SCRAMJET

Mapping and monitoring airports with Sentinel 1 and 2 data

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Urban geospatial mapping for the SCRAMJET business networking tool

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1. Problem and the target airports

Problem definition

- SCRAMJET: Business matching tool to connect business travellers at airports
  - Needs to identify **gates** and **buildings morphology** of about 200 airport
  - Uses Openstreet maps as base data (Google Maps will be used as reference only)

- SCRAMJET has two specific needs in order to have precise and updated maps
  - **Initial airport mapping:** some airports may have incomplete mapping with Openstreet
  - **Monitoring the airport changes:** detect changes on airports subject of works and transformations

Building morphology (outdoor and indoor)

POIs (indoor)

Gates (outdoor)

The study aims to confirm how Earth Observation satellites, in particular the latest Sentinels satellites, can be used to assure the best up-to-date outdoor mapping

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1. Problem and the target airports

Target airports definition

- 130 airports pre-selected
  - Sorted by the number of passengers/year
  - Grouped by continent: Europe 50, USA 50 and Asia 30
- Reference data used
  - IATA, ICAO, CANSO, Aeroportosdomundo, Wikipedia

Europe 50

Heathrow Airport
Paris Charles de Gaulle Airport
Istanbul Atatürk Airport
Frankfurt Airport
Amsterdam airport
Madrid Barajas Airport
München airport
Gatwick Airport
Barcelona El Prat Airport
Leonardo da Vinci–Fiumicino Airport

USA 50

Atlanta International Airport
O'Hare International Airport
Los Angeles International Airport
Dallas/Fort Worth International Airport
John F. Kennedy International Airport
Denver International Airport
San Francisco International Airport
McCarran International Airport
Charlotte Douglas International Airport
Miami International Airport

Asia 30

Beijing Capital International Airport
Dubai International Airport
Tokyo Haneda Airport
Hong Kong International Airport
Shanghai Pudong International Airport
Suvarnabhumi Airport
Singapore Changi Airport
Guangzhou Baiyun International Airport
Soekarno-Hatta International Airport
Indira Gandhi International Airport

Total of 9 airports were selected - 3 from each region (Lisbon - Pt, Ben Gurion - Israel added)

Sensing Data Timeframe: 1st December 2016 to 31st January 2017

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2. EO Data Availability

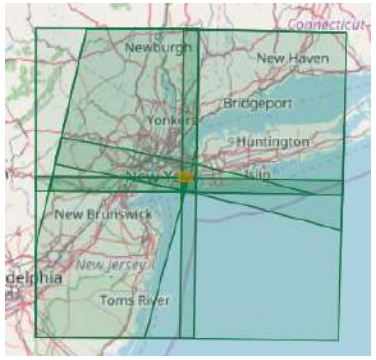
Sentinel-2 procurement

S2A has visible data from almost all airports

- including the 4 relevant bands with 10 m spatial resolution: B2, B3, B4 and B8.

Only a few issues found

- Munich during this period due to the cloud coverage
- JFK is right on the interception of 4 granules.



Europe

Lisbon 2016-12-19

Istanbul 2017-02-02

München No date

?

Asia

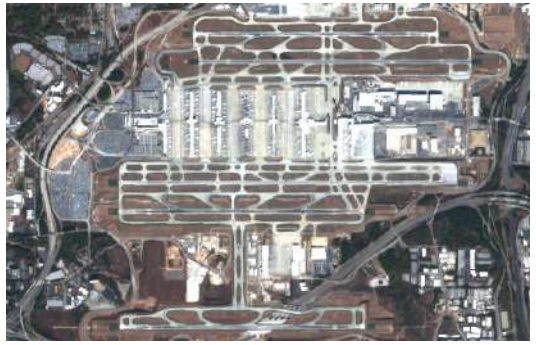
Abu Dhabi 2016-12-25

Israel 2017-02-10

Shanghai 2016-12-04

USA

Atlanta 2016-11-28



Miami 2017-01-06

New York 2016-12-04

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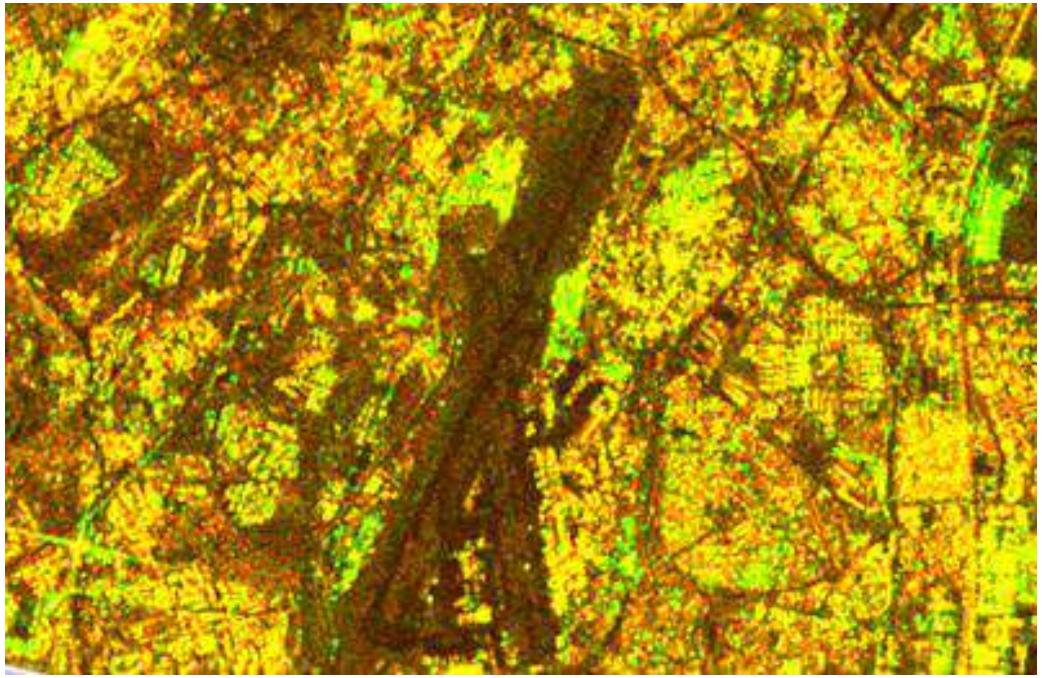
2. EO Data Availability

Sentinel-1 procurement

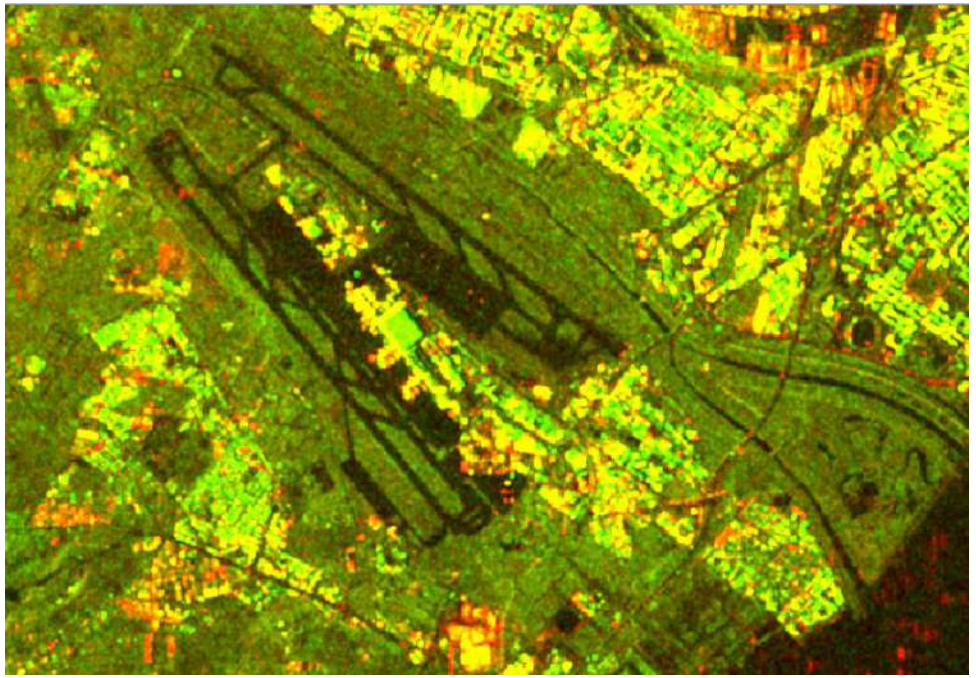
Lisbon 2017-01-19



SAR - Interferometric Wide swath (IW) mode VH VV

The acquisitions in **IW mode High Resolution** were widely available for all 9 airports selected (up to 25m)

Malaga 2014-11-27



SAR - Stripmap (SM) mode HH HV

Malaga was the only aerodrome found that was acquired in **Stripmap mode Full Resolution** (up to 10m)

2. EO Data Availability

Sum-up

- Sentinel 2 data procurement
  - Temporal frequency of Sentinel is fine
    - During winter season it may be dificult to capture images (e.g. Munique, Atlanta)
  - Spacial resolution may be just on the limit
    - Hardly recognize airplanes (see also analysis in 3.)
- Sentinel 1 data procurement
  - Very few Stripmode full resolution images are available (currently only some special zones – e.g. Gibraltar, Germany)
    - Used on request for extraordinary events such as emergency management
- Other open satellite data procurement (e.g. Landsat)
  - Landsat has worst quality

3. Airport Mapping analysis

Scope

- Analyse the adequacy of the procured data to meet requirements
  - Spectral, spatial and temporal resolution analysis
- Compare existing procured data with openstreet maps/google maps

GeoBasis-DE/BKG (© 2009)

München Airport in google maps has great resolution

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3. Airport Mapping analysis (3 case studies)

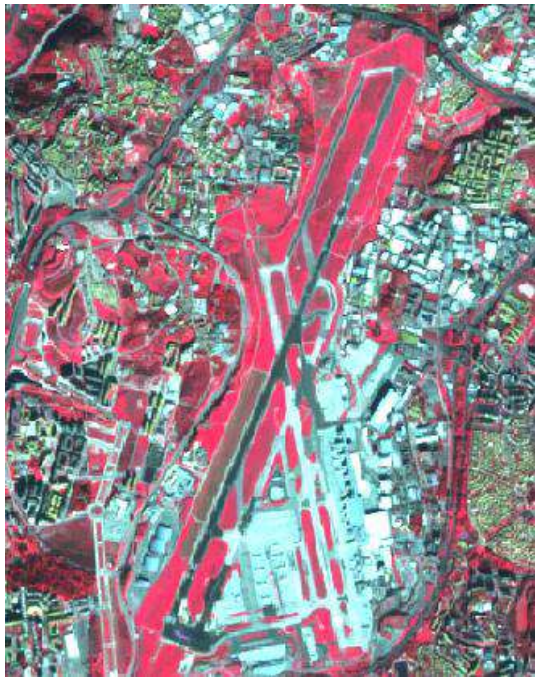
Lisbon (spatial and spectral analysis)

S2 Natural colour versus OSM

Hard to identify planes and gates
Many gates are mapped in openstreet maps

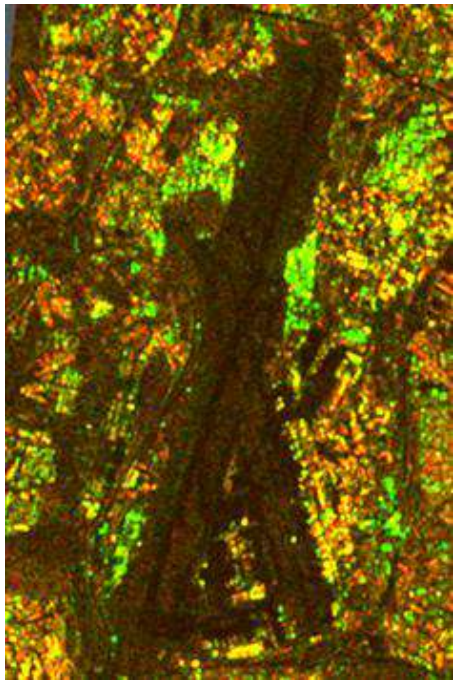
- 20 "aeroway"=>"gate
- 1 "aeroway"=>"helipad"

S2 infrared composition



Infrared composition In Lisbon during Winter may be an advantage to identify airport morphology

S1 analysis



IW High Resolution mode is not so good
Grass is difficult to distinguish from runways

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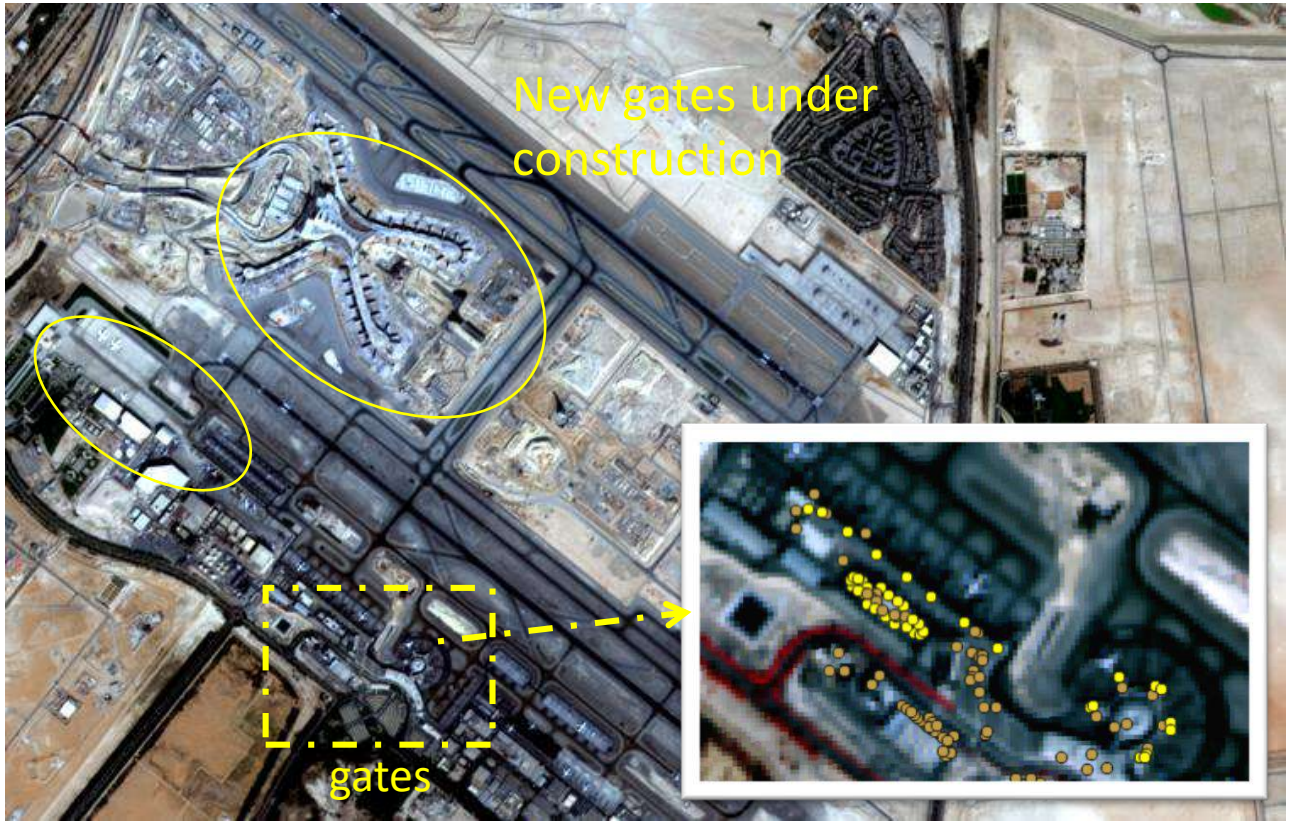
3. Airport Mapping analysis (3 case studies)

Abu Dhabi and Istanbul (natural colour analysis)

Abu Dhabi International Airport - 2016-12-25



- Very good visibility (parked airplanes are visible)
- New gates under construction
- 41 gates are mapped in OSM (new gates are not yet available on OSM)

Istanbul - 2017-02-02

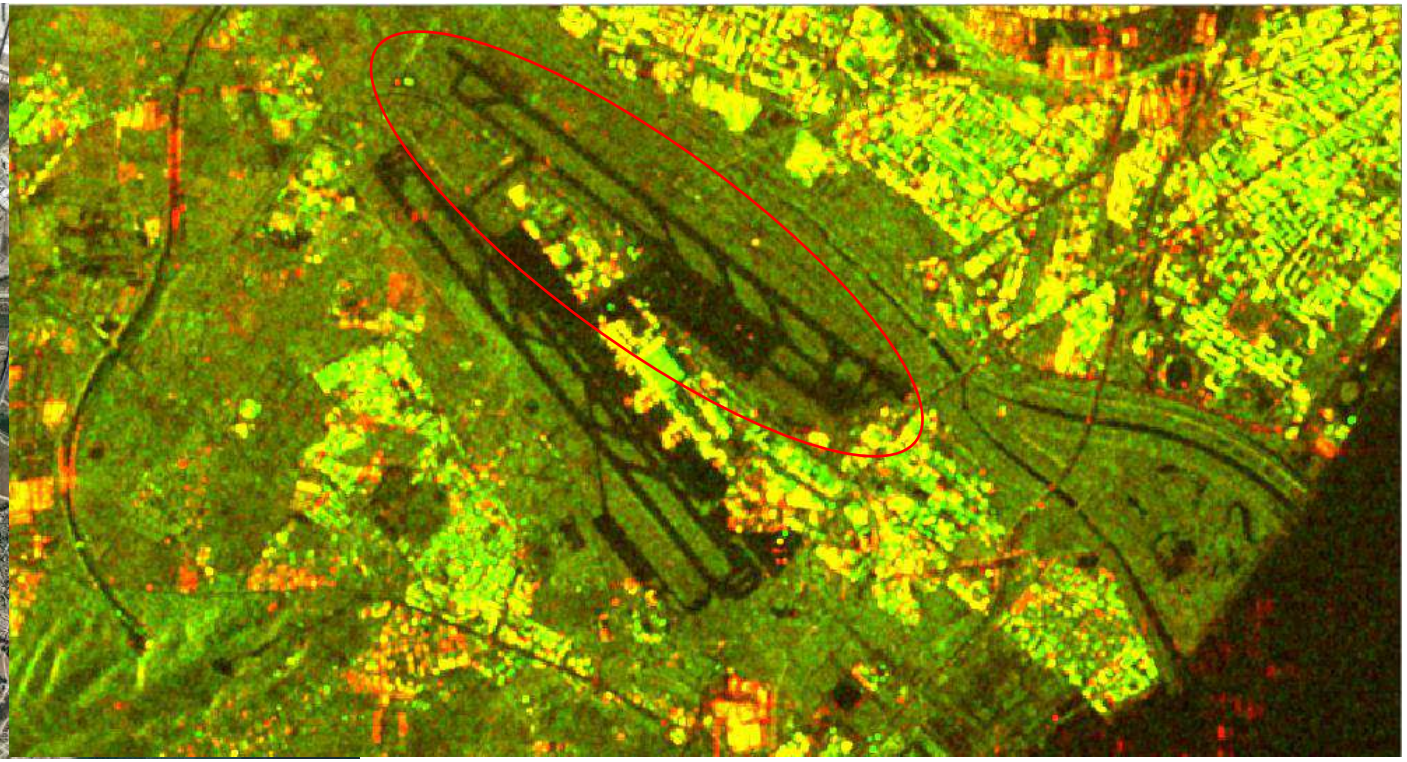
- Good visibility
- No gates available on OSM
- Additional support photos and maps needs to be used

3. Airport Mapping analysis (additional case study)

Malaga (4th busiest airport in Spain) - Sentinel-1 analysis

Google maps were outdated

A 2nd runway opened at the airport on 26 June 2012.



S1 2014-11-27

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3. Airport Mapping analysis

Non-open EO data

Satellite	Product
Pléiades 0.5-m €250.00	Lisbon airport Apr 6, 2016  Invoiced Surface: 19 km² PMS - Pansharpened 50cm 4-band DIMAP - 12 bits (JPEG 2000) / 16 bits (GeoTIFF)
SPOT-6 1.5m €380.00	Dec 5, 2015 11:02:52 AM  Pansharpened 1.5m 4-band DIMAP - Regular JPEG 2000 bits (JPEG 2000) / 16 bits (GeoTIFF) **Coordinate system** WGS 84 / UTM Zone 29N
Deimos-2 – 1m – 4m	Mini-satellite for high-resolution EO applications from Deimos Imaging subsidiary of Urthecast 1 m panchromatic and 4 m multispectral images swath of 12 km at nadir, at an orbit altitude of ~600 km. Multispectral with 4 channels in the visible and near-infrared spectral range (red, green, blue and NIR).

Pléiades, **Langkawi International Airport (LGK),** Malaysia - 2017

Lisbon

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3. Airport Mapping analysis

Conclusion

Morphology

- Some Sentinel-2 images may be used to support visual mapping and validation of morphology
- Additional support photos and maps may be needed.
  - Note that Airport Buildings do not have clear boundaries. They are often confused with surrounding builds (hotels, etc…)
- Sentinel 1 can be also support the identification of runways and build-up areas

Gates

- Not all airports have gates identified in OSM
- Additional support photos and maps may be used for mapping
- Sentinal-2: some airports may be possible to identify gates

Acquisition frequency of Sentinel is a great benefit.
Best solution uses a combination of different sources depending on location.

	S2	S1	Pleiades	OSM
Lisbon	Blurred	Low resolution (IW)	N/P	20 gates
Istanbul	Good visibility	N/P	N/P	No gates
Abu Dhabi	Very good visibility	N/P	N/P	41 gates
Malaga	N/P	Good resolution (SM)	N/P	N/P
Malaysia	N/P	N/P	V High resolution	N/P

4. Monitoring the airport changes

Approaches analysed

Land Cover changes

Urban to demolition

Demolition/Null Soil/Vacant Land to Urban

Change detections w/ Sentinel-2 in reasonable number of pixeis (between 9=3x3 a 25=5x5)

- Detection Ratio Of Means using NIR and SWIR individual bands
- Detection Root mean square differences between sets of bands
- Normalized index change detections (NDBI)
- Post Classification Comparison

  Abandoned since it was considered more relevant with global and regional scales

InSAR w/ Sentinel-1

- Detect surface deformations using InSAR technique
  - Analysis of the phase difference between two radar signals acquired from the same area at different times
- Identify hotspots Subsidence resolve millimetre-scale urban ground movements
  - Requires at least 10 SAR images. It was considered expensive in terms of resources and costs and thus dropped

Case Study Rio Galeão airport

Extension performed for 2016 Olimpic Games

Sentinel-2	23rd June 2015 (Sentinel-2A) 7th March 2017 (Sentinel-2B)

Sentinel-1	3rd April 2014 (Sentinel-1A) 25th April 2016 (Sentinel-1B)

4. Monitoring the airport changes

Validation of Rio Galeão case study (Sentinel-2)

Rio de Janeiro works started in 2014 and finished in Abril 2016

2014-08-03

2016-11-17

2015-08-08: 1st S2 image available

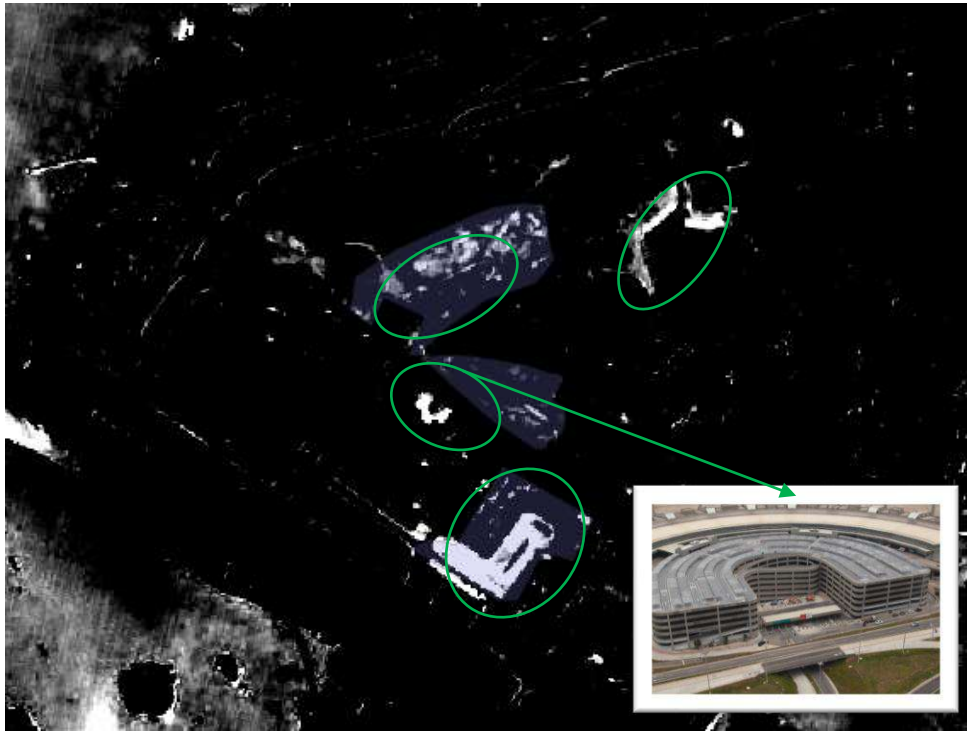
2016-11-10: S2 image after works

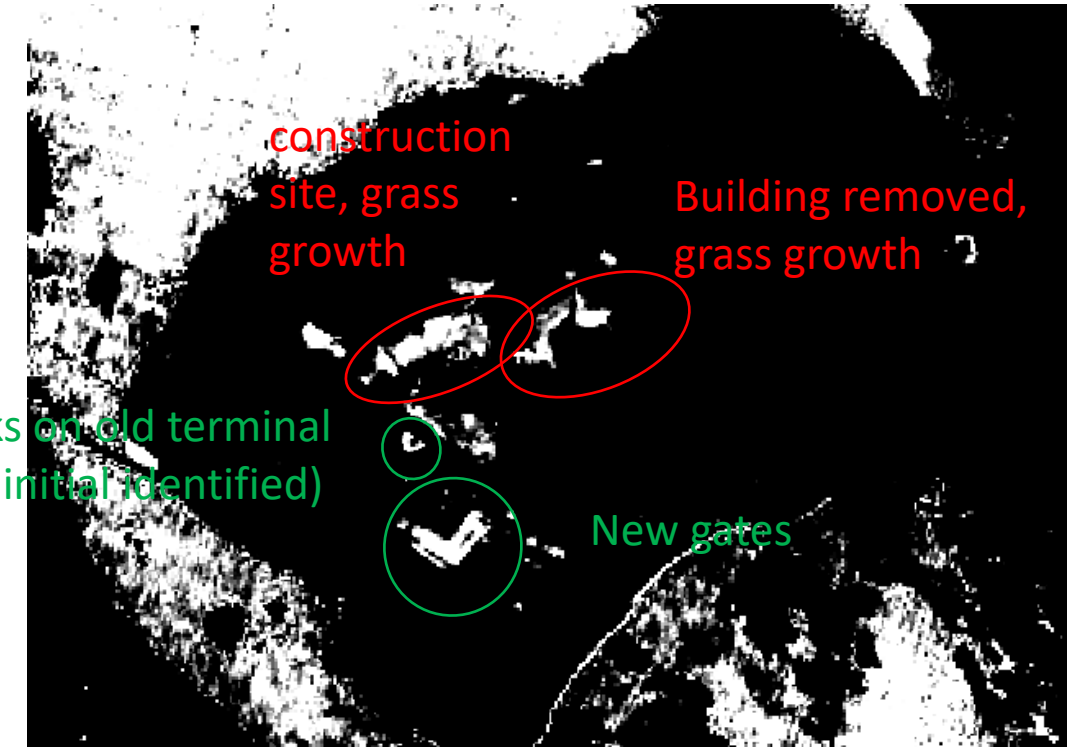
New gates

4. Monitoring the airport changes

Validation with Ratio Of Means using NIR and SWIR band

- Ratio of means with NIR (2015 B8 / 2016 B8) and SWIR (2015 B11 / 2016 B11) pair of images





Acceptable detection with NIR – detector needs improvement to be bounded and normalized

Acceptable detection with SWIR - it has less resolution also achieved similar results

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4. Monitoring the airport changes

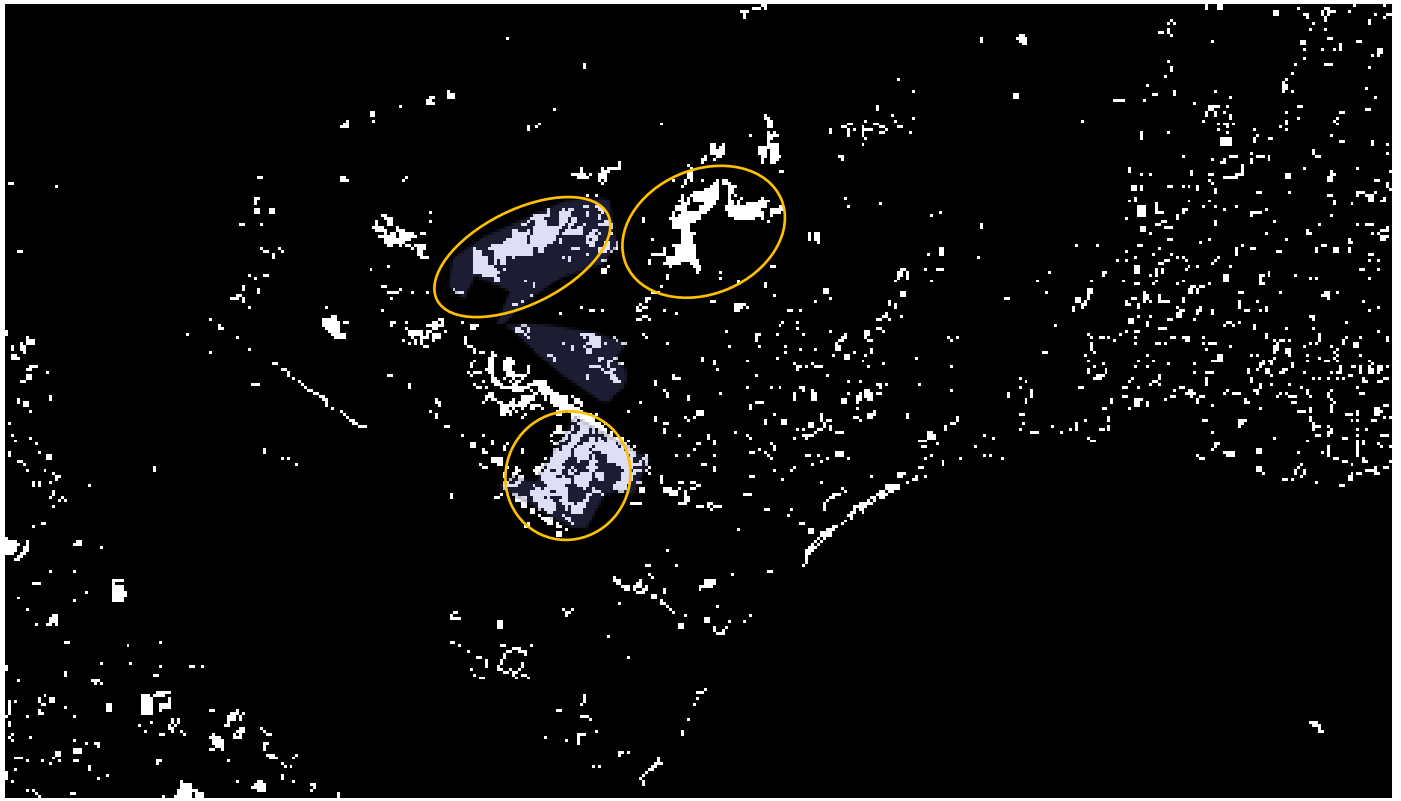
Validation with Root mean square differences using 4 bands

Root Mean Square Differences was computed with the visible and near infrared bands (B2, B3, B4 and B8).

Unclear detection

Although the high density areas allows to identify the change spots they are not well defined

Areas susceptible of works that requires SCRAMJET update



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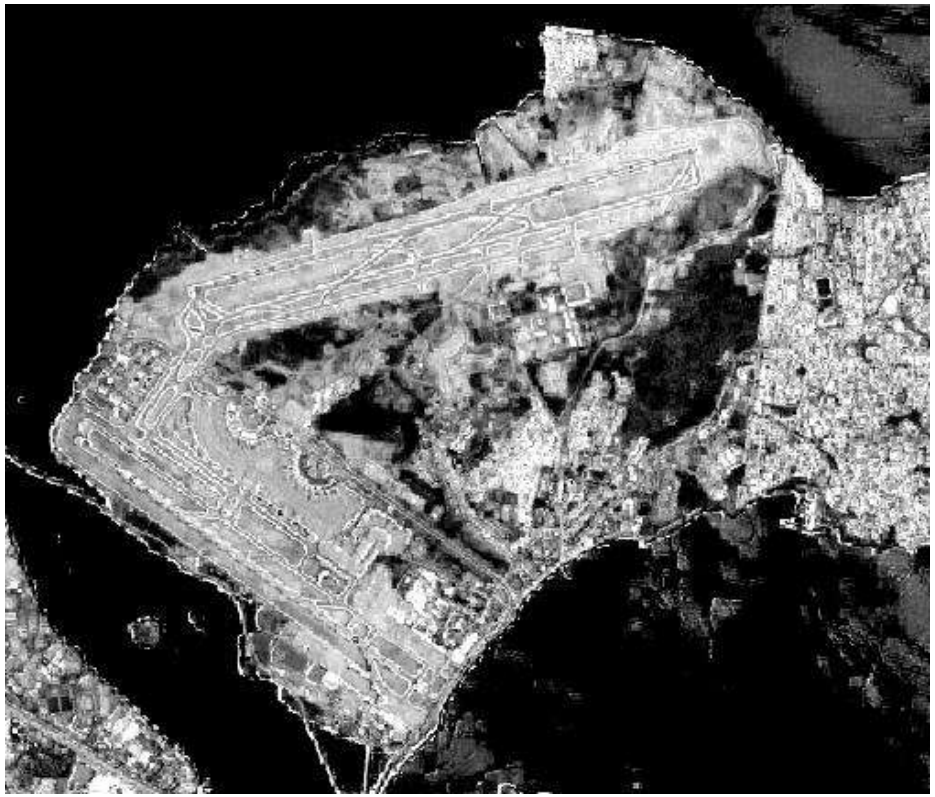
4. Monitoring the airport changes

Validation with NDBI (Normalized Difference Built-up Index)

NDBI for S2 uses SWIR (B11) e NIR (B8)

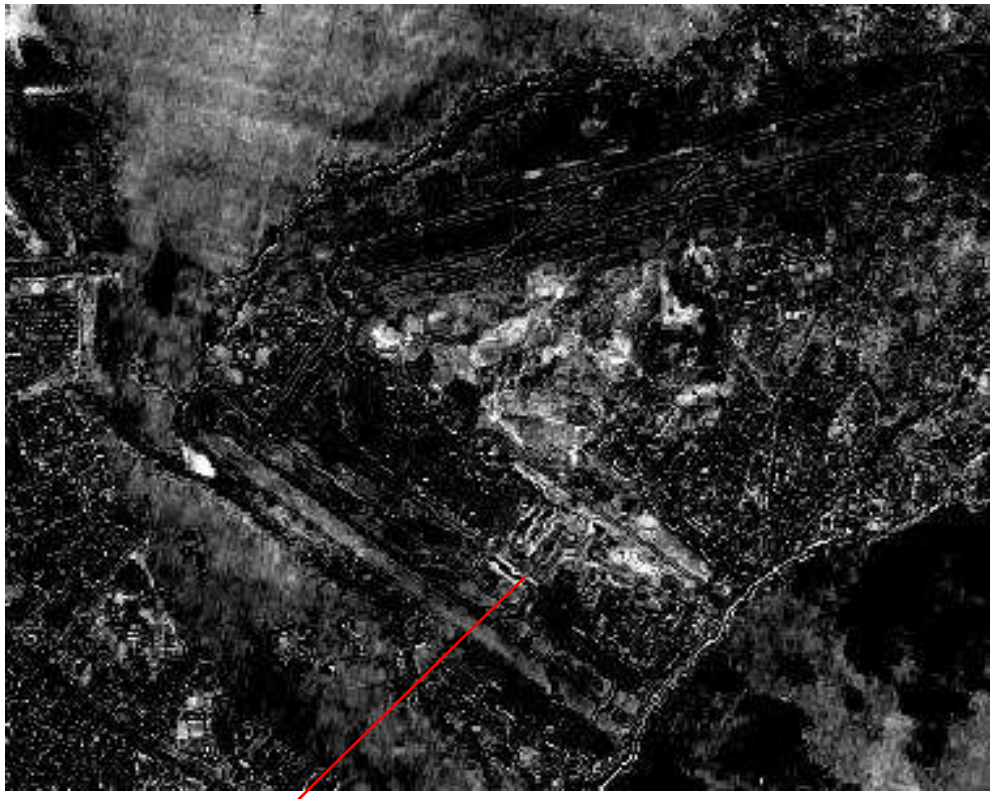
$NDBI_{S2} = (B11 - B08) / (B11 + B08)$

NDBI 2016



NDBI may be good to improve morphology mapping

Change detection: NDBI 2015 / NDBI 2016



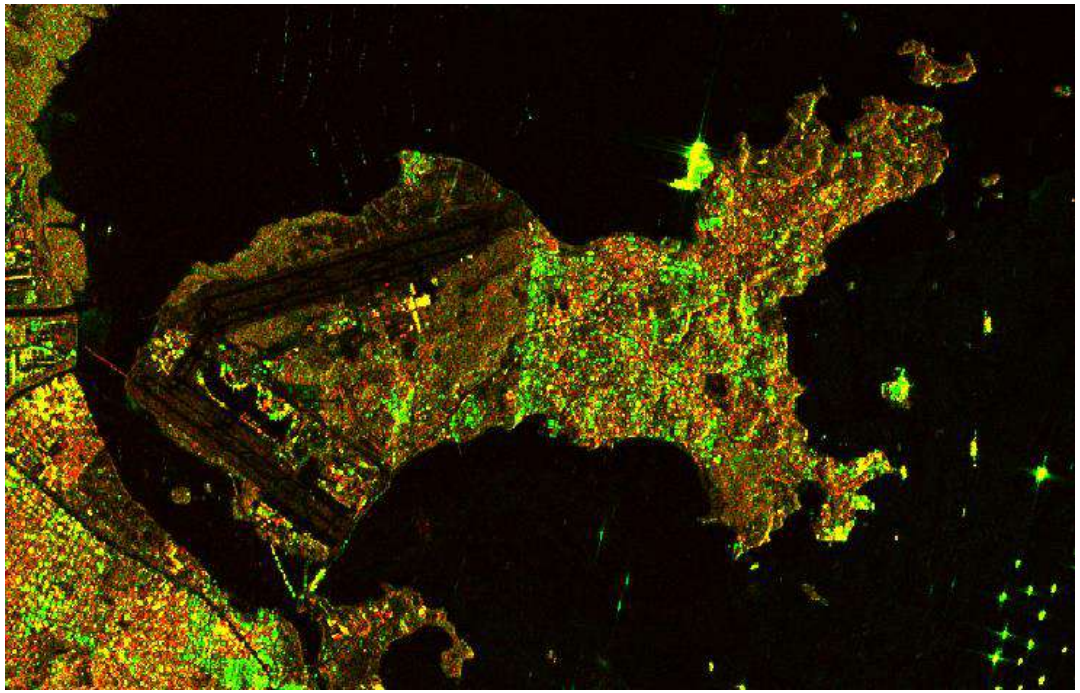
Confusing detection. No use.

4. Monitoring the airport changes

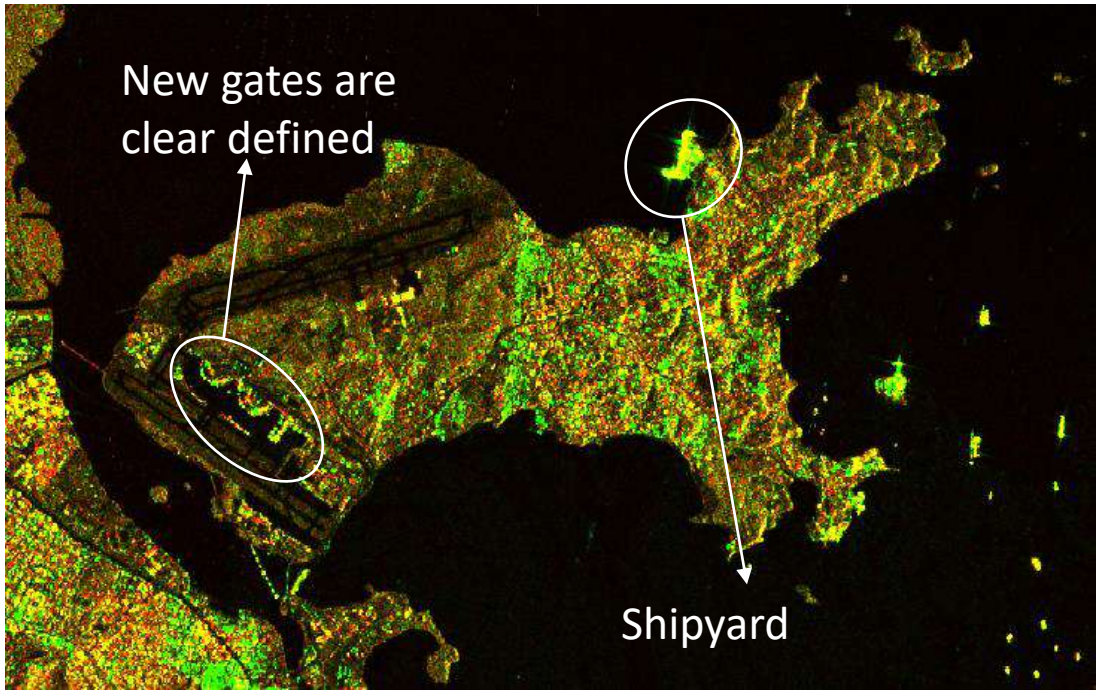
Validation with Interferometry processing of a pair of S1 images

RGB colour-composite from VH and VV polarization images before and after works

2015-08-12 Intensity VH and VV



2016-11-16 Intensity VH and VV

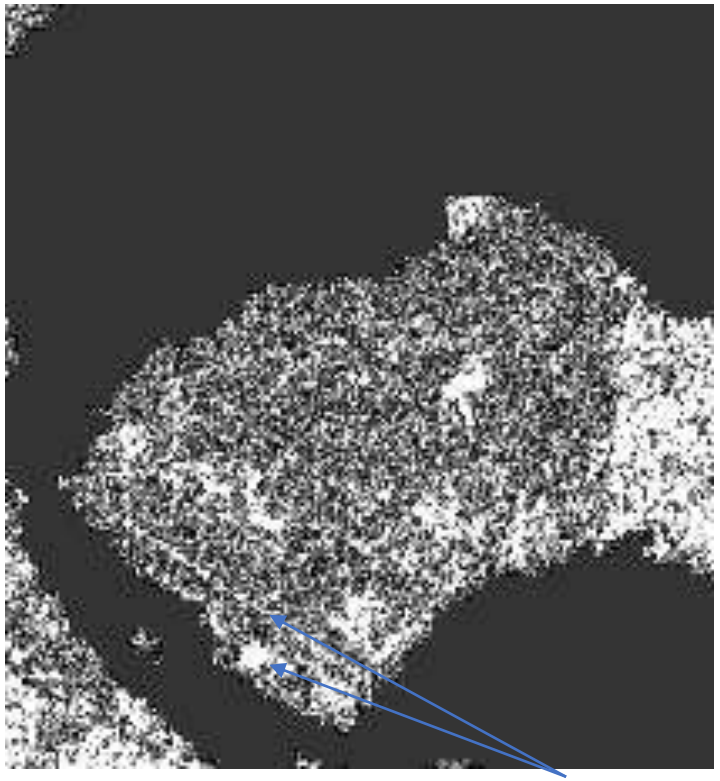


4. Monitoring the airport changes

Validation: Interferometry processing of a pair of S1 images

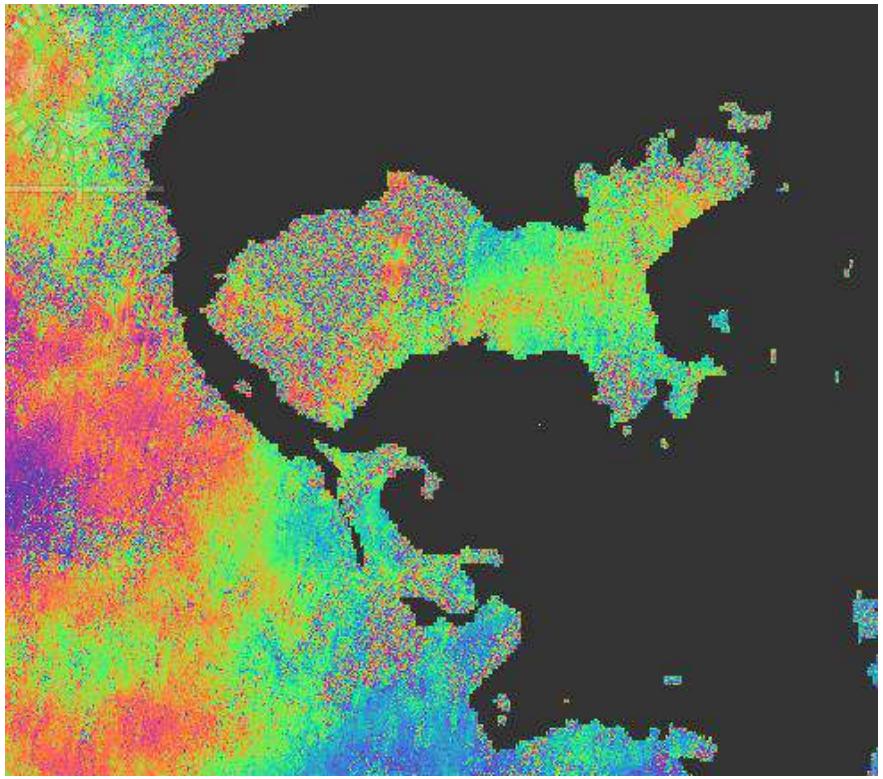
Analysis of the phase difference between two radar signals acquired at 2015-08-12 and 2016-11-16.

Coherence estimation 2015/2016



Low coherence: Runway and some buildings seem the only thing that was maintained (bright areas)

Phase Interferogram 2015 / 2016



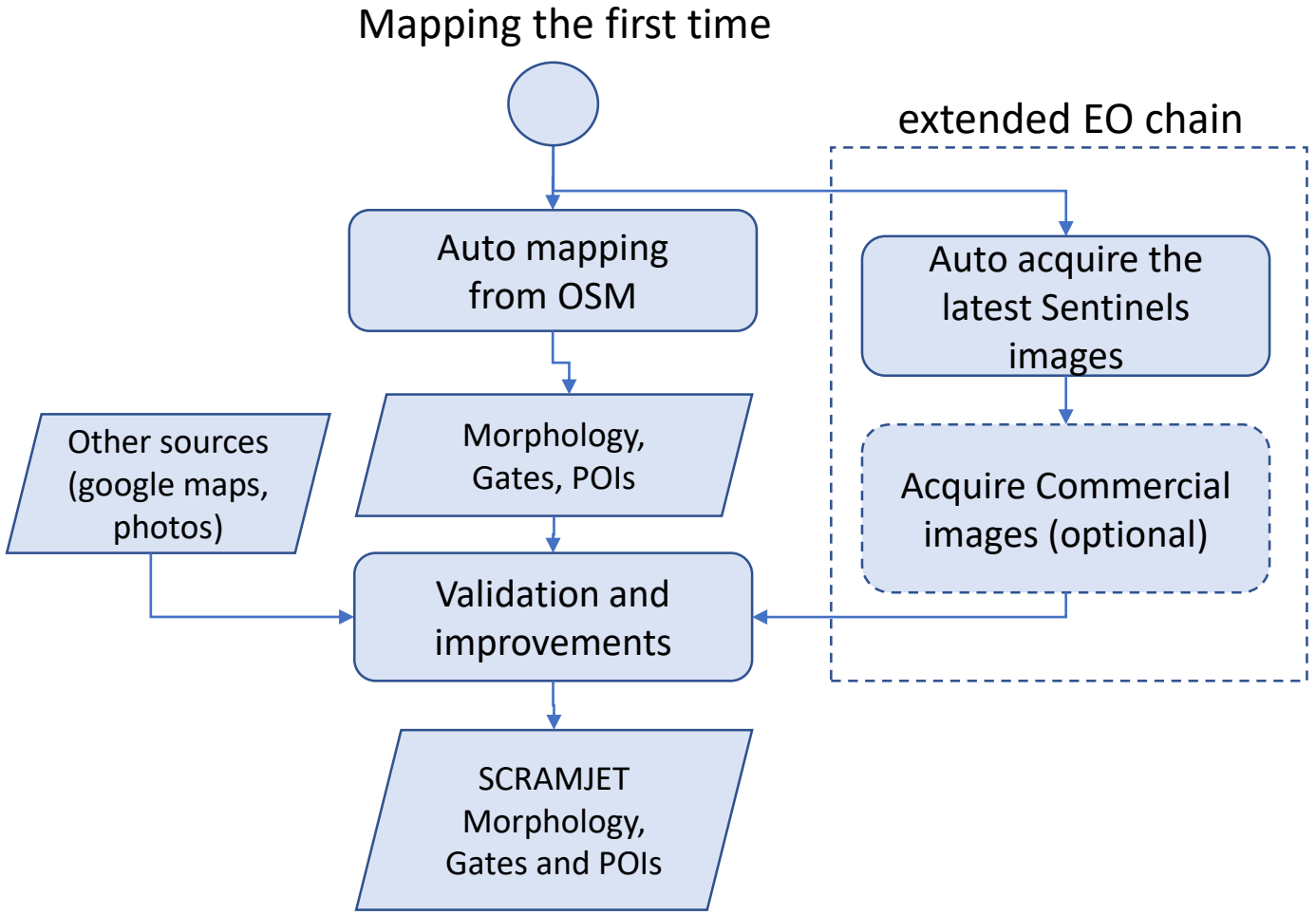
Not effective

Although the interferogram needs to be analysed by a specialist, the preliminary analysis does not spot relevant changes and the spatial resolution may not be sufficient.

5. Conclusion and Recommendations

Mapping of morphology and gates

- Sentinels lacks spatial resolution but its great temporal resolution allows to get very up-to-date data
  - Visual inspection can be used for validation and mapping improvement
  - Some morphology automation can be performed but it will always require manual effort
- Commercial acquisition of very high resolution images is not so expensive and thus could be performed when it is needed



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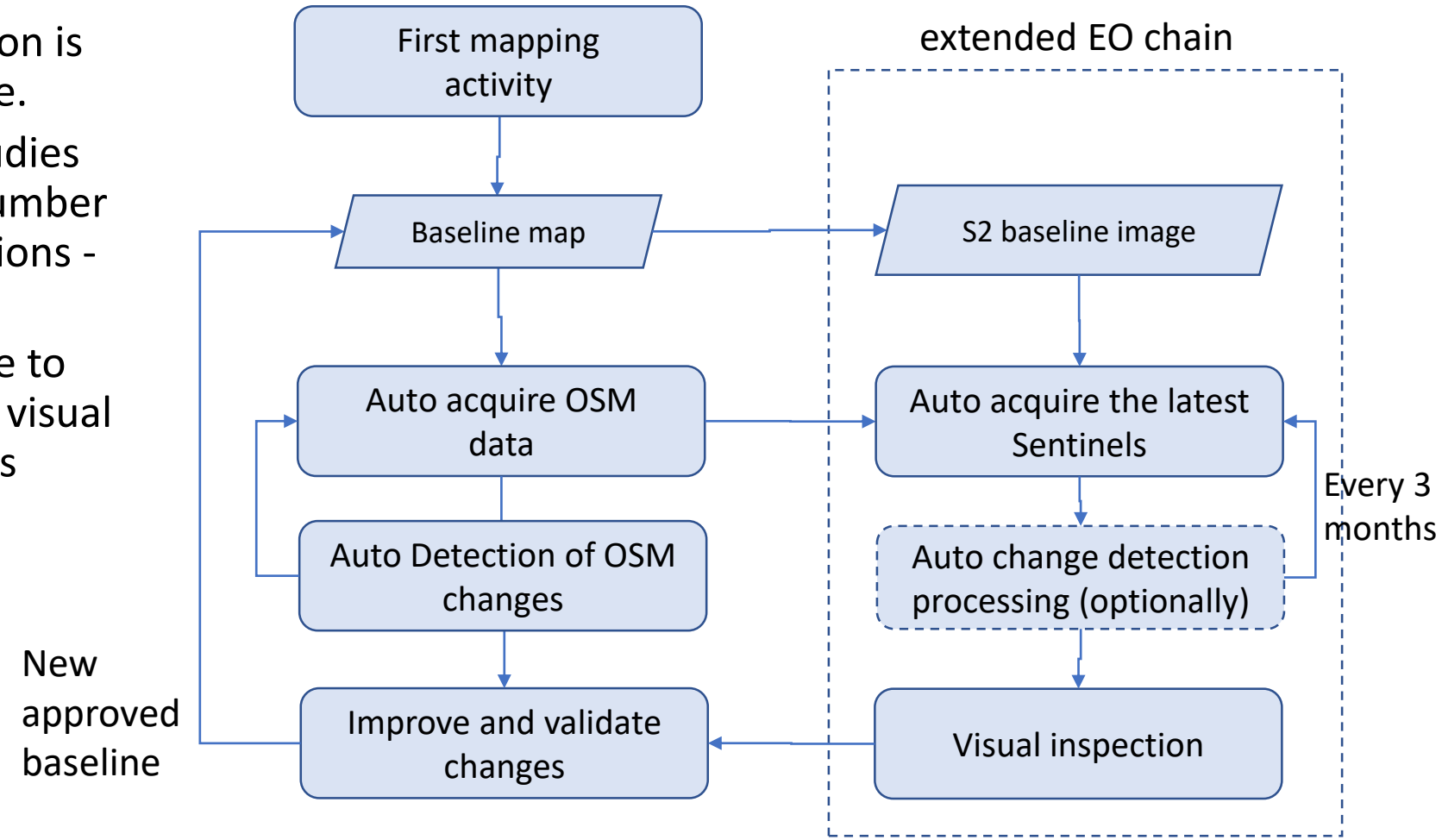
5. Conclusion and Recommendations

Monitoring the airport changes

- NIR and SWIR change detection is the most promising technique.
  - Requires further case studies and investigation (e.g. number of true positives - detections - and false positives)
- Automation tasks are possible to detect changes supported by visual inspection to confirm changes



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5. Conclusion and Recommendations

Final recommendations

The SCRAMJET recommended approach for a target of 200 airports

- Mapping with visual inspection of Sentinels
  - Use automatic data acquisition and pre-processing
  - Sentinels will used for mapping validation and improvement (or complement existing sources)
- Semi automatic change detection
  - Automatic change detection is technically feasible to generate alerts.
    - The algorithms need to be fine-tuned for the airports particular needs with more case studies
  - Frequency can be triggered with OSM changes or fixed (every 3 months)

A proof-of-concept is recommended to validate the assessment

- Start with up to 10 airports
- Automate data acquisition and pre-processing of Sentinels images per airport
- Automate change detection processing to start collecting validation results and fine processing algorithm

Mapping and monitoring airports with Sentinels

THANK YOU

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