Geo-Informatics and Space Technology Development Agency (Public Organization)

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Washington DC, USA

Progress of THEOS and CAL/VAL Activities in Thailand

Tanapati CHOOMNOOMMANEE

THEOS Engineer / GISTDA

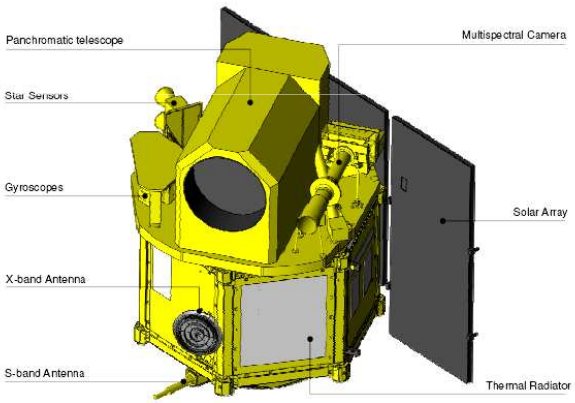
tanapati@eoc.gistda.or.th

GISTDA

Topics

- THEOS Overall Status
- THEOS Image Quality
- THEOS CAL/VAL activities 2010

THEOS System



Total mass	715 kg
Dimensions	2.1 x 2.1 x 2.4 m
Solar array	840 W
Nominal Lifetime	> 5 years
Local Solar Time	10:00 am
Recording capacity	51 Gbit solid-state memory
Image Telemetry	120 Mbit/sec (X band)
Off-nadir viewing	+/- 50° (roll and pitch)
Attitude control	Earth pointing and high agility
No. orbits/day	14+5/26 orbits/day Sun-synchronous near-circular orbit

THEOS Satellite : Payload

Optical Payload

- Panchromatic Camera
- Multispectral Camera

	PAN	MS
Resolution (m) / Imaging swath (km)	2 / 22	15 / 90
Spectral ranges (um)	0.45 – 0.90	B1 (Blue): 0.45-0.52 B2 (Green): 0.53-0.60 B3 (Red): 0.62-0.69 B4 (NIR): 0.77-0.90
Signal to Noise Ratio	> 90	>100
Imaging dynamics	8 bits among 12 bits	
Absolute localizations accuracy (level 1B)	< 300 m	
Onboard image processing	2.8 or 3.7 compression ratio (DCT)	

THEOS Ground Segment

Ground segment:

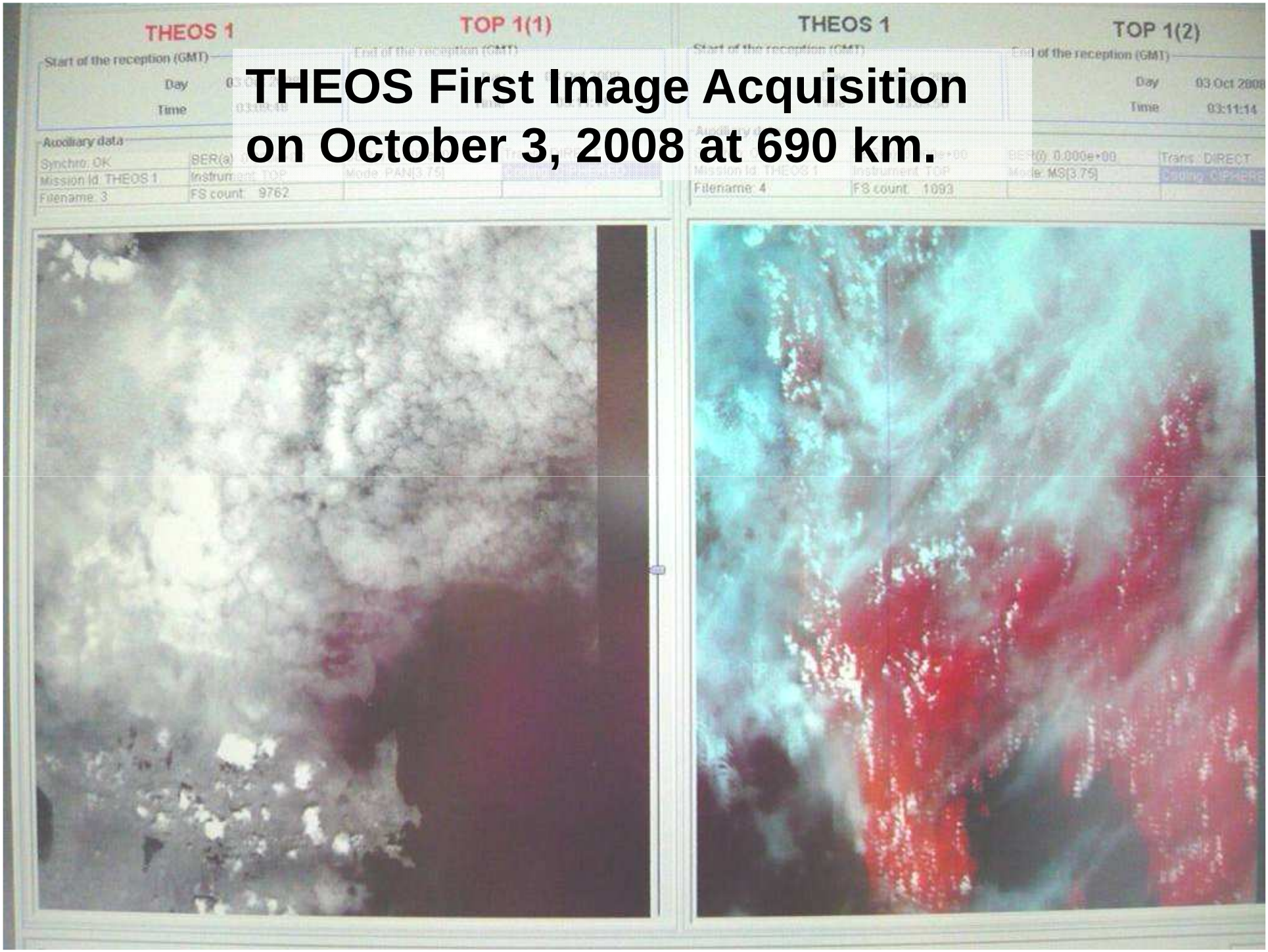
Control Ground Segment (CGS)
at Si-Racha:
Monitor and control the satellite according to the daily optimised mission programming by taking into account user requests and satellite utilisation.

Image Ground Segment (IGS)
at Ladkrabang (Bangkok):
Acquire, process, archive, and exploit the imagery from standard products to value added products.

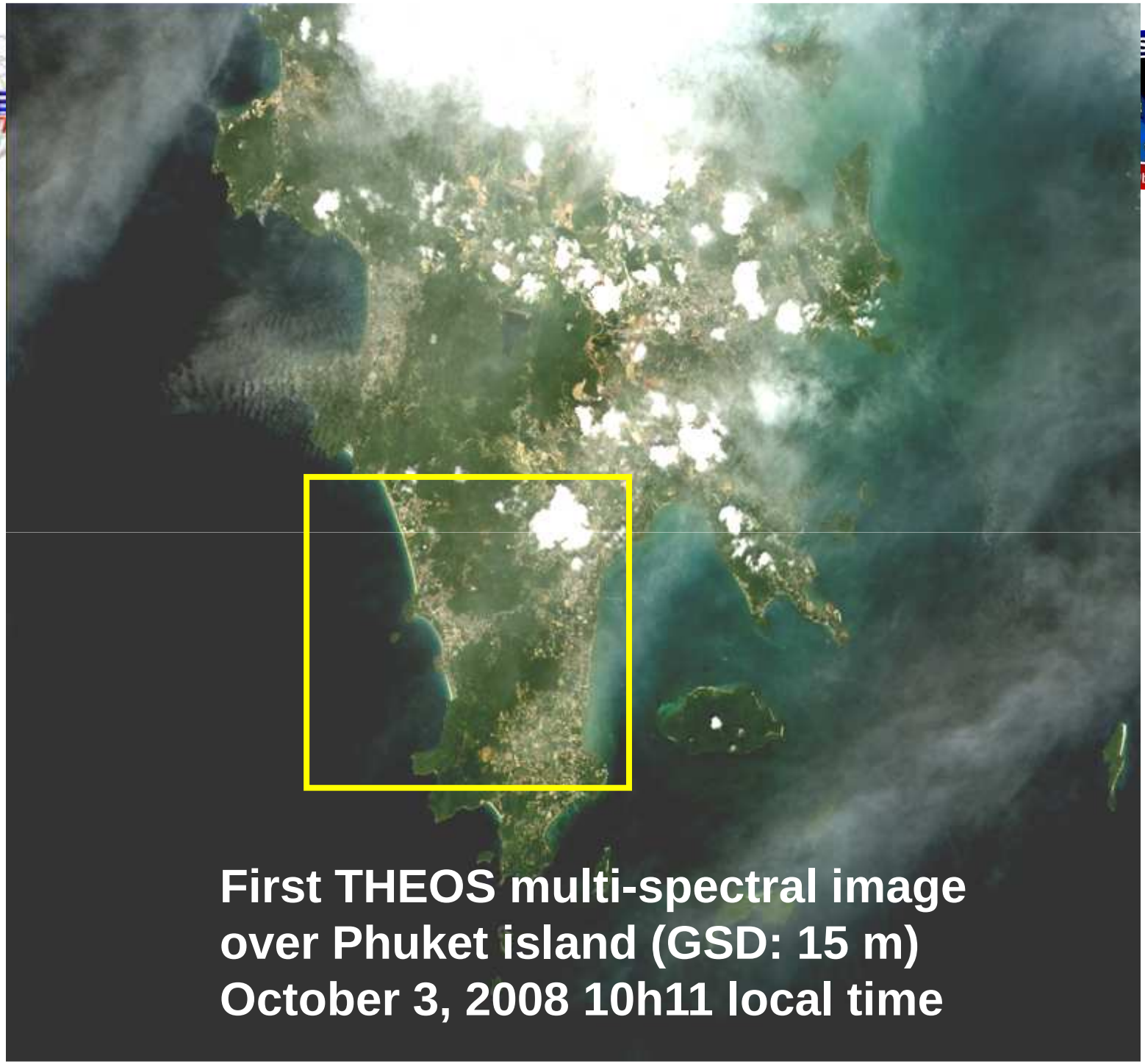
THEOS Ground Station

THEOS Launch

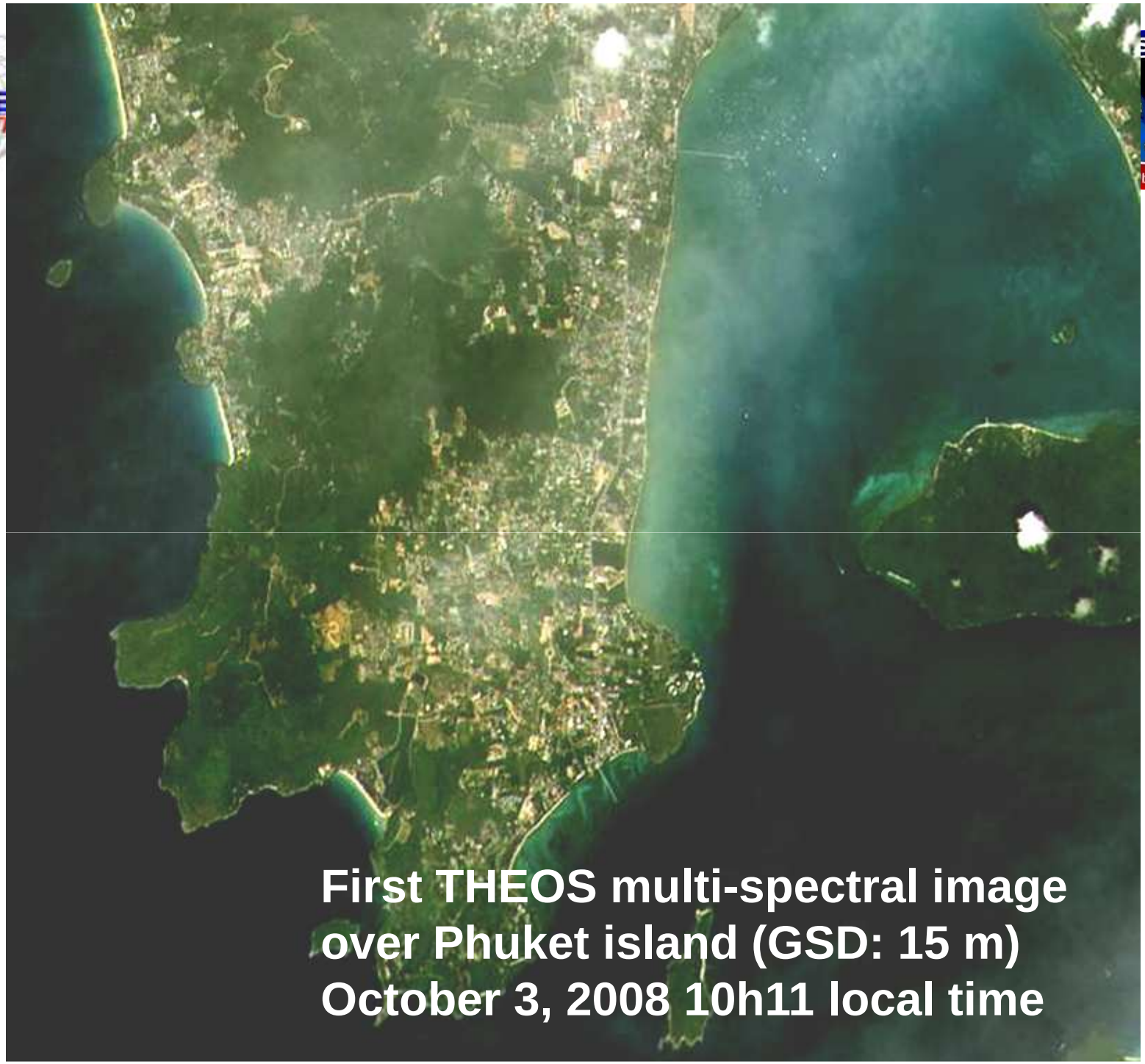
THEOS was launched, at 13.37 BKK time on October 1, 2008, from Yasny launch site in Russia by Dnepr Rocket.



THEOS First Image Acquisition on October 3, 2008 at 690 km.



First THEOS multi-spectral image over Phuket island (GSD: 15 m) October 3, 2008 10h11 local time



First THEOS multi-spectral image
over Phuket island (GSD: 15 m)
October 3, 2008 10h11 local time

THEOS Programming 2009

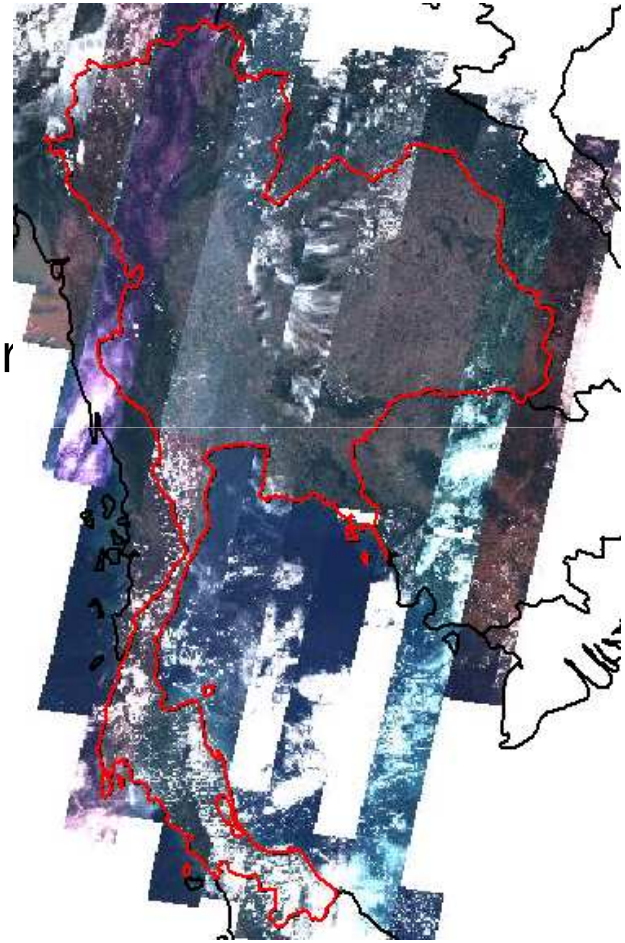
Example of THEOS Programming in 2009

- THEOS Image over Thailand (November 2009 – April 2010)
- THEOS World Collection
- THEOS for disaster

THEOS Thailand Collection

November

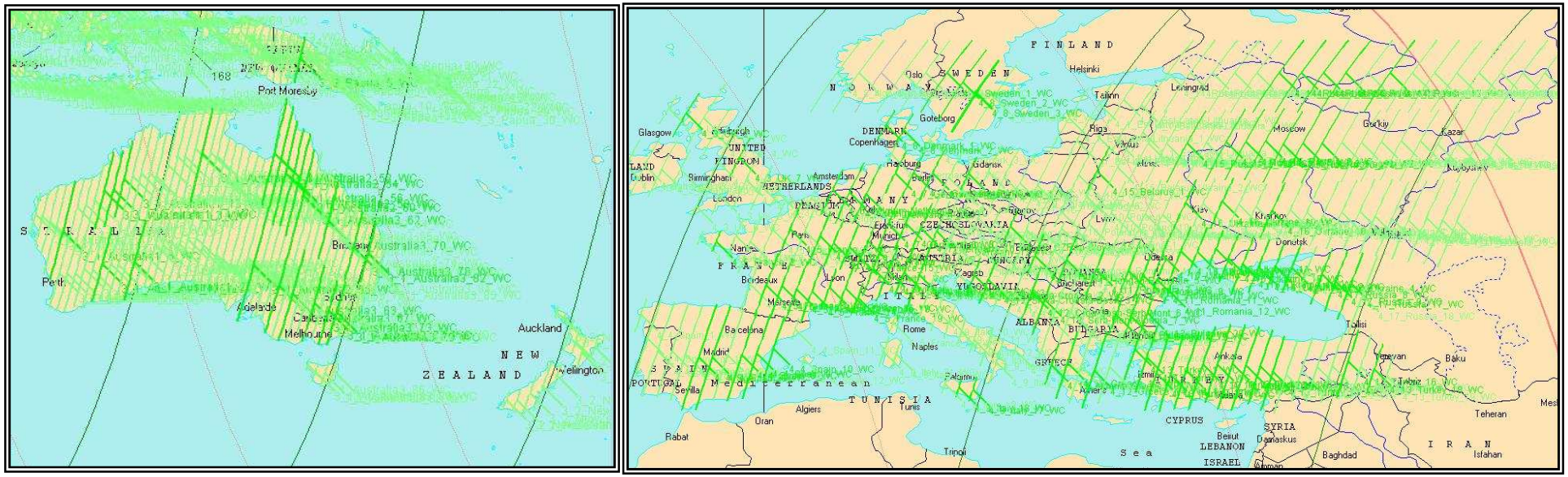
December



Thanks to THEOS MS large swath width, all Thailand (around 600,000 sq.km) can be covered within one month

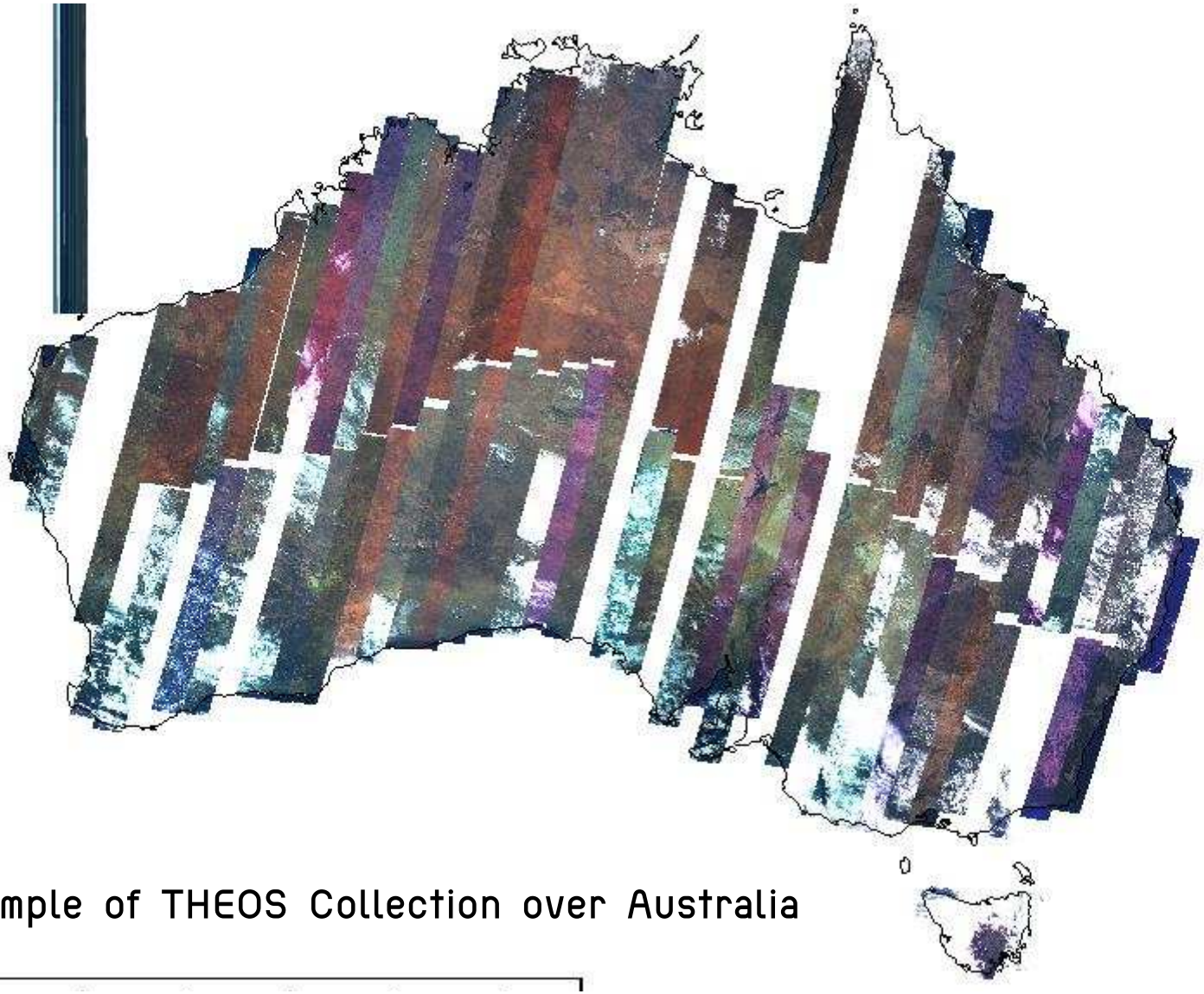
THEOS World Collection

Even though THEOS may not have officially provide images to foreign requests, we have received a large number of enquiries. This is due to the fact that THEOS' images may be utilized in myriad applications. Therefore, we have taken the initiative to capture images of various point around the world since July 2009.



Example of THEOS Planning over Australia and Europe

THEOS World Collection



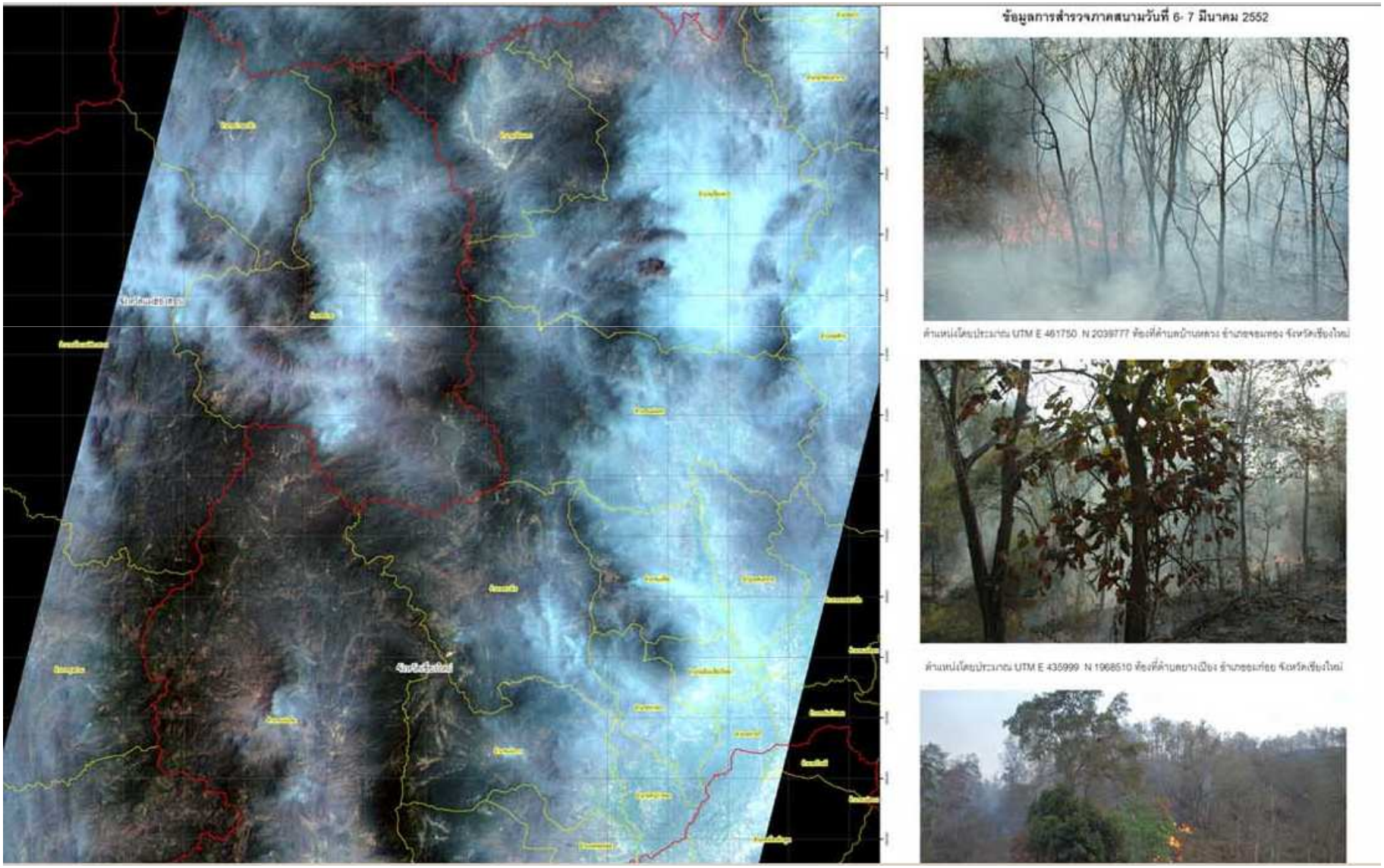
Sample of THEOS Collection over Australia

THEOS Disaster Images

List below are the examples of disaster images taken by THEOS

Event	Type	Country
Dust Storm Blankets Sydney As Drought Bites	Dust	Australia
Lampang restores 7 villages hit by flood	Flood	Thailand
Power out, trees down as typhoon nears Vietnam	Storm	Vietnam
Tsunami in Samoa	Tsunami	American Samoa
Thousands trapped under rubble after powerful Indonesia earthquake	Earthquake	Indonesia
UNICEF Pacific to provide support to children and families of Samoa	Tsunami	Tonga
Typhoon lands in Japan, leaving 1 dead, 24 injured	Storm	Japan
Landslides Add to Philippines' Storm Toll	Landslides	Philippines
Taiwan gears up for new typhoon	Storm	Taiwan
Bhutan: Earthquake	Earthquake	Bhutan
Landslides, flood victims suffering from illnesses and hunger	Landslides	Nepal
Worst floods in 100 years hit India	floods	India
A Villager Walks Through A Partially Dried Reservoir In Yingtan	Drought	China
Ida's threat ebbs but US Gulf energy output disrupted	Hurricane	USA

Forest fire in Thailand

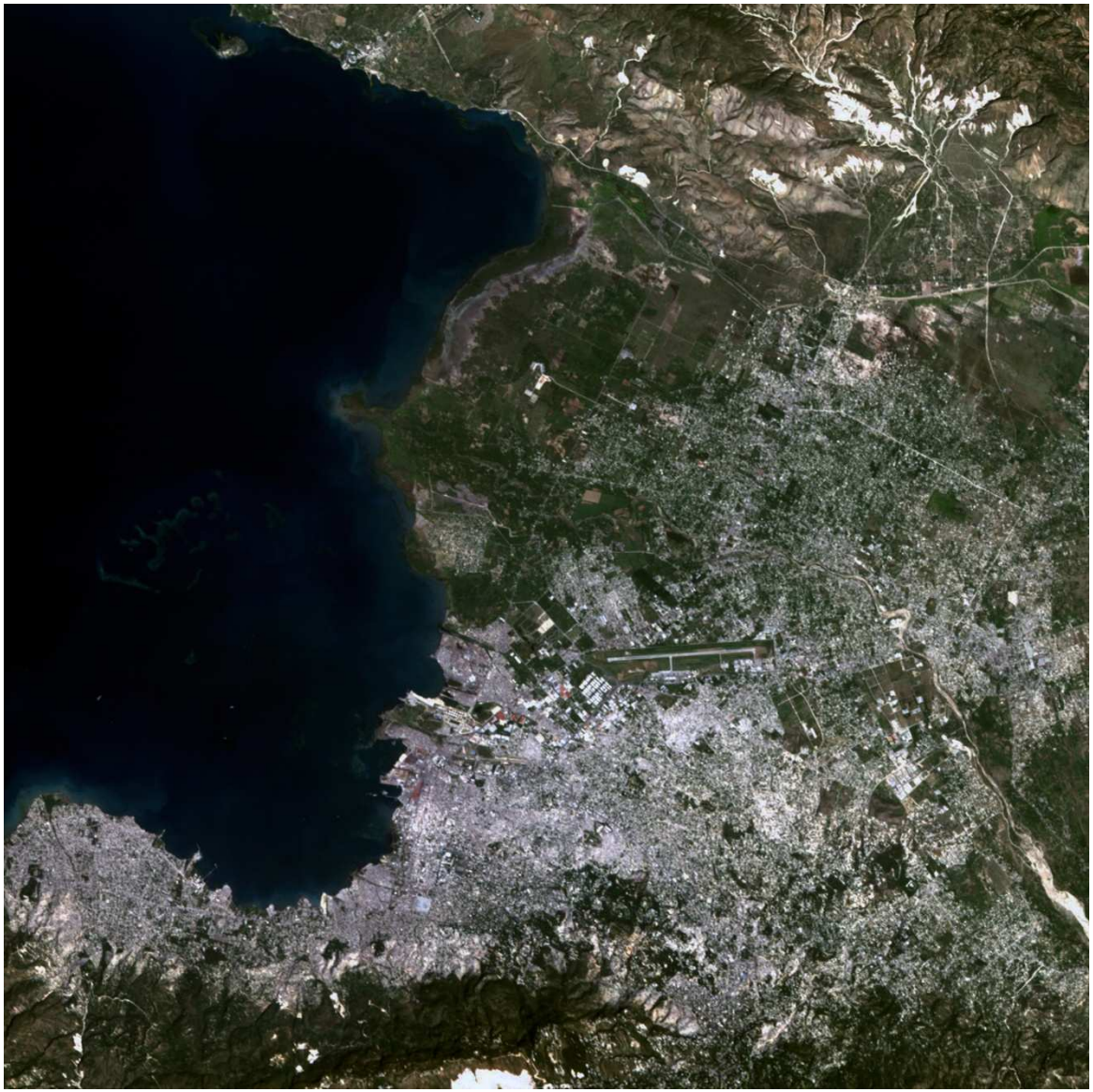


Haiti Earthquake

Before :

September 2009

Haiti Earthquake



After :

January 2010

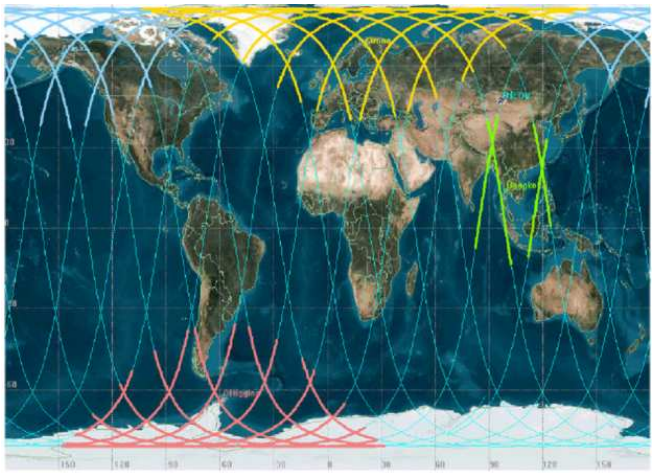
THEOS Key Projects in 2010

THEOS receiving station in China

2 X-Band stations will be established in collaboration with CEODE. The footprint of all THEOS receiving stations (include station in Thailand) cover most part of ASIA.

THEOS Key Projects in 2010

- THEOS polar station at Esrange Space Centre, Kiruna under a contract with Swedish Space Corporation (SSC) offering around 10-13 orbits' contact.
- THEOS System capacity enhancement (THEOS on the global market)



Joint Research Center

This open invitation to tender (ITT) deals with the supply of satellite remote sensing (SRS) data products and associated services from sensor or sensor series grouped in 8 independent lots: Quickbird (QB2), WorldView (WV1/WV2), Landsat (L5, L7, LDCM), Terra (ASTER), Envisat (ASAR), Radarsat (1, 2), Cartosat (Cartosat 2), and Theos (Theos).

QUANTITY OR SCOPE OF THE CONTRACT

Total quantity or scope:

It has been decided to establish FCs in 8 independent lots for the supply of SRS data products, and associated services, from sensor or sensor series as follows:

1. Quickbird (QB2);
2. WorldView (WV1/WV2);
3. Landsat (L5, L7, LDCM);
4. Terra (ASTER);
5. Envisat (ASAR);
6. Radarsat (1, 2);
7. Cartosat (Cartosat 2);
8. Theos (Theos).

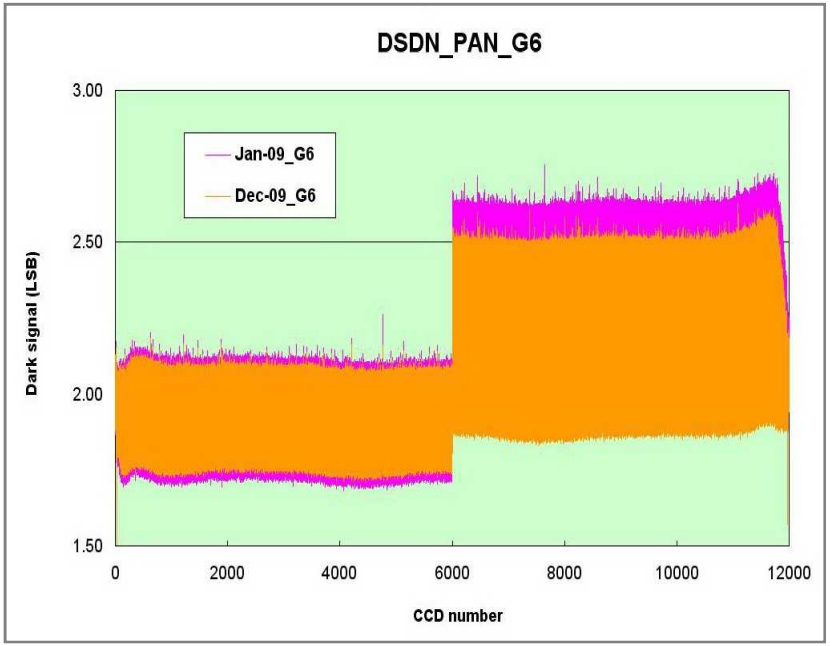
Estimated value excluding VAT: 15 200 000 EUR.

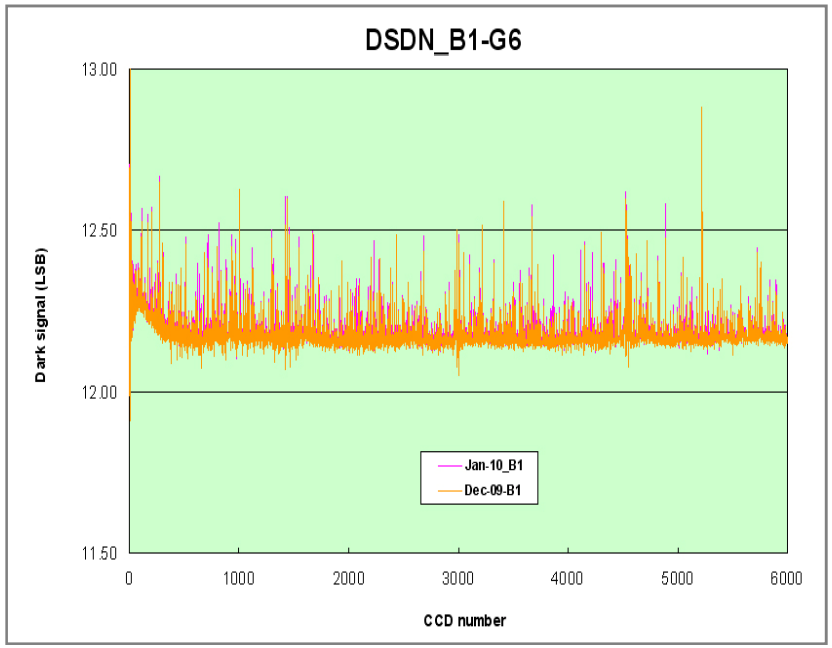
Overall image quality

- All planned tasks achieved
  - dark signal, relative gains
  - SNR, dynamic range
  - absolute calibration
  - geometric calibration
  - pointing knowledge, pointing accuracy measurement
  - MTF measurement
  - overall image quality
    - product analysis
    - restoration settings
    - pan-sharpening

Dark Signal

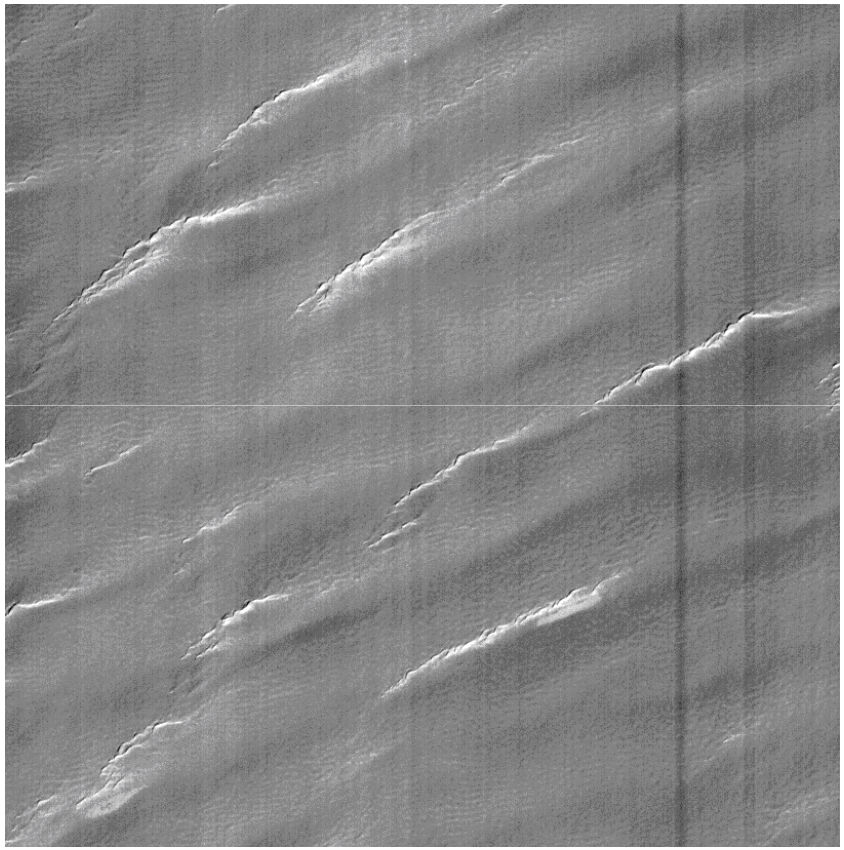
- Acquisition ocean (Pacific and Atlantic) images by night
  - No major change with ground measurement, except a slight reduction of dark noise (mainly due to thermal environment)
  - Very small change after one year in orbit

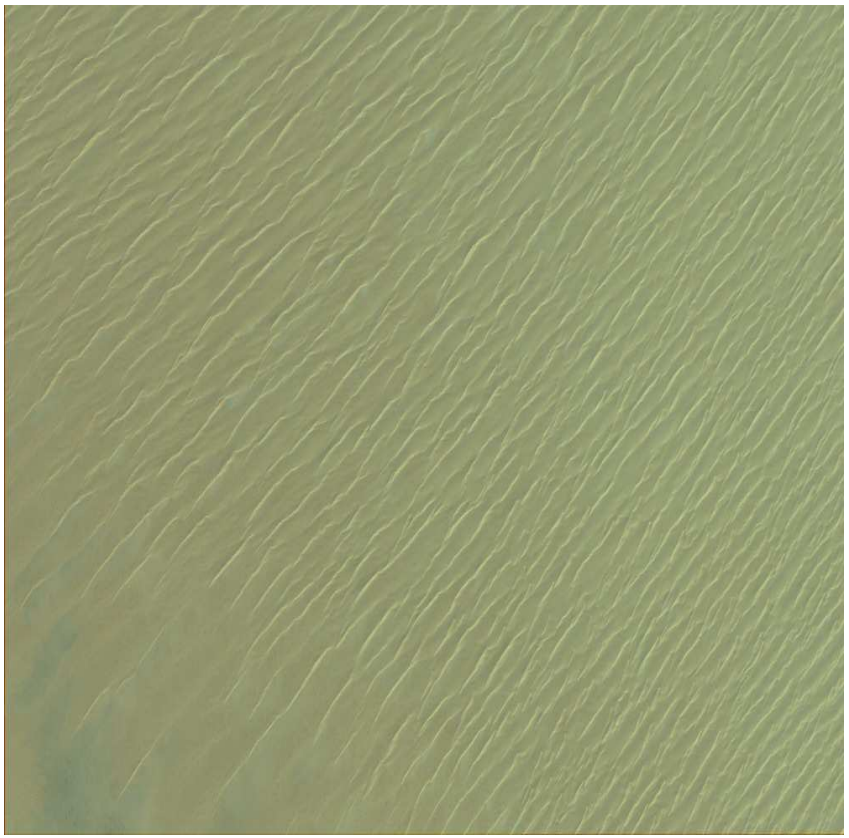




MS

Non-Uniformity

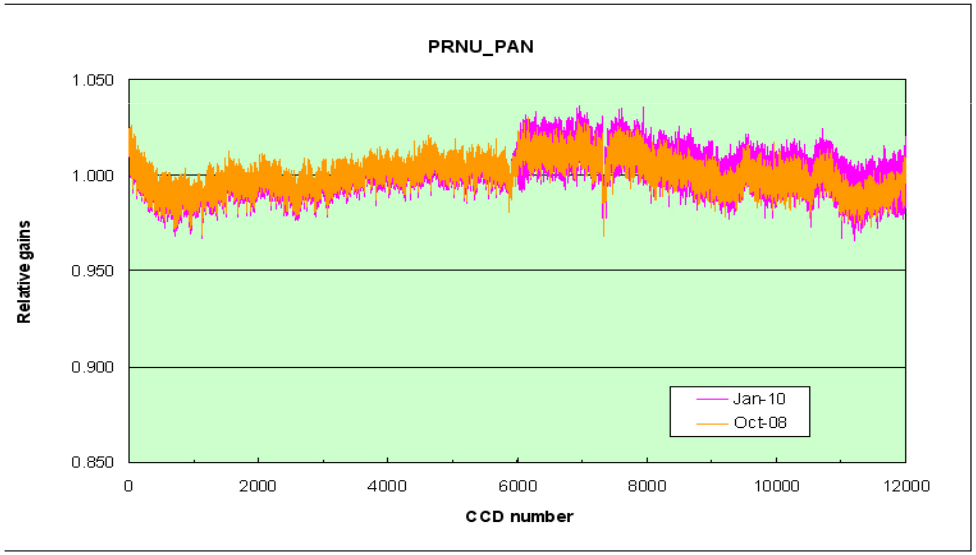




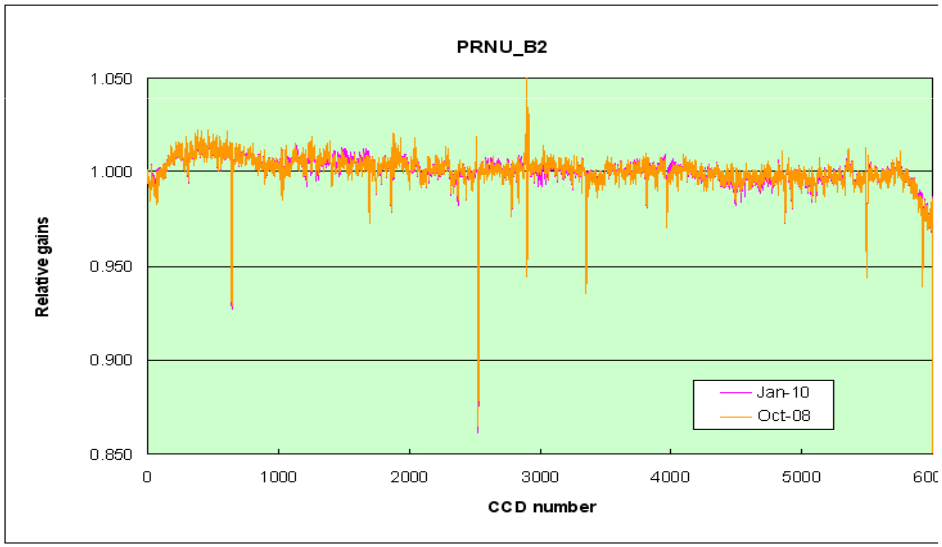
PAN and MS image over PRNU test site (Arabie)

Non-Uniformity

- Variation over one year in orbit:
  - very good stability
  - filters non-uniformity is stable; no change of the defects transmission



PAN



MS

Absolute calibration

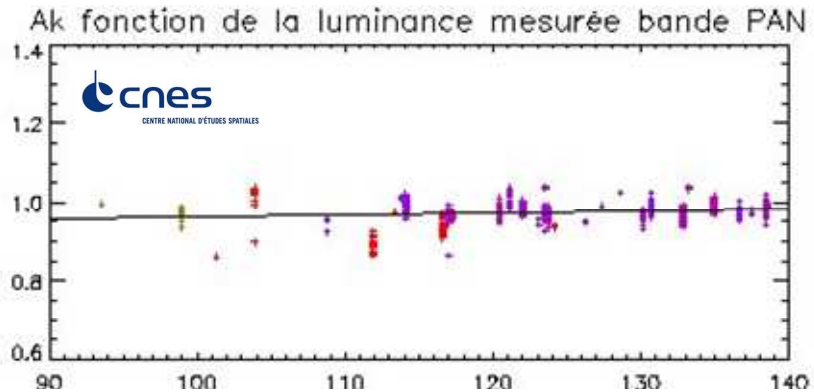
- Approach based on SADE database
  - CNES method using desert sites
  - requires continuous acquisitions over selected sites
  - requires pre-processing of data (tool provided by Astrium)
- Dataset acquired during IOT
  - more than 50 measurements available and pre-processed
  - synthesis file generated, analysed and sent by Astrium to CNES
  - preliminary results available through cross-calibration performed with respect to CNES operated sensors, used as reference

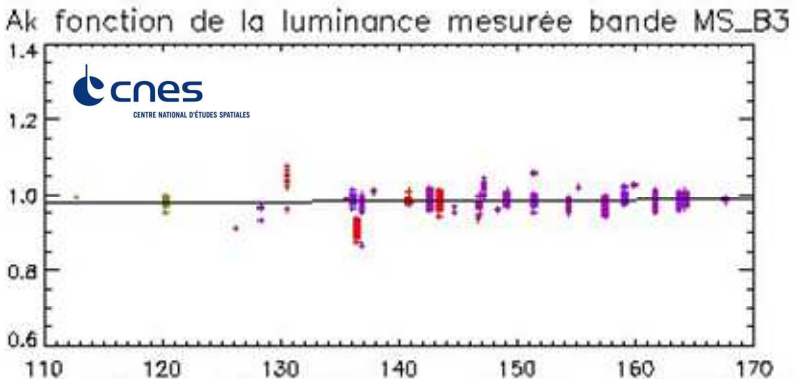
Absolute calibration

- Preliminary results
  - initial coefficients are within 10% consistency
  - update may be planned after about 3 months data accumulation

SADE processing synthesis

BANDE	ADEOS/POLDER	ADEOS2/POLDER	PARASOL/POLDER	SPOT5/VGT	MOYENNE
PAN	0.984	0.975	0.975	-	0.978
MS_B1	0.943	0.935	-	-	0.939
MS_B2	1.023	1.020	1.001	-	1.014
MS_B3	1.007	0.978	0.984	0.992	0.990
MS_B4	1.024	1.019	1.017	1.023	1.021





Signal to Noise Ratio

- SNR computed from
  - radiometric model (dark noise, photonic noise, detection chain gains, quantisation noise)
  - absolute gains from ground measurement
  - updated dark noise
- Dark noise is slightly improved w.r.t on-ground configuration
- SNR is slightly increased and much better than specification (given at R2 for gain 4)

	PAN	B1	B2	B3	B4
SNR	147	202	234	246	246
spec	90	100	100	100	100

Dynamic range / saturation

- Dynamic range is computed from
  - radiometric model (dark noise, photonic noise, detection chain gains, quantisation noise)
  - absolute gains from ground measurement
  - updated dark signal and dark noise
  - relative gain of 1

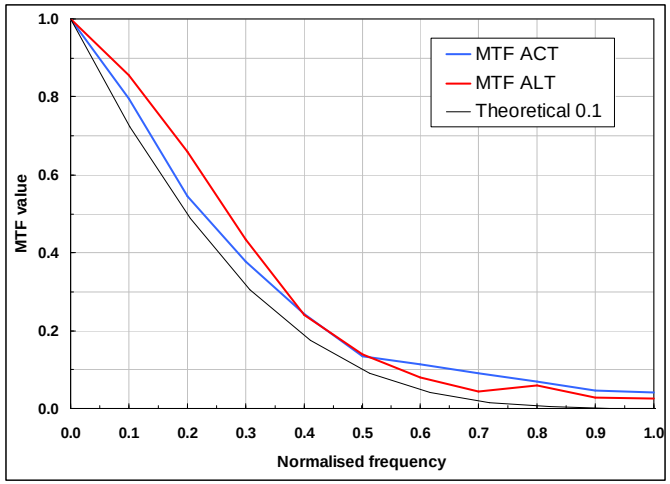
Gain Label	PAN ($W.m^{-2}.sr^{-1}.\mu m^{-1}$)		B1 ($W.m^{-2}.sr^{-1}.\mu m^{-1}$)		B2 ($W.m^{-2}.sr^{-1}.\mu m^{-1}$)		B3 ($W.m^{-2}.sr^{-1}.\mu m^{-1}$)		B4 ($W.m^{-2}.sr^{-1}.\mu m^{-1}$)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
G1	1.9	473.7	1.9	485.4	1.9	474.9	1.7	420.1	1.7	426.5
G2	1.3	335.0	1.4	343.3	1.3	335.9	1.2	297.1	1.2	301.6
G3	0.9	236.2	1.0	239.8	0.9	234.6	0.8	208.4	0.8	210.7
G4	0.7	167.1	0.7	169.6	0.7	165.9	0.6	148.0	0.6	149.0
G5	0.5	117.6	0.5	117.0	0.5	114.5	0.4	102.6	0.4	102.8
G6	0.7	83.1	0.3	82.7	0.3	80.9	0.3	73.1	0.3	72.7
G7	0.5	58.2	0.2	55.4	0.2	54.2	0.2	49.7	0.2	48.7
G8	0.3	41.2	0.2	39.2	0.2	38.3	0.1	35.8	0.1	34.5
G9	0.3	28.6	0.2	24.7	0.2	24.1	0.2	23.3	0.2	21.7
G10	0.3	20.2	0.2	17.4	0.2	17.1	0.1	17.0	0.1	15.4

MTF

- Approach:
  - Measurement of Knife Edge Function on ground pattern
  - Derivation of MTF by mathematical formula

- Result
  - PAN MTF = 0.14
  - MS MTF > 0.2

Salon de Provence pattern



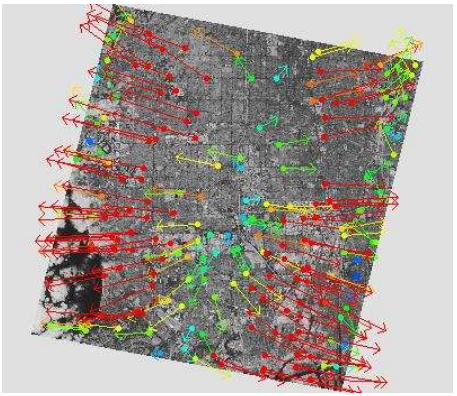
GSD / Swath

- Measurement over well referenced sites
  - Salon, LosAngeles, Hamburg, BuenosAires, MarDelPlata,…
- Difference between GCP distance
  - Measurement made separately along and across track
- Measurement error around 1%

	ACT GSD	ALT GSD	Swath width
PAN channel	**1.86 m**	**2.03 m**	**22.3 km**
MS channels	**15.68 m**	**14.24 m**	**94.1 km**

Geometric calibration

- Adjust parameters of the geometrical model (LOS physical model)
  - fine registering of MS channels
  - relative MS / PAN LOS calibration
  - absolute location error minimisation



- Approach
  - use of sites with dense GCP's (orthorectified large image) for MS channels registration

    Herault and Los Angeles
  - use of a large set of images with various latitudes, and acquisitions in various pointing conditions
    - to accurately compute pointing error, with a good statistic, and correct biases
    - 10 specific sites have been included in IOT plan to this aim

Pointing knowledge

- Objective
  - measure the absolute location accuracy
- Approach
  - use GCP's
  - measure distance with location restituted in 2A products
- Results
  - method applied on images produced with:
    - initial CPF
    - CPF updated with preliminary bias correction (with very few images)
  - initial geolocation error was ~ 900m (before bias removal)
  - performance is below 190m in all pointing conditions

Pointing accuracy

- Objective
  - measure the accuracy of satellite pointing, given the CGS command
- Approach
  - comparison of MPC computed segment and real segment realised by satellite
  - most efficient approach is to compare top corners locations given by MPC (FUP), and top corners locations restituted in the catalog
- Results
  - performance is below 1.3 km

Ortho-rectification Image

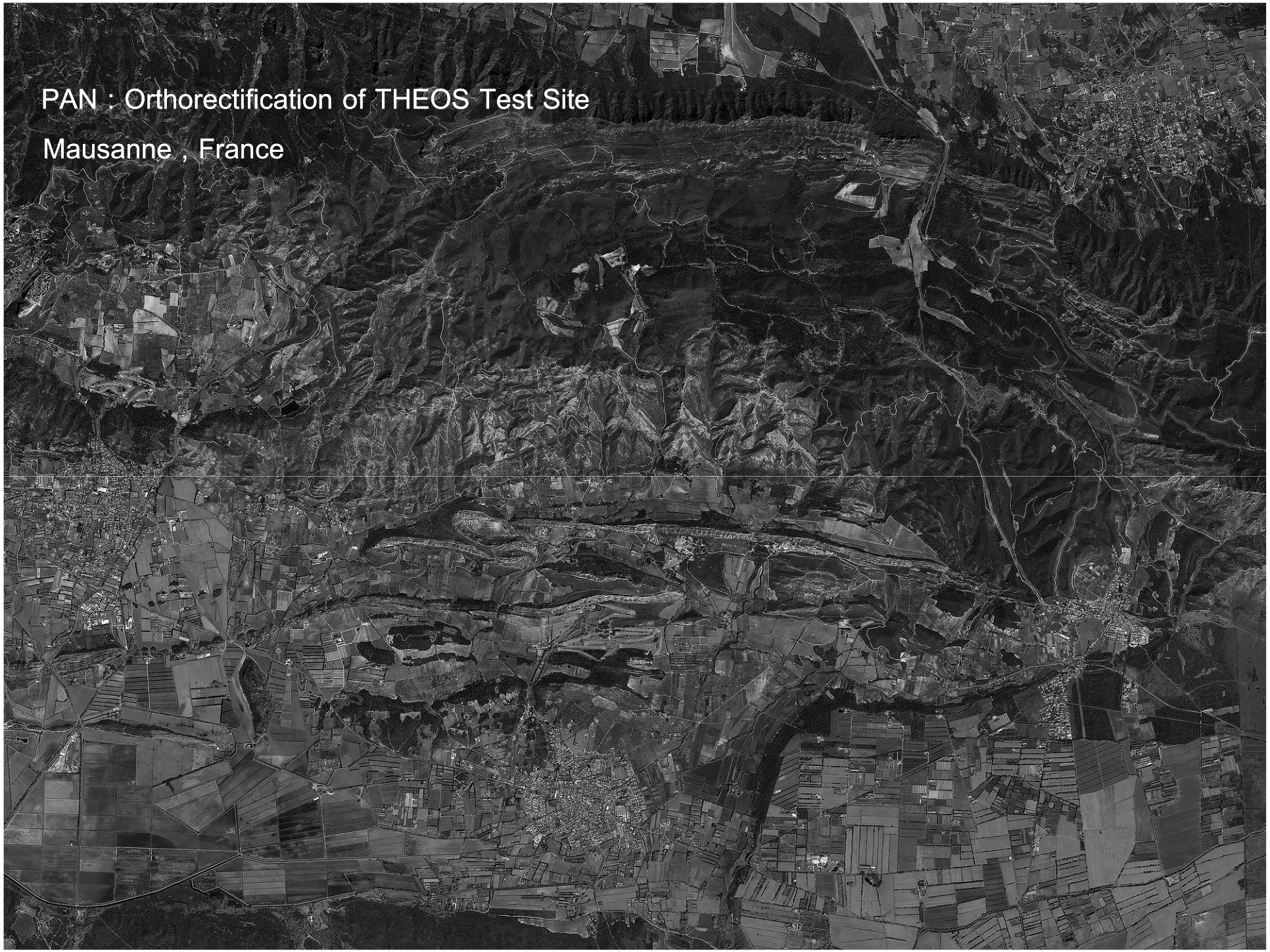
Orthorectification of THEOS imagery over Mausanne,France from SPACE METRIC

Type	Acquisition date	Incidence angle (degrees)	RMS Error_X	RMS Error_Y
PAN 1A	2/12/2009	5.0	1.1 m	0.8 m
	17/12/2009	21.6	1.2 m	1.0 m
	8/12/2009	37.2	0.9 m	1.4 m
MS 1A	2/12/2009	5.0	4.4 m	6.6 m
	8/12/2009	17.5	4.1 m	5.8 m
	17/12/2009	21.6	4.7 m	2.9 m

Ortho-rectification Image

Conclusions : Orthorectification of THEOS imagery

The results show that high accuracy can be obtained in THEOS imagery also at high incidence angles. Indeed, the accuracy appears to be independent of the incidence angle. On average pixel accuracy in PAN and 1/3 pixel accuracy in MS was found from the checkpoints. This is made possible by a combination of a rigorous orbital geometric model with the high quality of imagery and metadata in the basic images from GISTDA


PAN : Orthorectification of THEOS Test Site
Mausanne , France


MS : Orthorectification of THEOS Test Site
Mausanne , France

Cal/Val Projects 2010

- Participate Tuz Gölü Campaign
- Absolute Calibration (SADE Database)
- THEOS – Landsat cross calibration