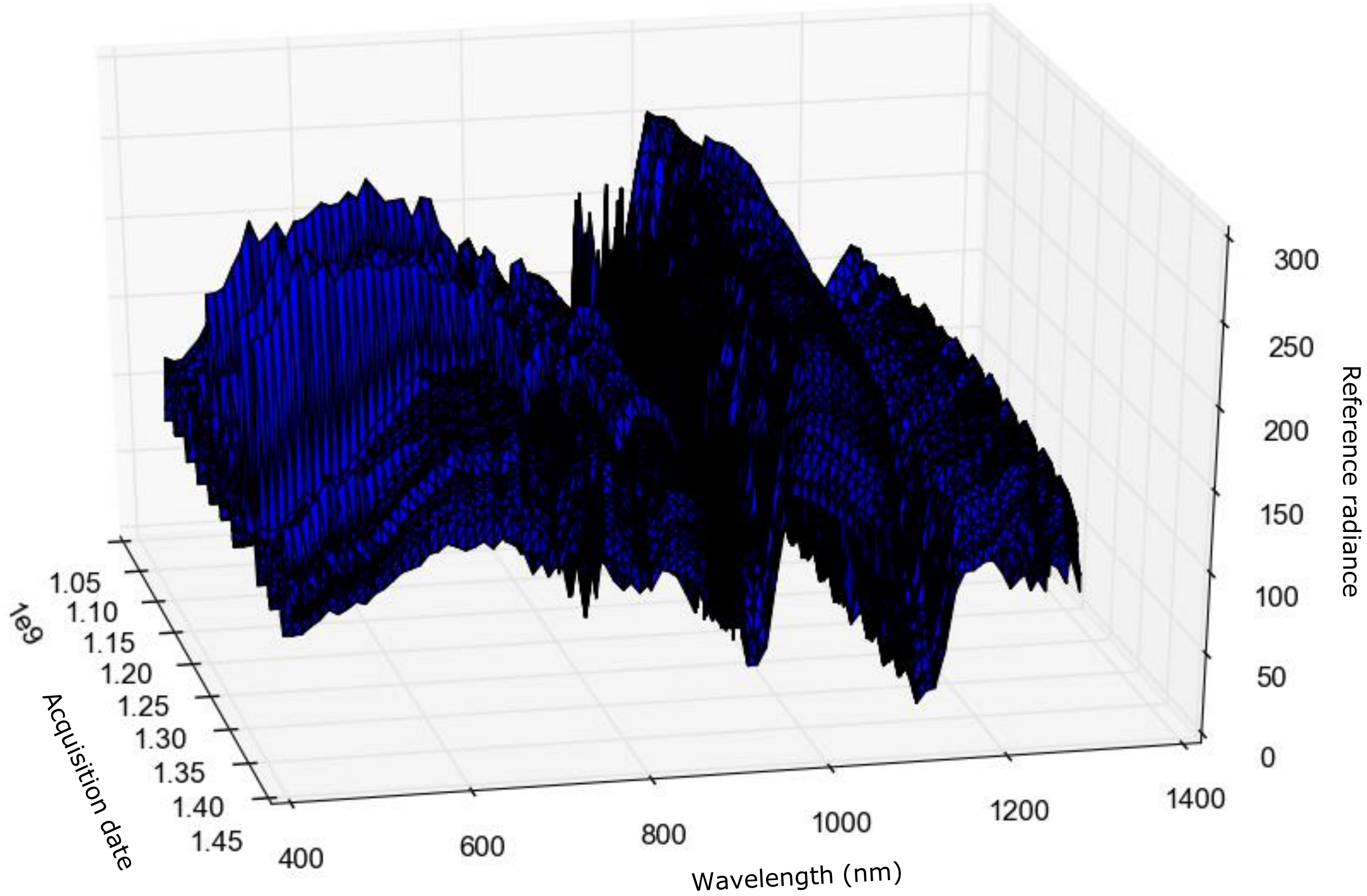
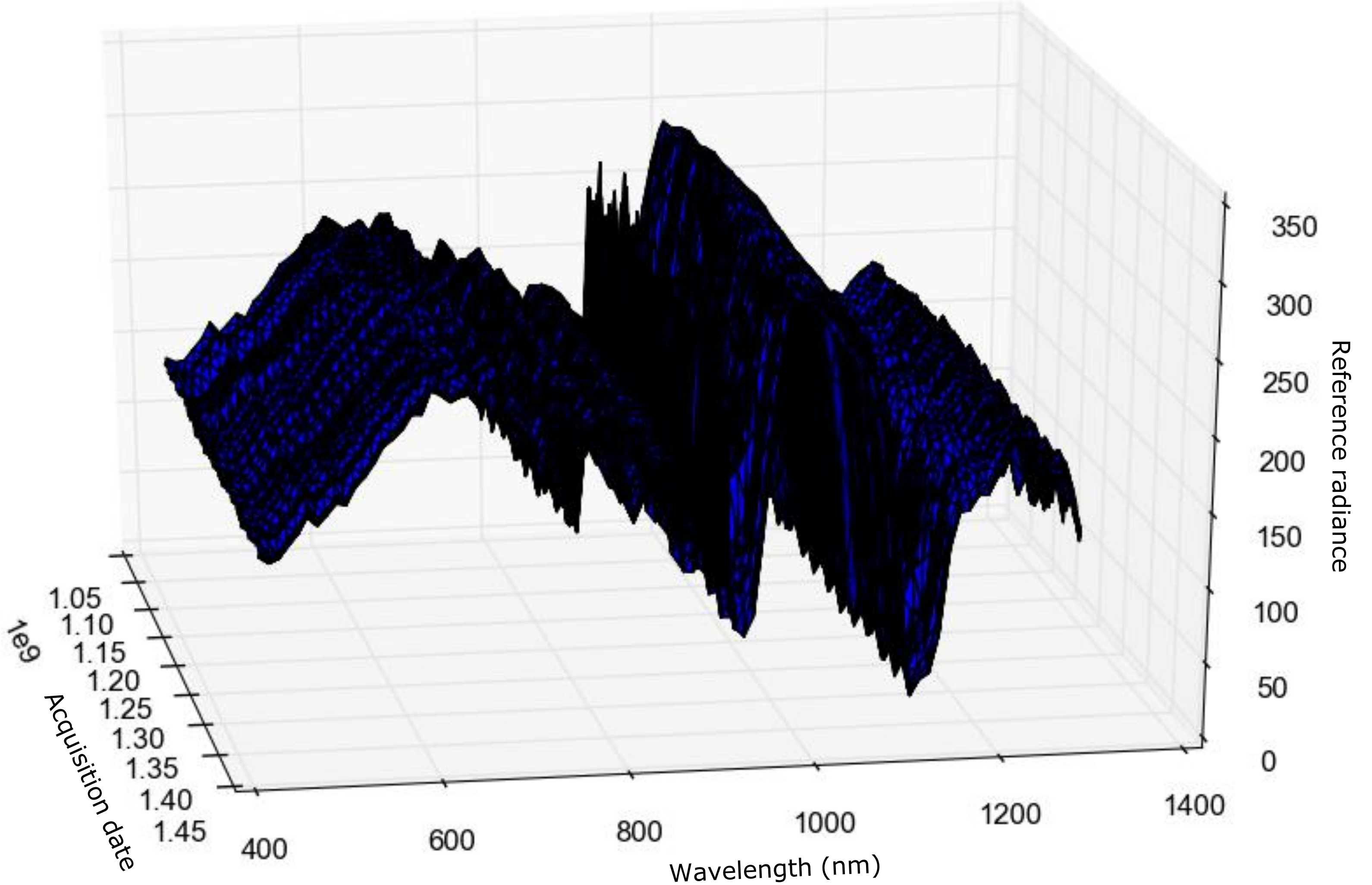
Absolute calibration VII

Hyperion data before filtering and correction



Absolute calibration VIII

Hyperion data after filtering and correction



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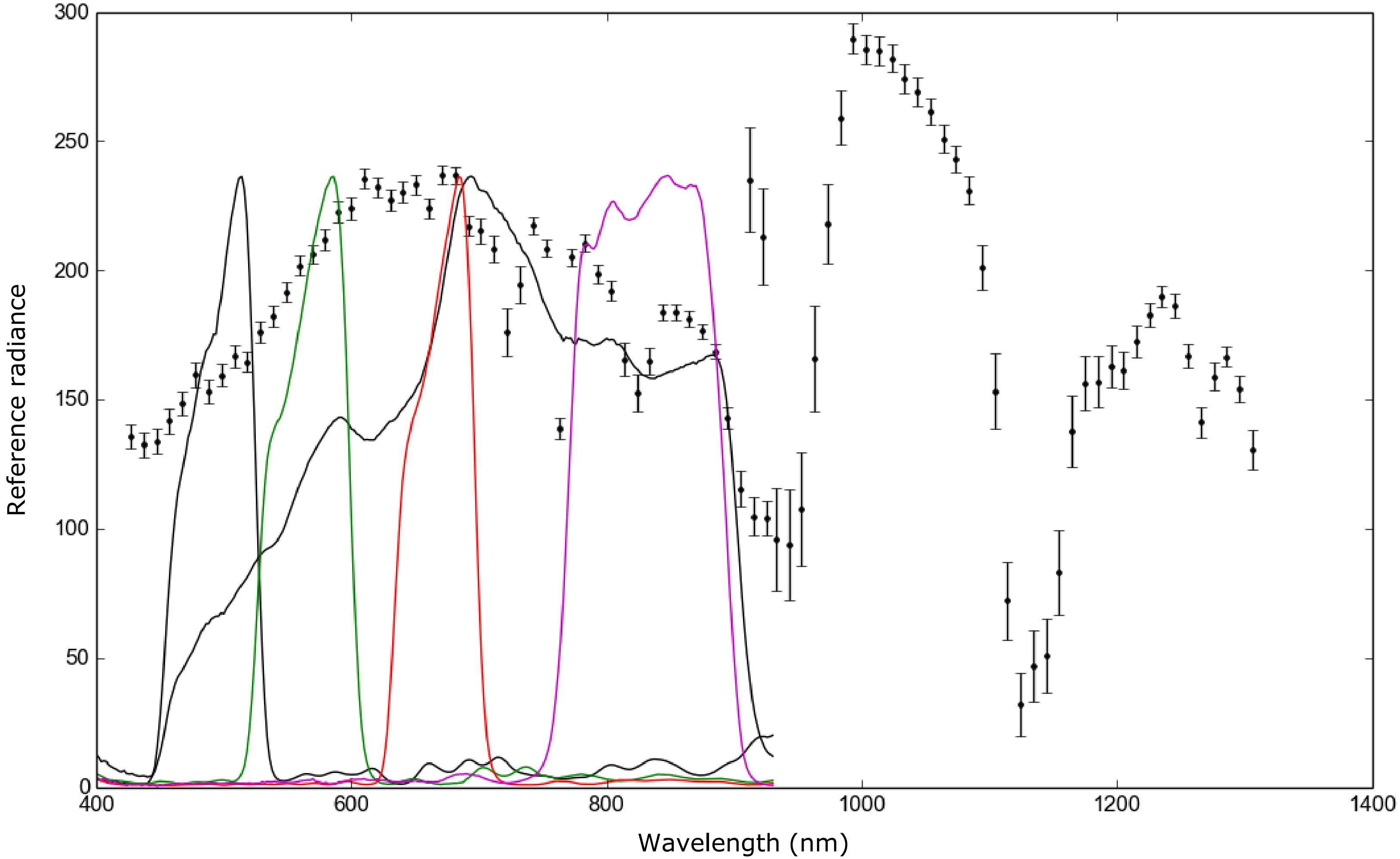
Absolute calibration IX

Libya-4 spectral model and Deimos-2 transmissivity profiles



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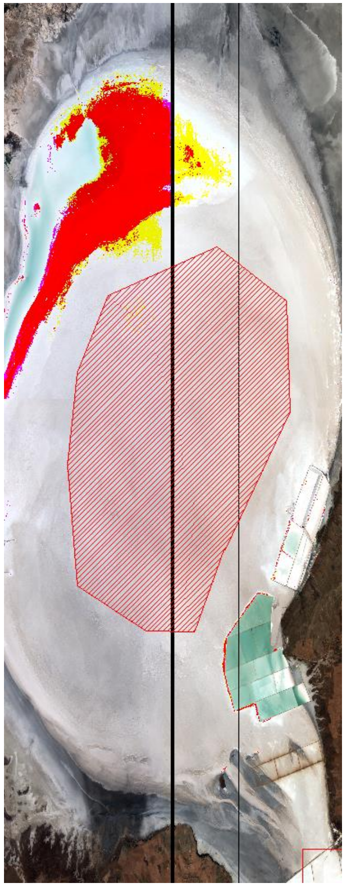
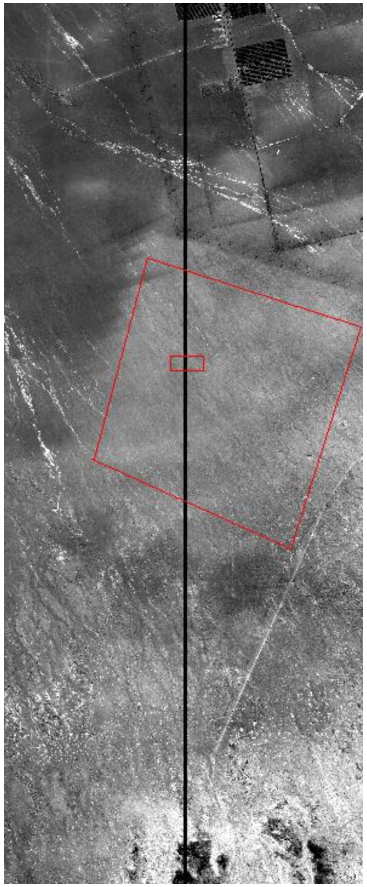
Absolute calibration X

The absolute calibration has been assessed by using a less thorough version of the same procedure in the following targets:

- Tuz Golu
- Danhuang
- Dolan Springs
- Frenchman Flat
- Ivanpah Playa
- La Crau
- Negev
- Railroad Valley





4 Results summary

Results summary

Quality indicator	Calibration results
Radiometric correction	OK
Absolute calibration uncertainty	< 5.4% MS, ~7.4% PAN
SNR	~112:1 PAN, > 90:1 MS
MTF	~9.1% PAN, > 31% MS @Nyquist

No major issues found

The uncertainty is expected to improve as more data becomes available

The absolute calibration procedure results are considered acceptable, but not validated until a vicarious calibration campaign is performed