



Aalto University
School of Electrical
Engineering

ICEYE

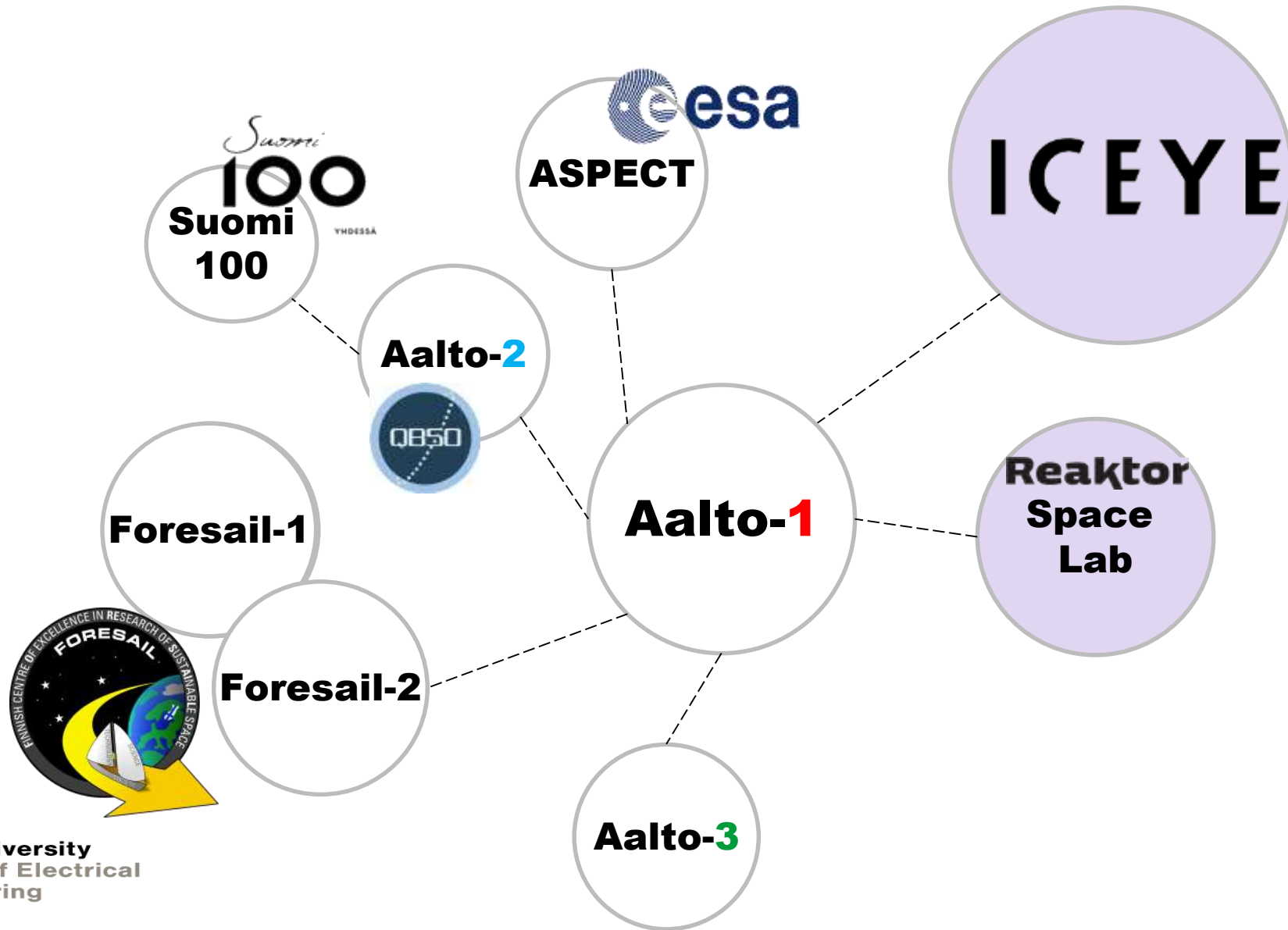
Operational microsatellite based SAR for Earth Observation applications: Status and perspectives

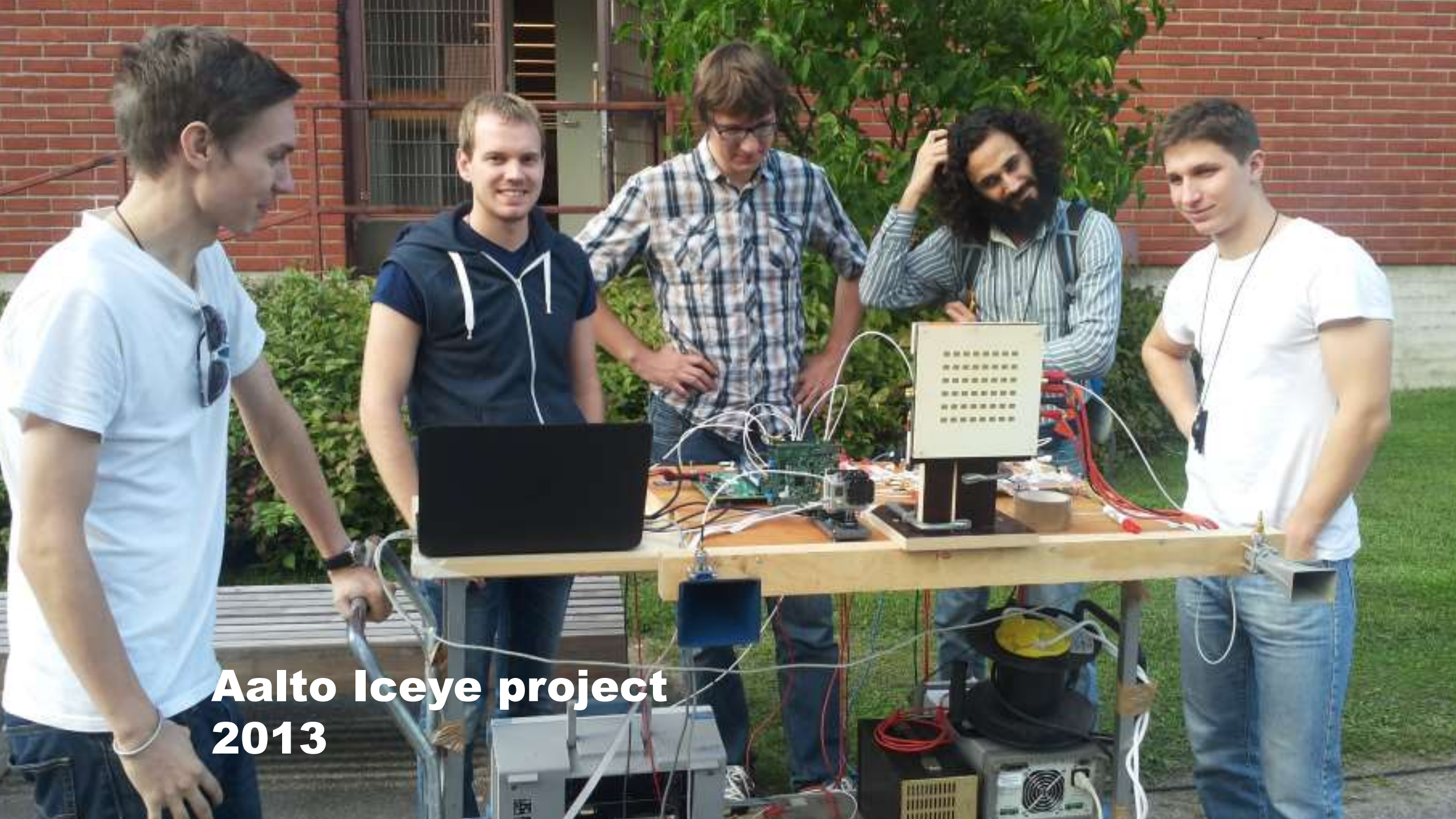
Oleg Antropov^(1,2), Jaan Praks⁽¹⁾, Miska Kauppinen⁽¹⁾, Pekka Laurila⁽²⁾,
Vladimir Ignatenko⁽²⁾, Sanja Sepanovic⁽²⁾, Rafal Modrzewski⁽²⁾

(1) Aalto University, School of Electrical Engineering, Department of Electronics and
Nanoengineering

(2) ICEYE Ltd, Espoo, Finland

In the center of small satellite ecosystem

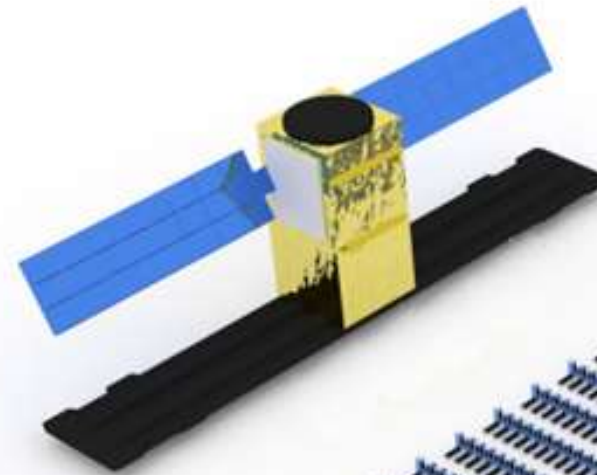




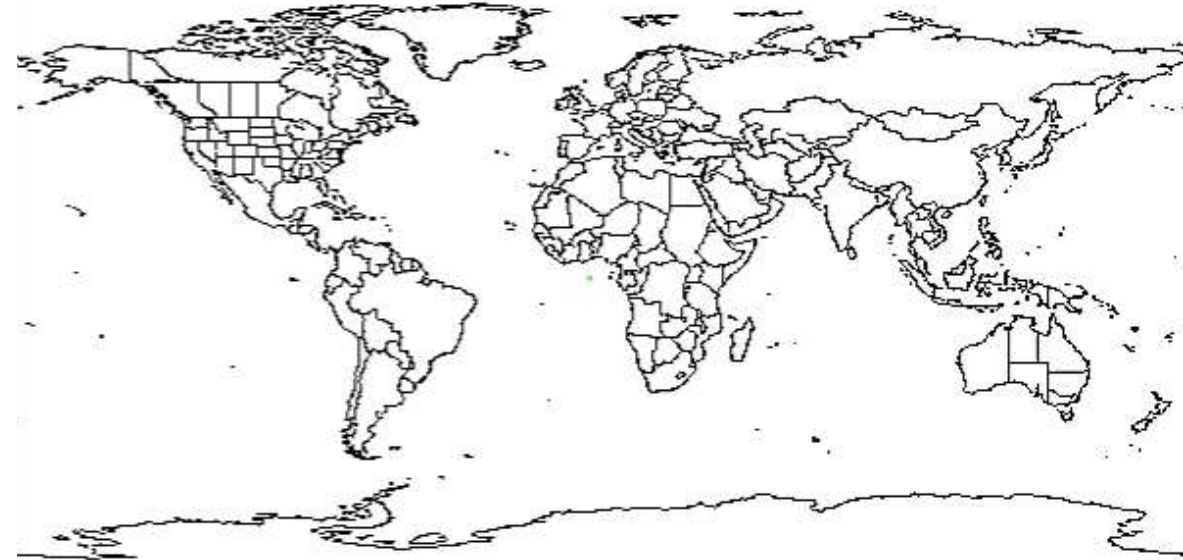
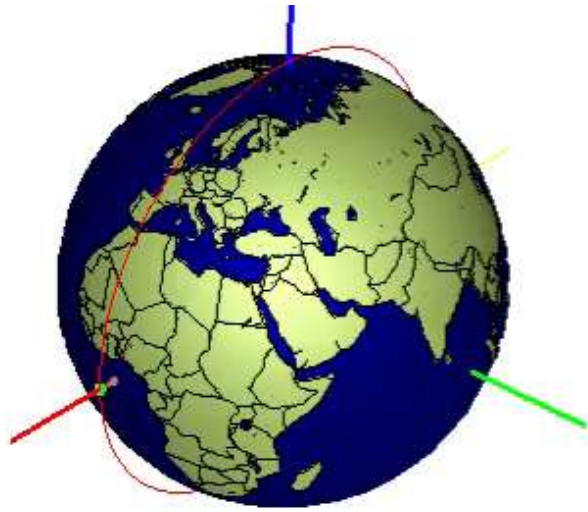
**Aalto Iceye project
2013**

Motivation

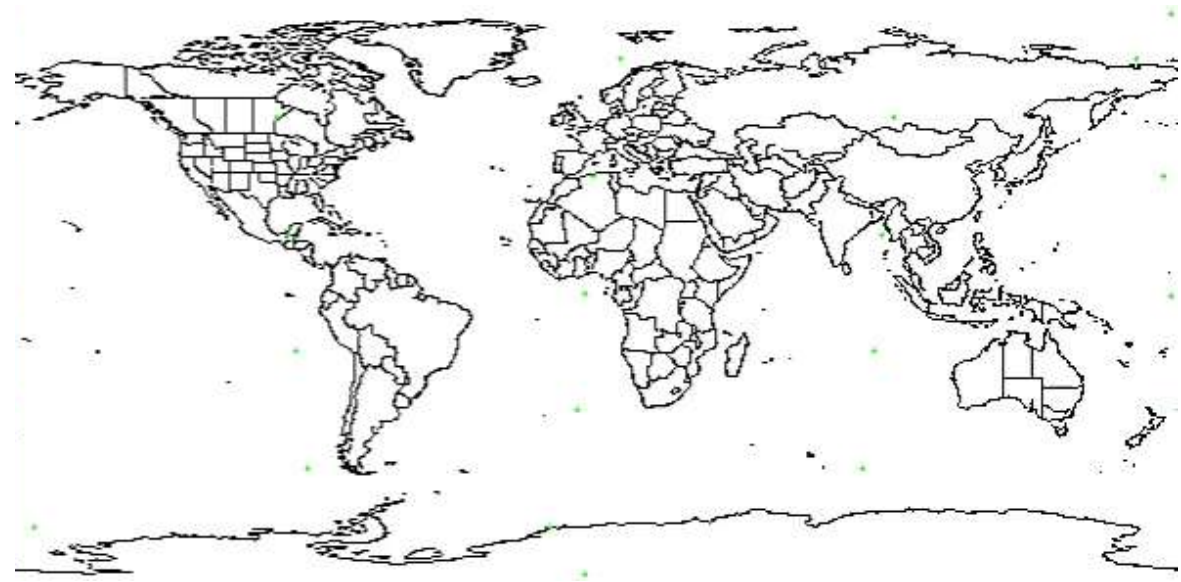
- **Strong market demand for near-real-time monitoring**
- **Satellite constellation is only way to provide global coverage**
- **Constellation is viable only when cost of single unit is low enough**



One satellite is good



Many satellites are better



ICEYE

**WORLD LEADER IN SMALL SAR
SATELLITES**

Finnish company of 50 people
A-round investments 7 M\$
B-round investments 34 M\$

2012

Development at
Aalto
SAR
demonstrations

2015

- Company starts
- Satellite building starts

2018

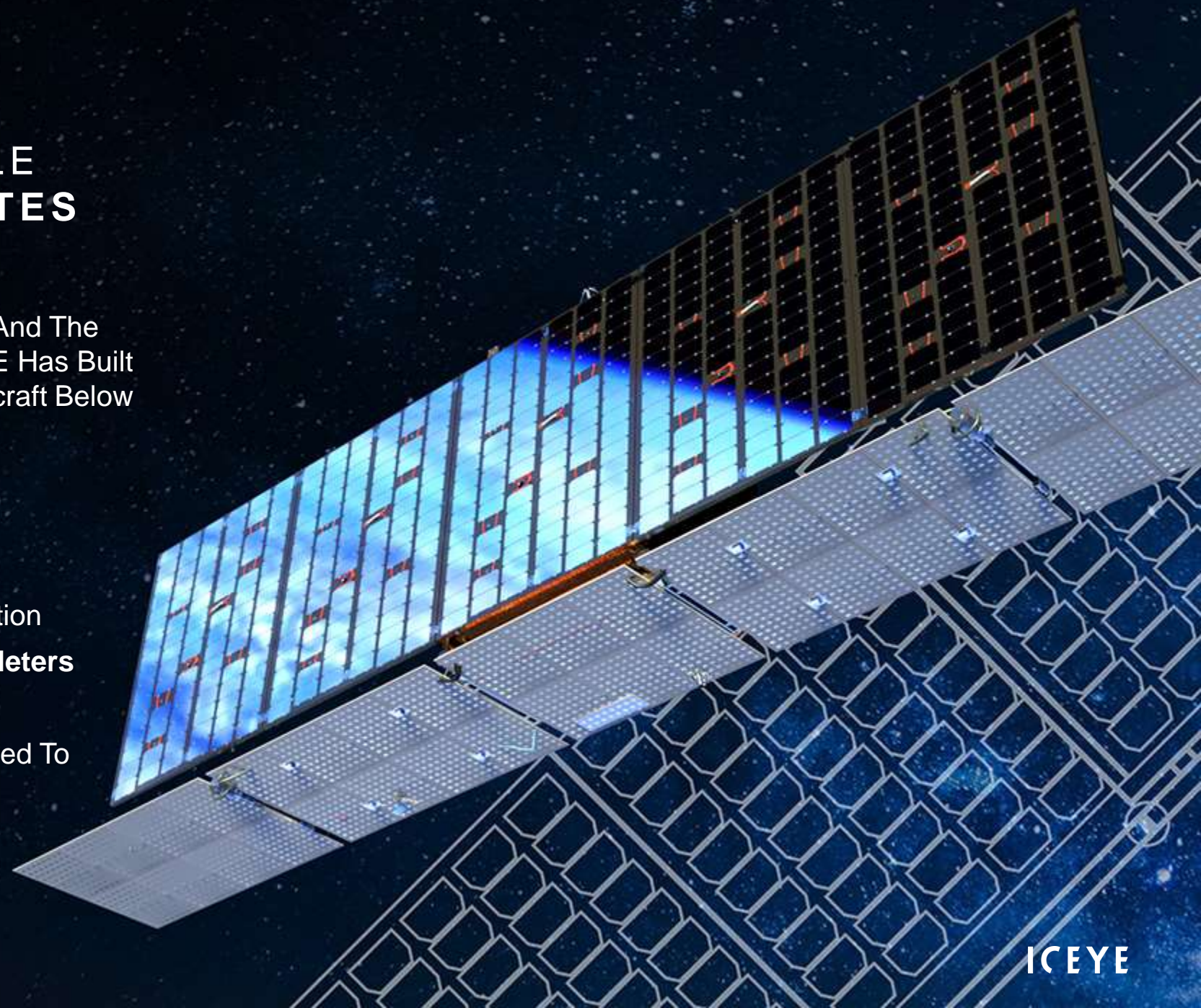
- First satellite launch
- 34 M\$ investment round B

THE MOST VERSATILE SAR MICROSATELLITES

Adopting Cutting-edge Technologies And The New Space Design Philosophy ICEYE Has Built The World's First Sar-capable Spacecraft Below 100kg Mass.

FEATURES:

- **Microsatellite** Class Spaceraft
- **ICEYE-X1** At 10x10 Meter Resolution
- Future Satellites Resolution **3x3 Meters**
- **Proprietary SAR Instrument**
- **100-fold Cost-efficiency** Compared To Traditional SAR Satellites









X1 SAR instrument

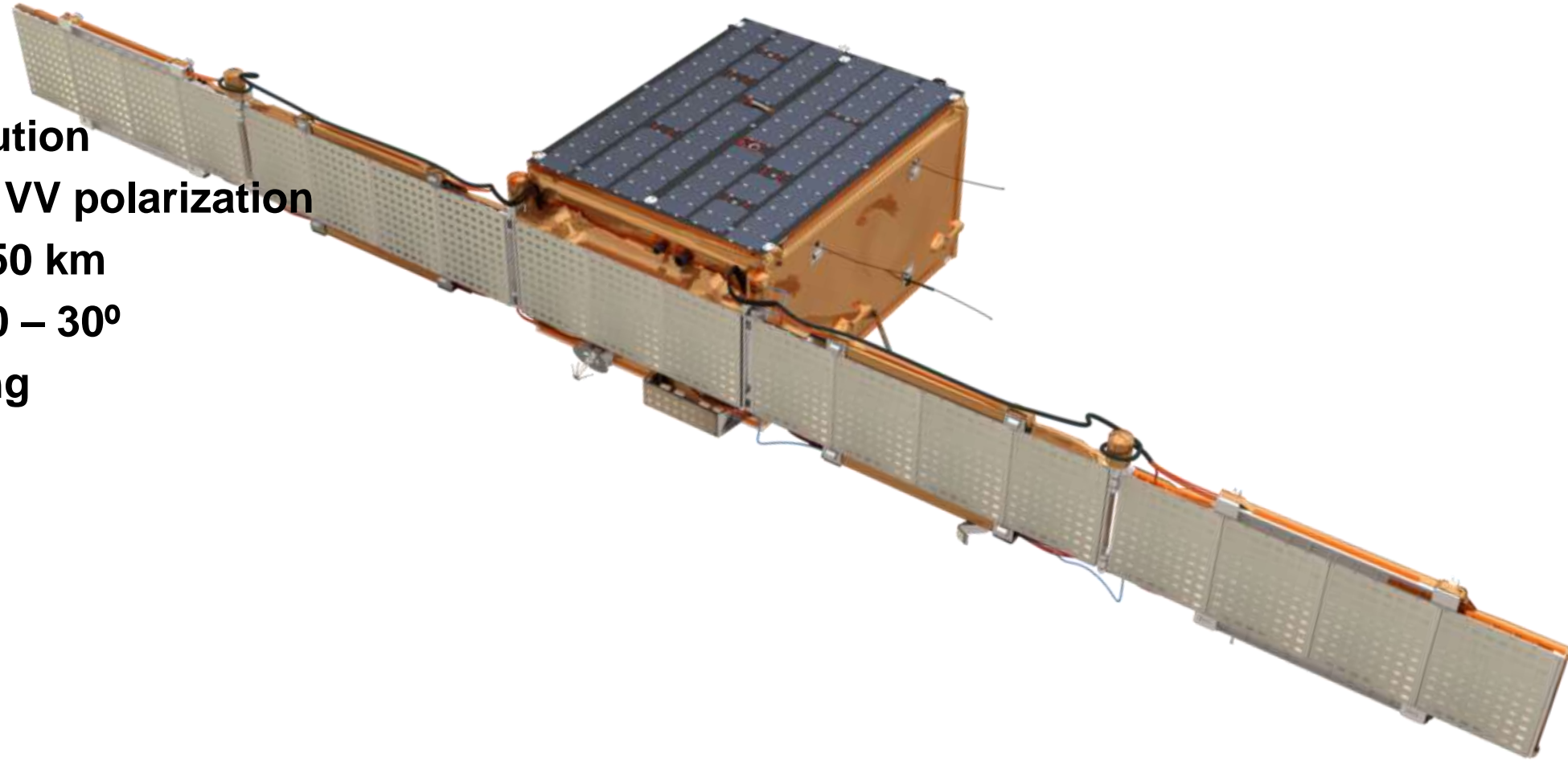
10 m ground resolution

X-band (9.65 GHz), VV polarization

Swath width: 20 – 50 km

Incidence angle: 10 – 30°

Left or right imaging



X1 satellite launch and orbit

Launcher PSLV

PSLV C40 launch campaign

18 January 2018

Orbit: 500 km SSO

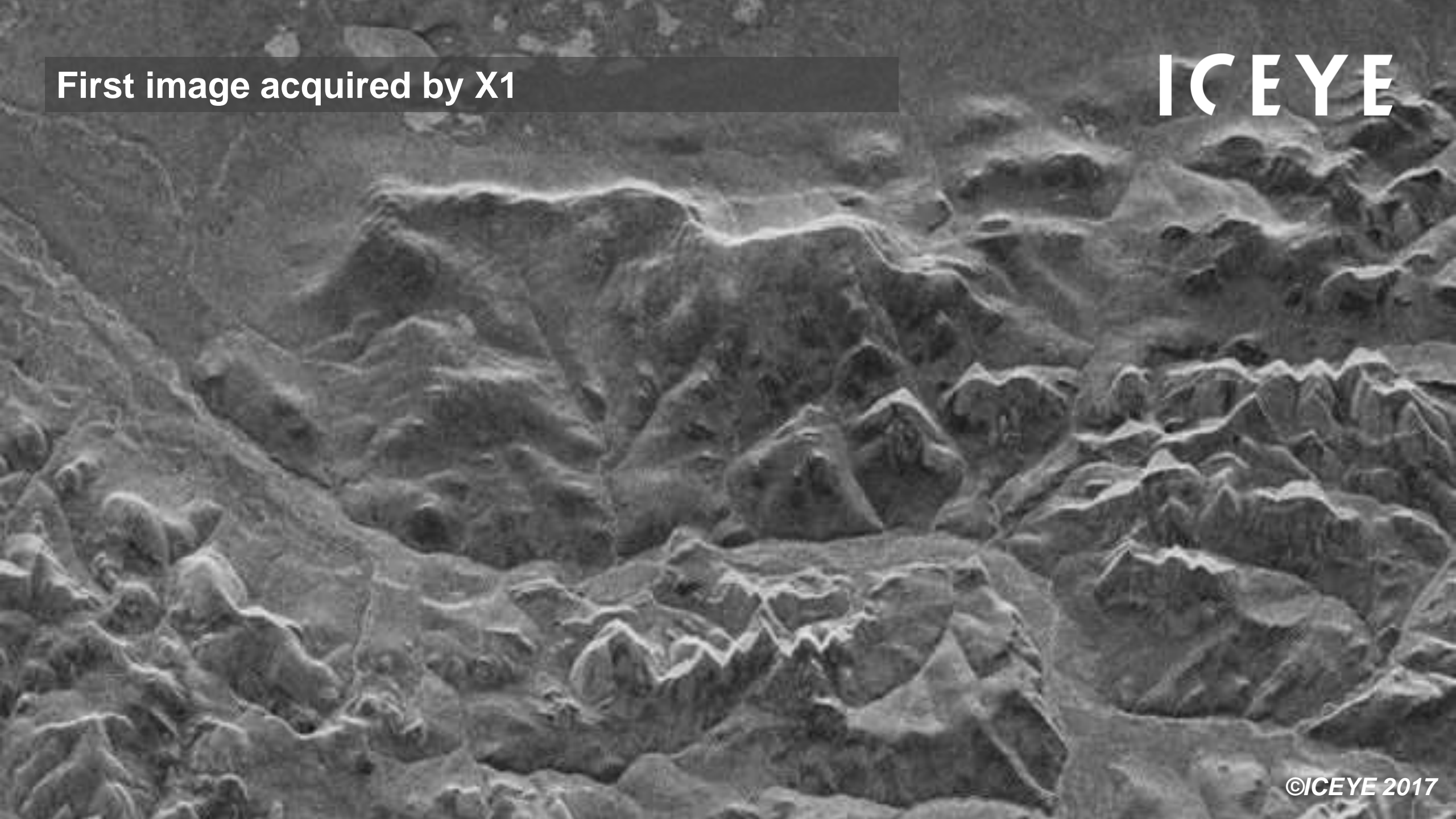


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First image acquired by X1

ICEYE



Data quality assessment for X-1 imagery

Visual comparison with:

- **ESA Sentinel-1 (C-band)**
- **DLR TerraSAR-X/TanDEM-X (X-band)**

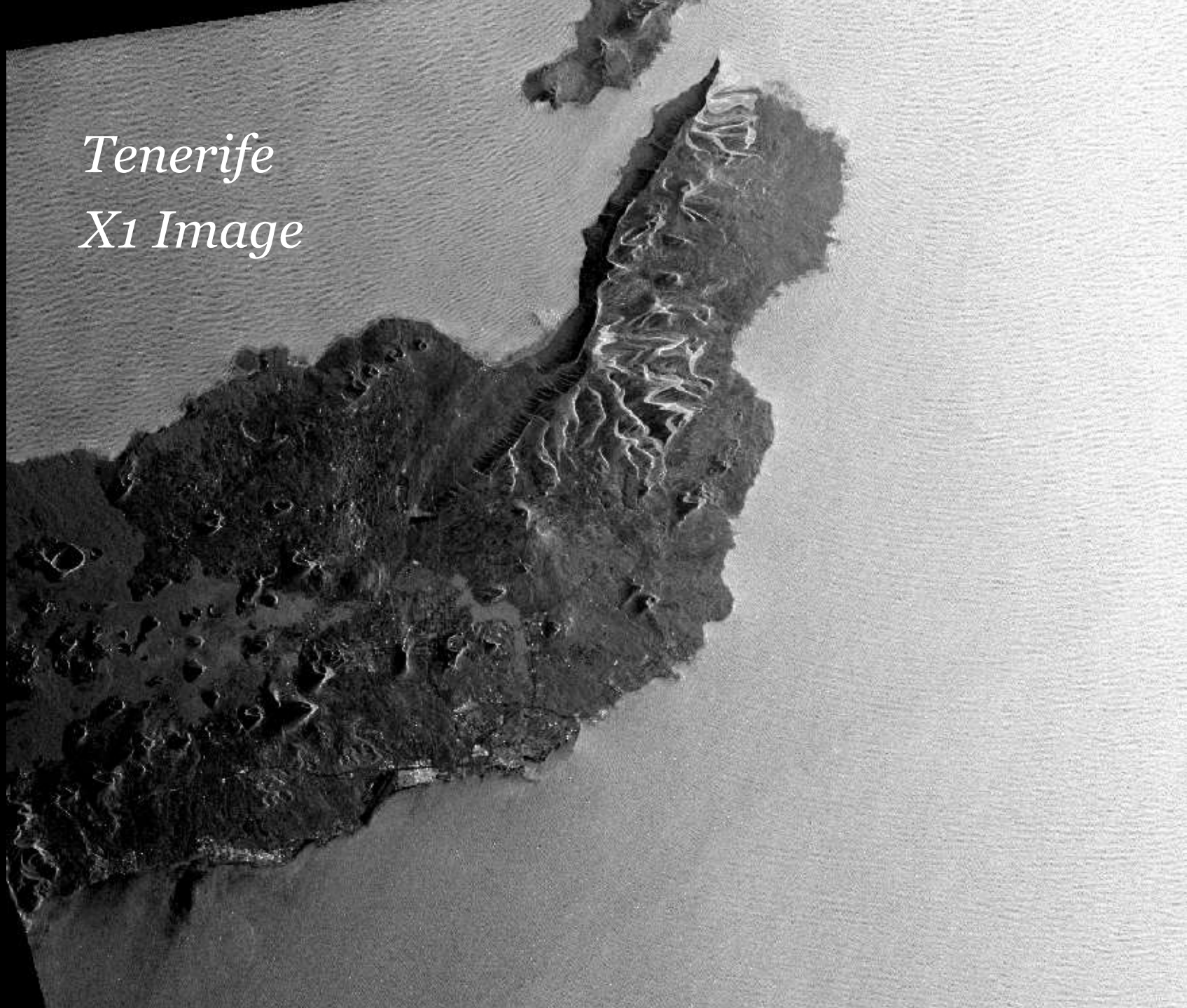
Screening of the data suitability for several simple use case scenarios:

1. Change detection over agricultural areas;
2. Land cover (urban area) delineation;
3. Sea ice cover monitoring;
4. Vessel tracking
5. Oil spill detection.

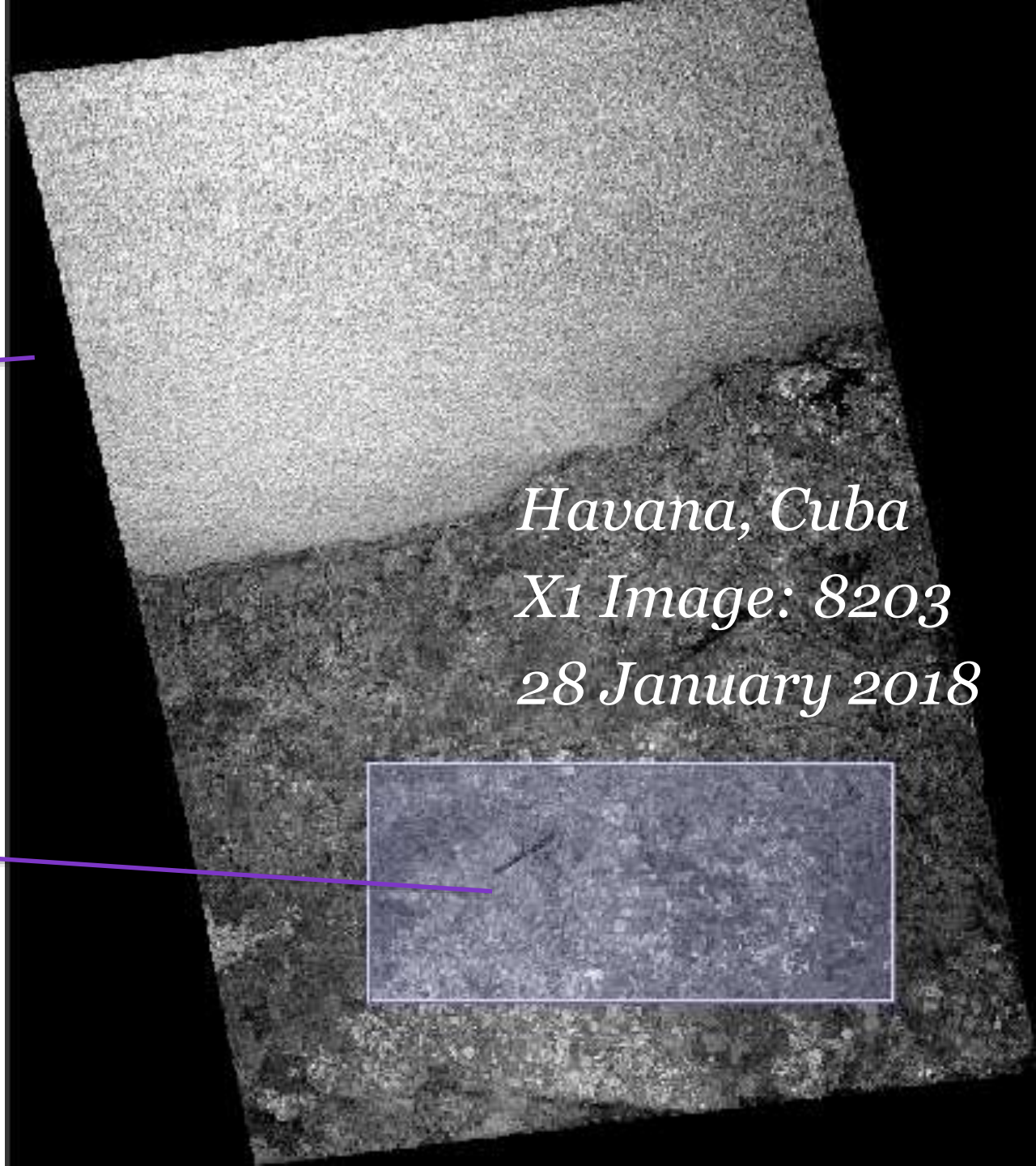
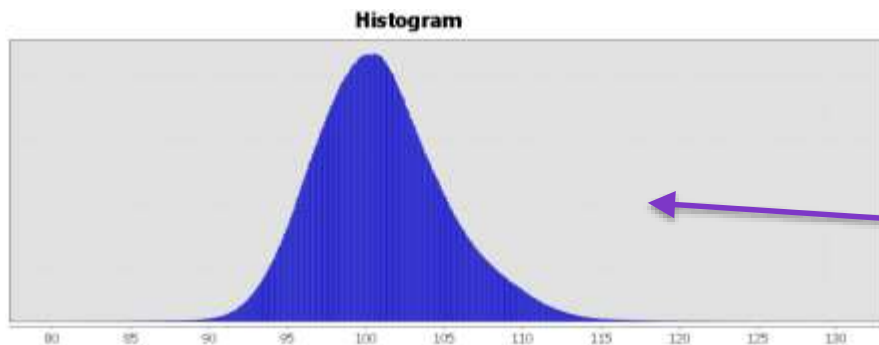
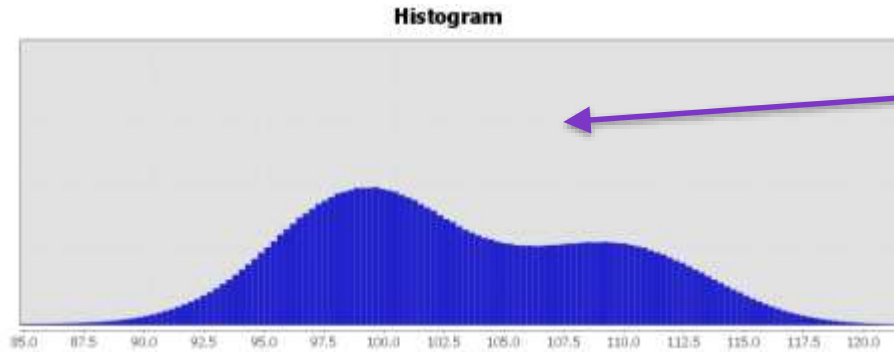


AT-RASC 2018
2nd URSI Atlantic Radio Science Meeting

Tenerife
X1 Image



Amplitude distribution



*Havana, Cuba
X1 Image: 8203
28 January 2018*

Havana, Cuba

X1 Image: 8203

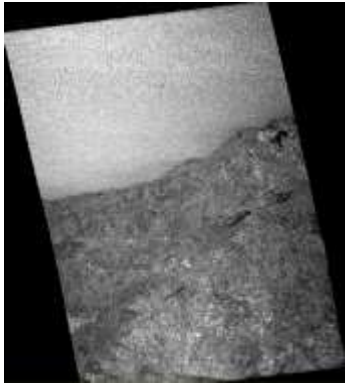
1/28/2018

©ICEYE 2018

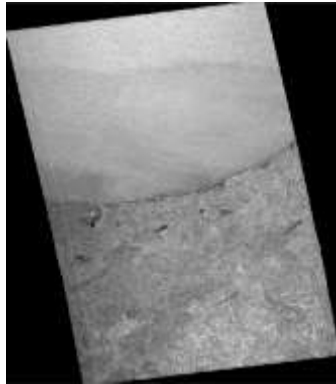
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Aalto University

Change detection I

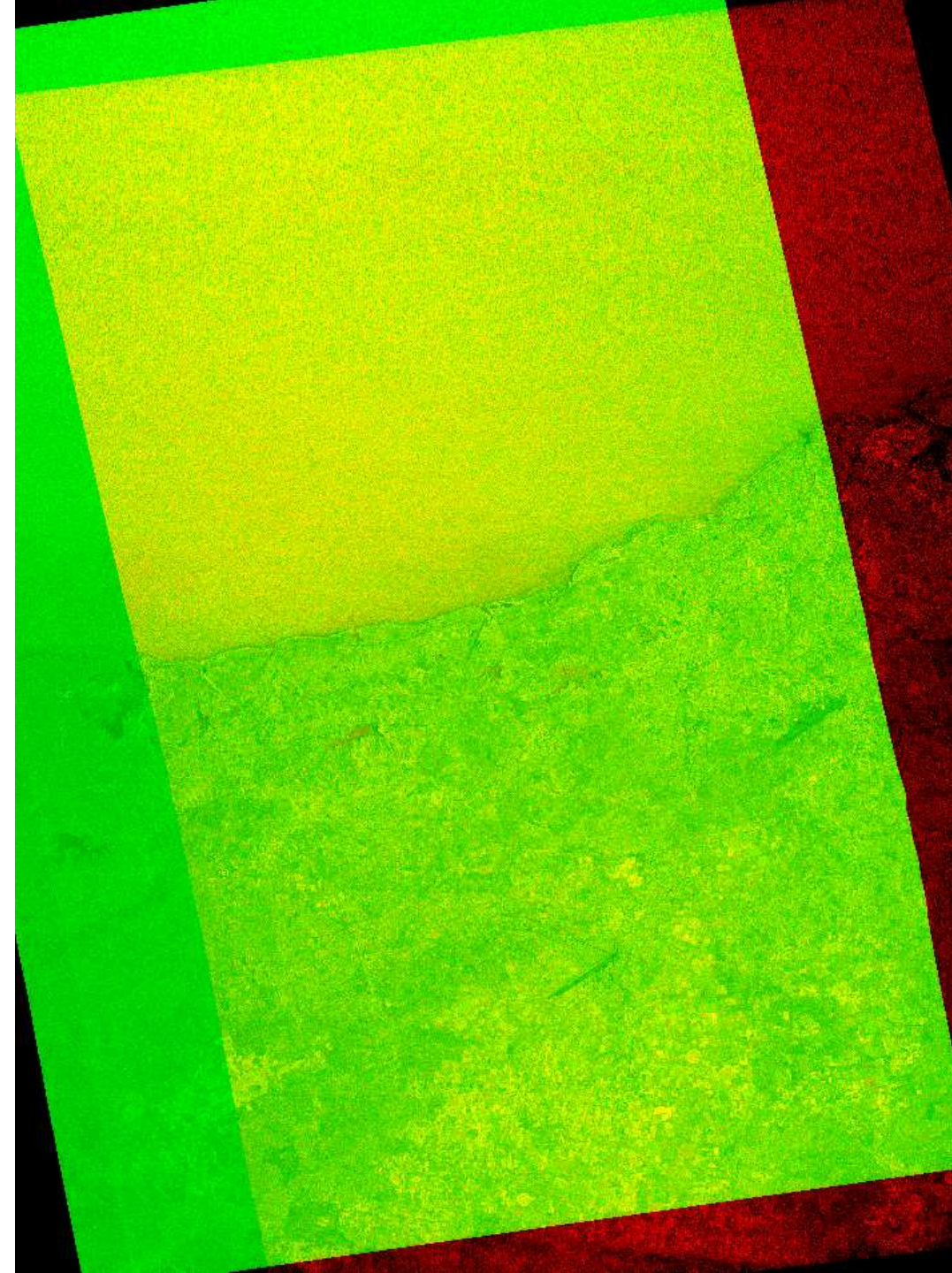


+



=

*8203 + 8512 color composite for
change detection*



Havana, Cuba

Color composite

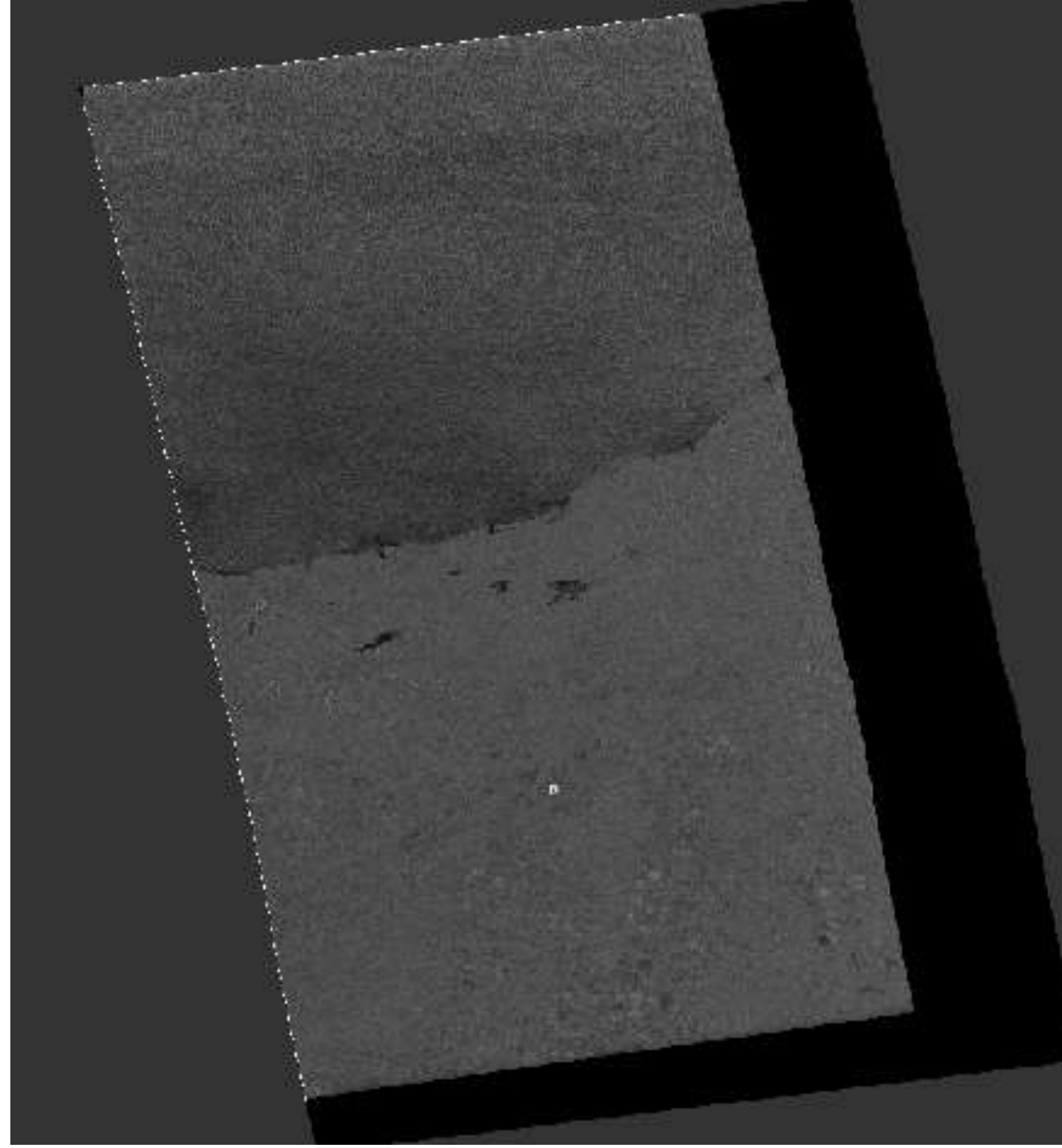
X1 Image [28 Jan 2018] GREEN

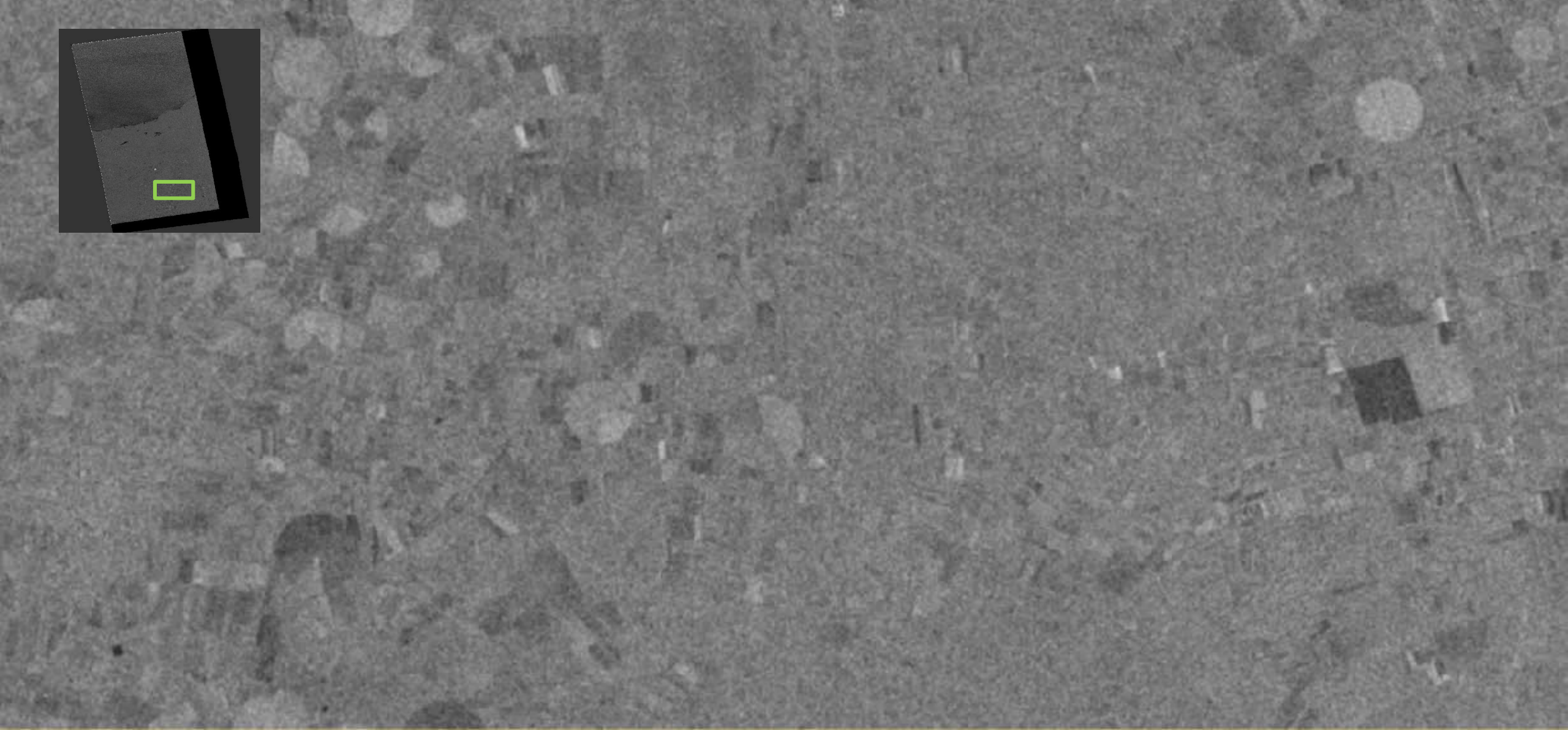
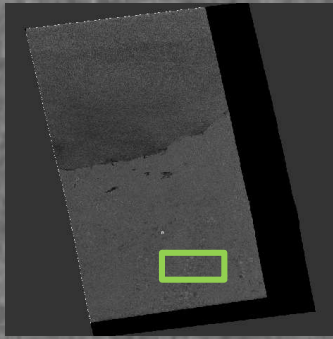
X1 Image [21 Feb 2018] RED

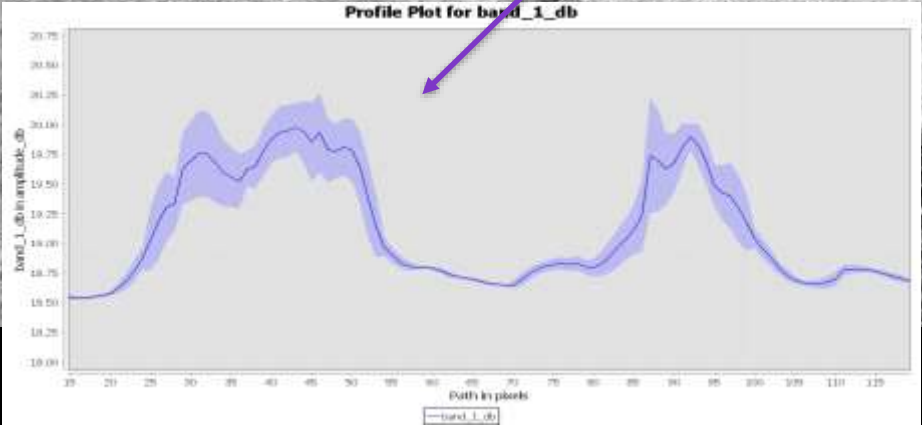
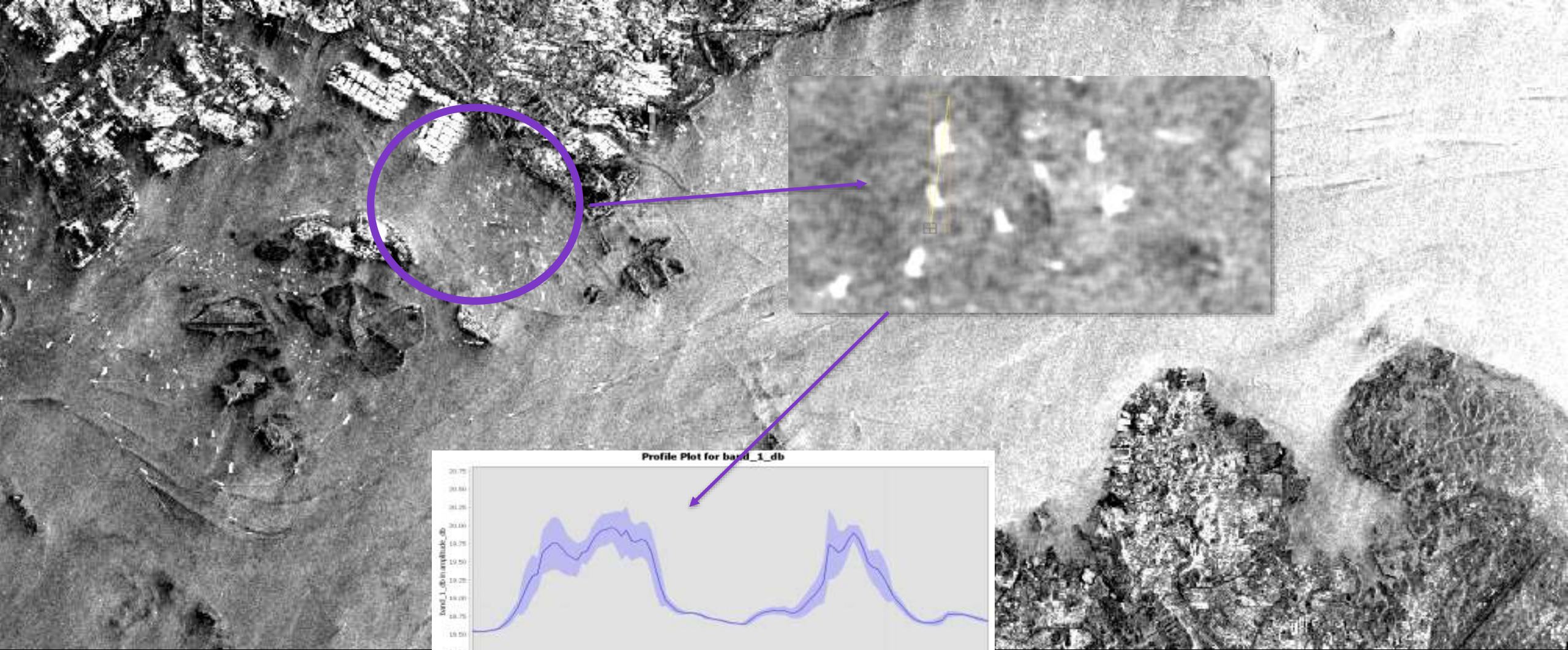
Change detection II

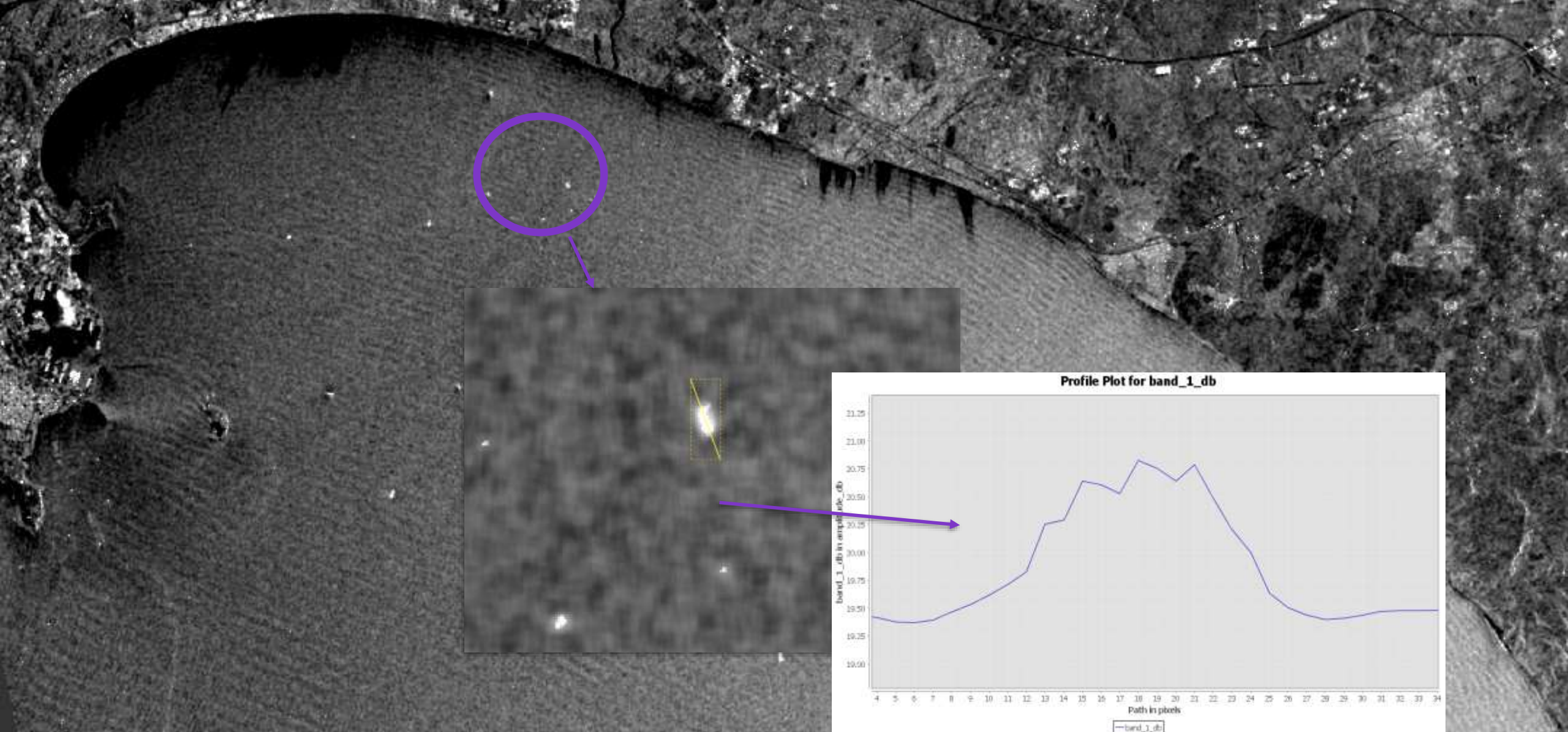
Bi-temporal image processing.

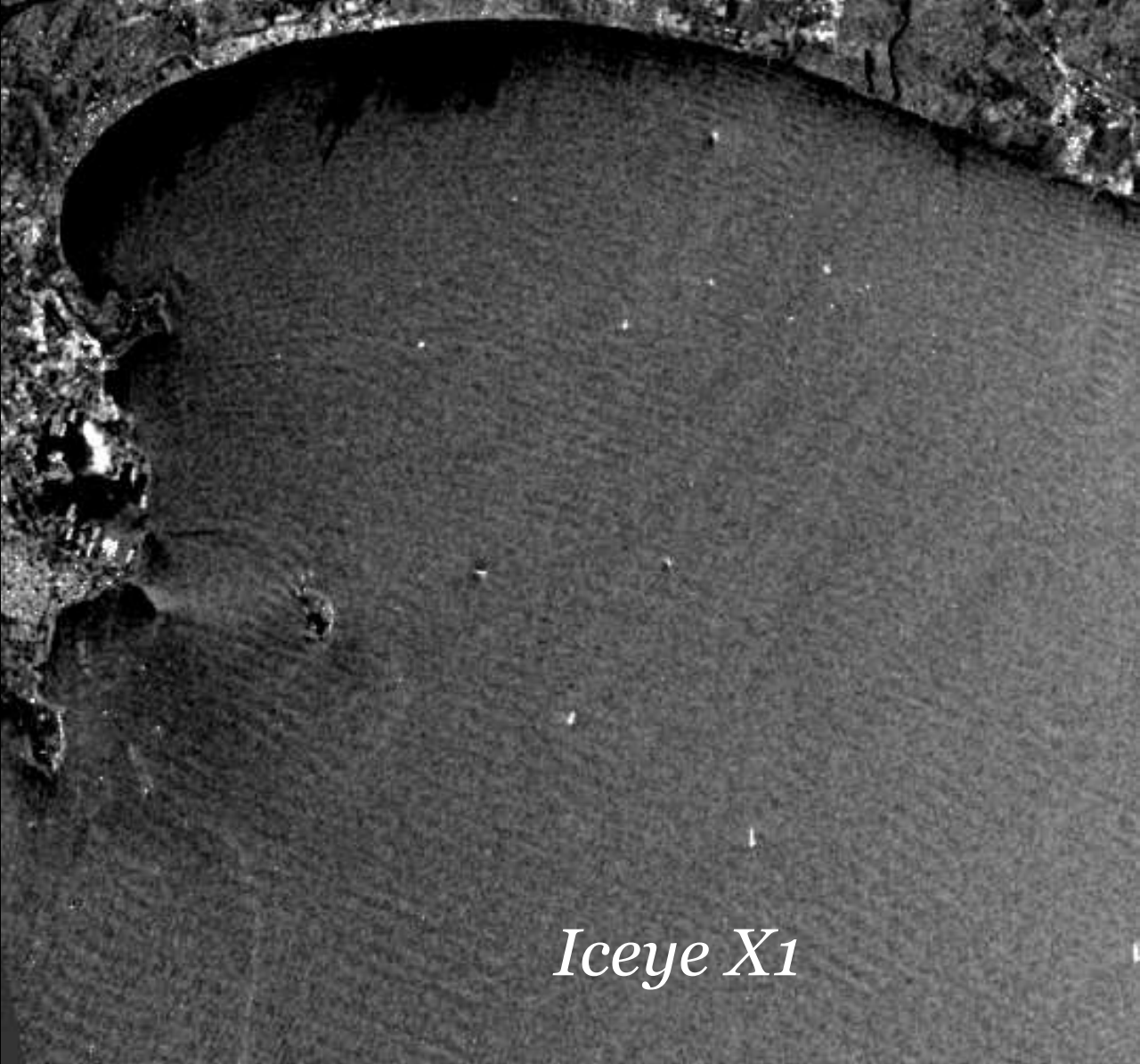
Log-ratio image difference between X_1 scenes acquired on 1/28/2018 and 2/21/2018 over Havana. Scenes right looking, ascending







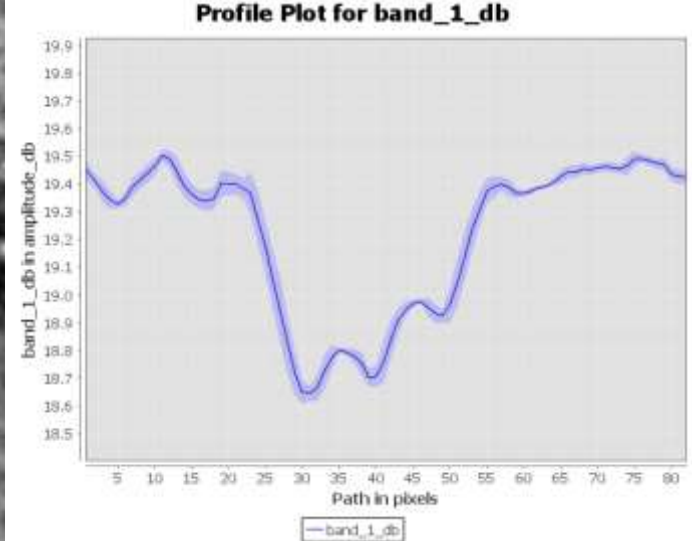
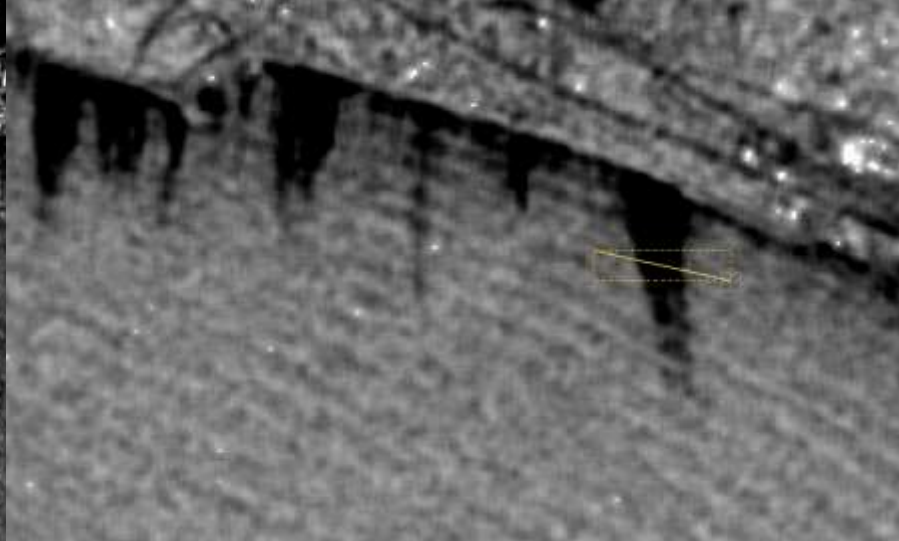
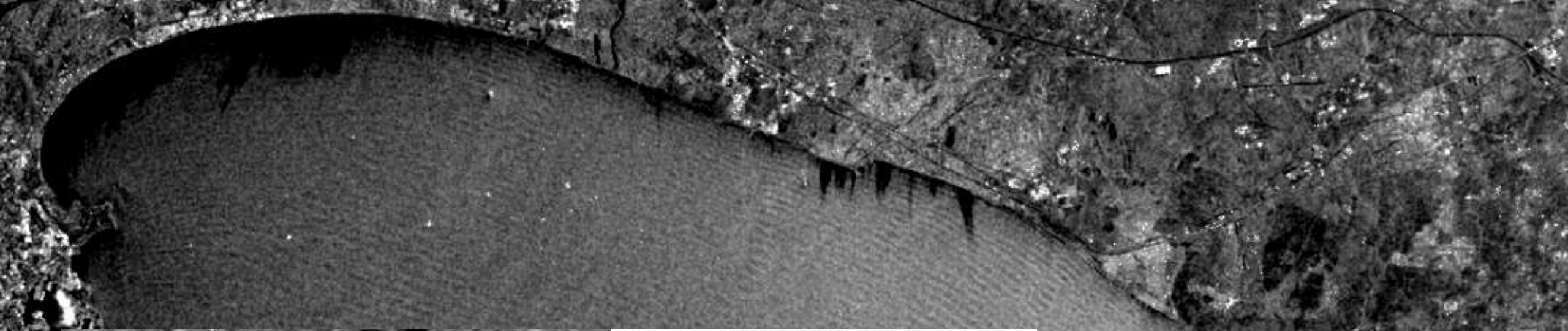




Iceye X1



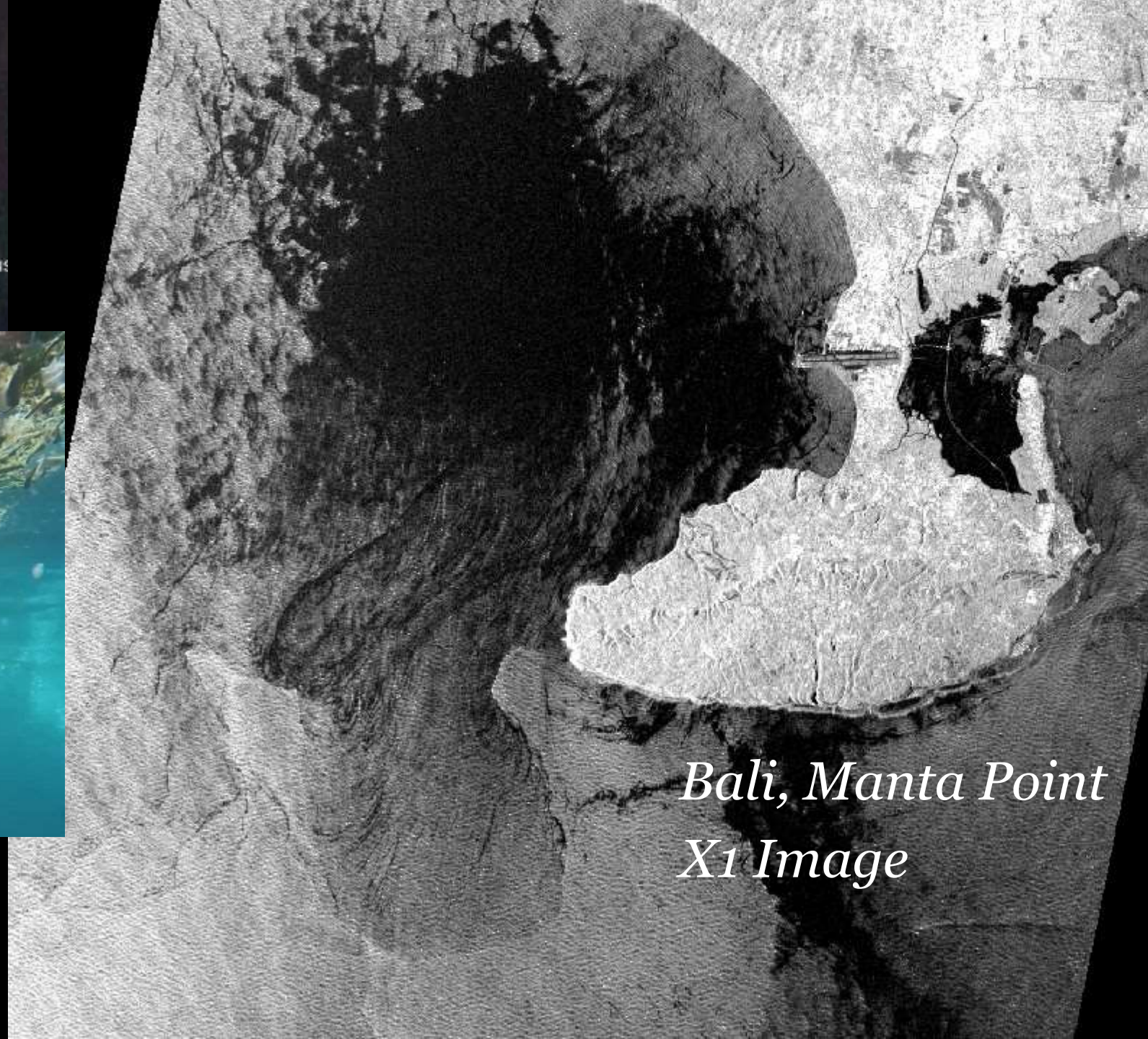
Sentinel 1



Hindu Temple
pura sekar kuning

Marine pollution

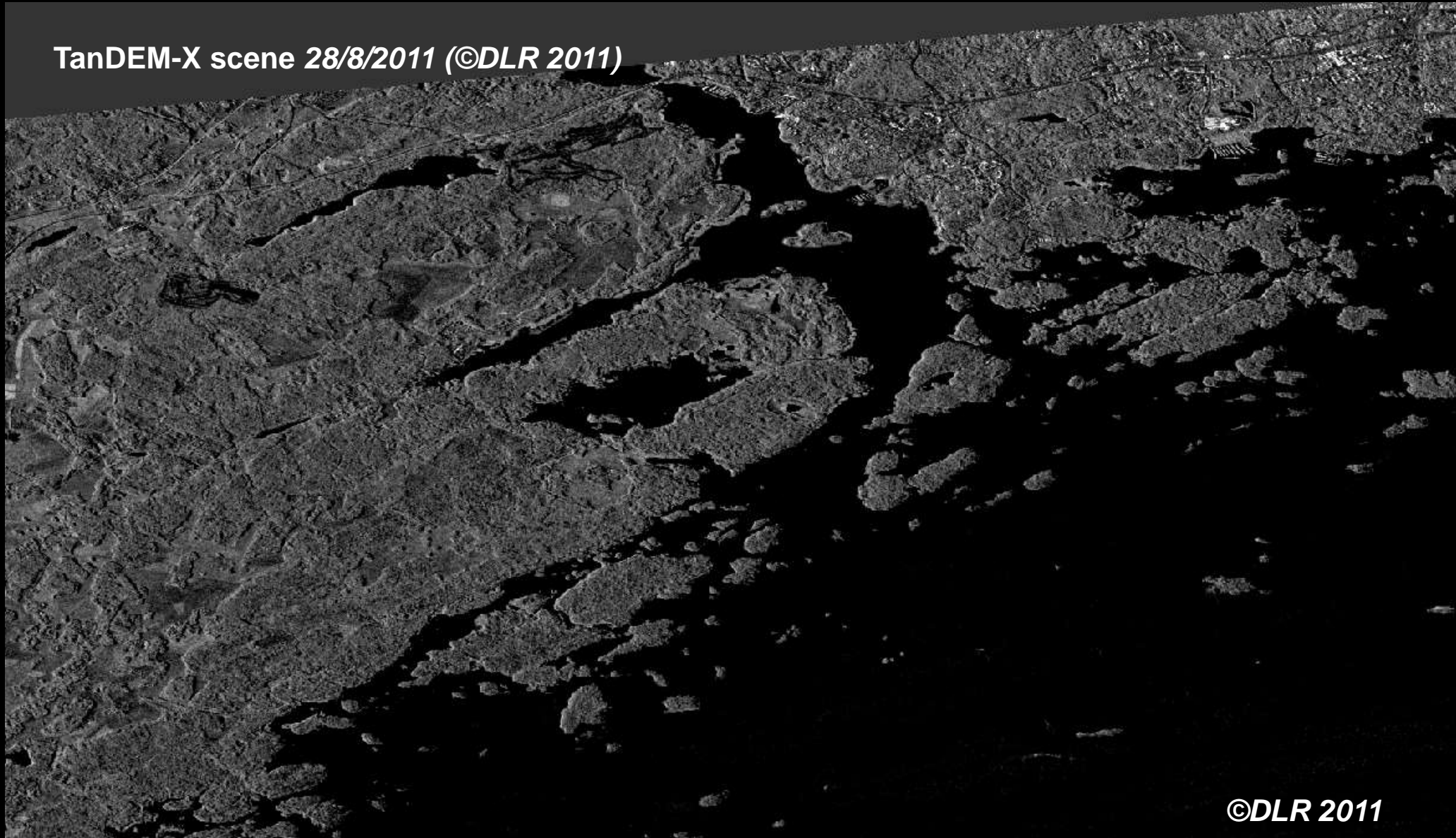
Manta Point Nus



*Bali, Manta Point
X1 Image*

TanDEM-X scene 28/8/2011 (©DLR 2011)

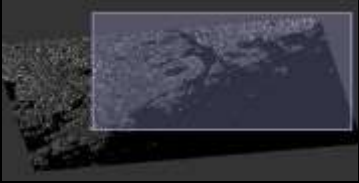
TanDEM-X scene
acquired 28/8/2011
HH-pol
summer conditions



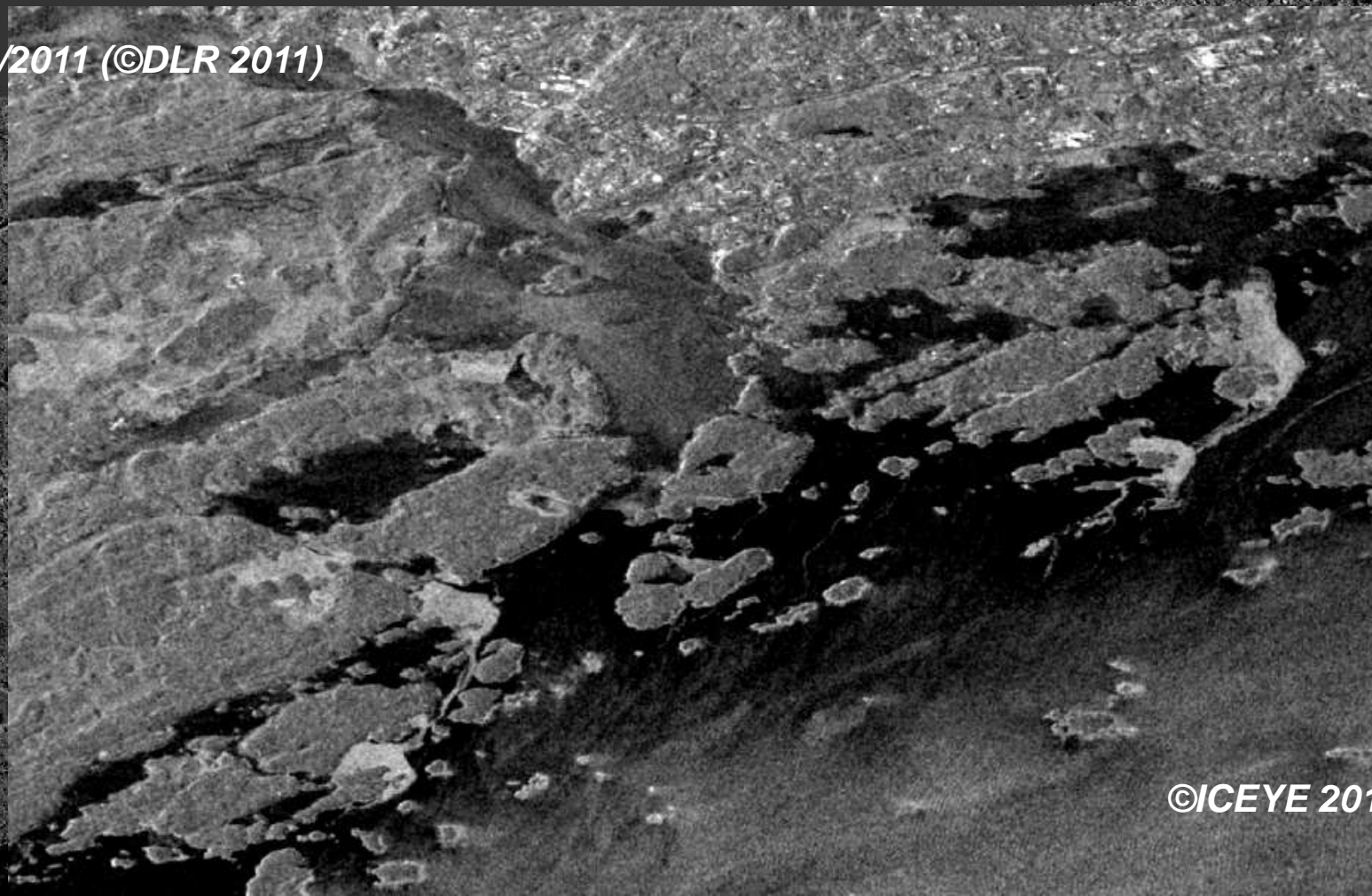
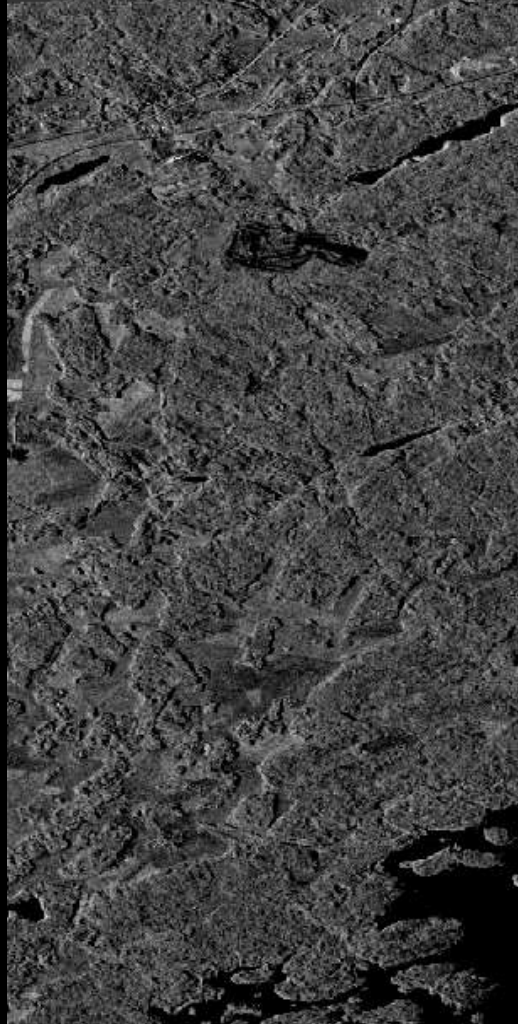
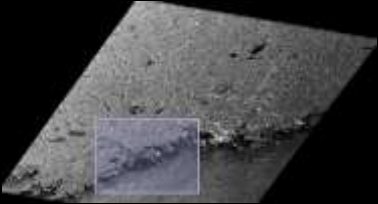
©DLR 2011

TanDEM-X scene 28/8/2011 (©DLR 2011)
X1 scene 30/1/2018

TanDEM-X scene
acquired 28/8/2011
HH-pol
summer conditions



X1 scene 30/1/2018
winter conditions

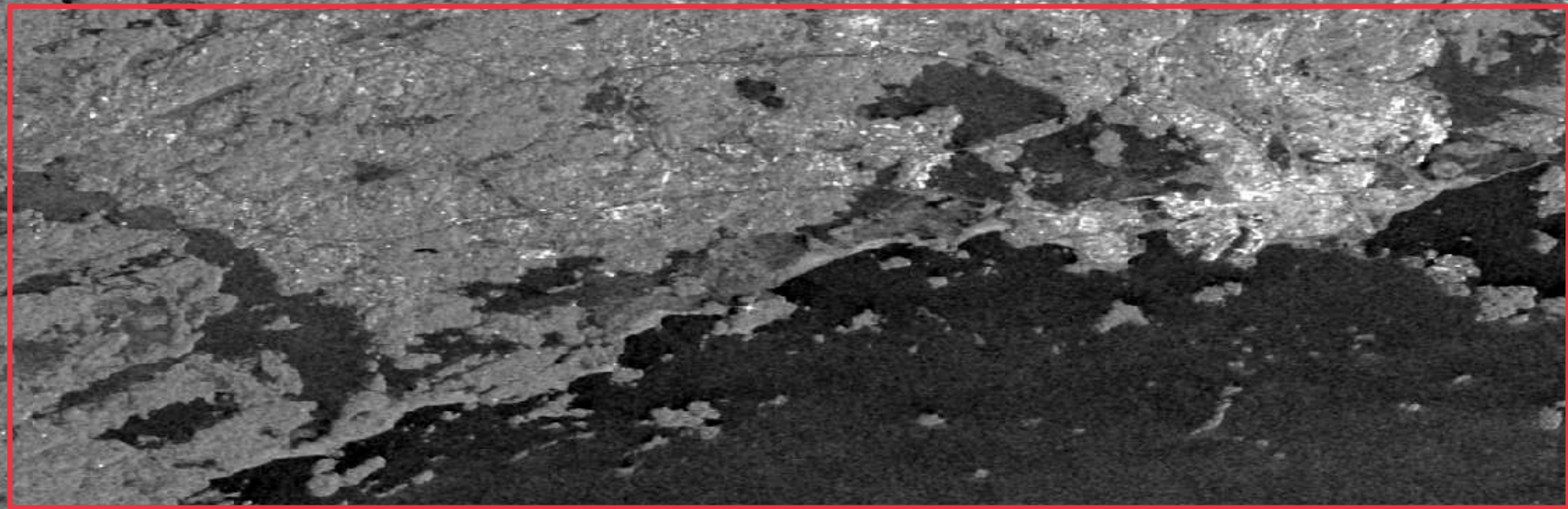


©ICEYE 2018


©DLR 2011

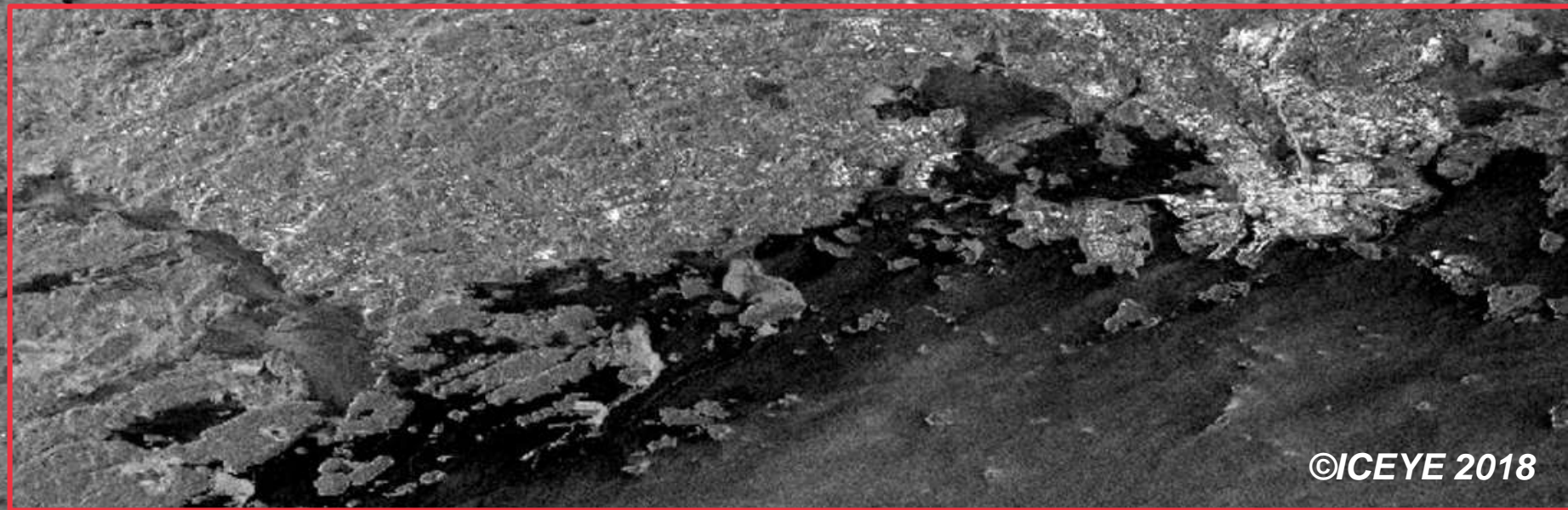
Comparison with Sentinel-1

Sentinel-1 scene 2/2/2018
X1 scene 30/1/2018 
same winter conditions



Comparison with Sentinel-1

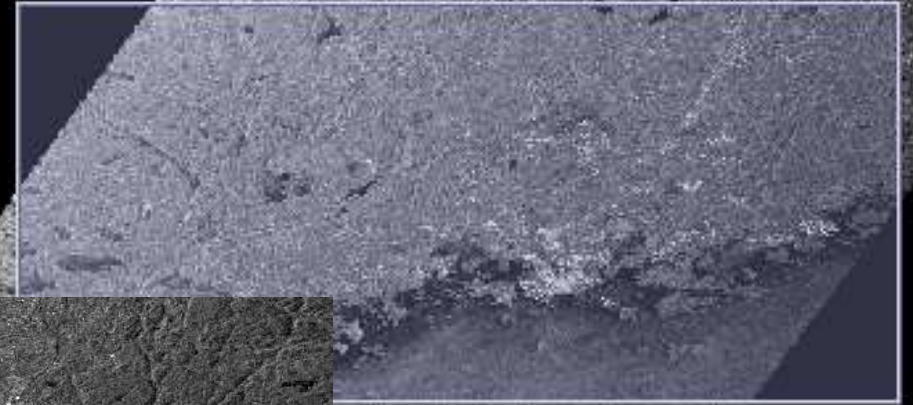
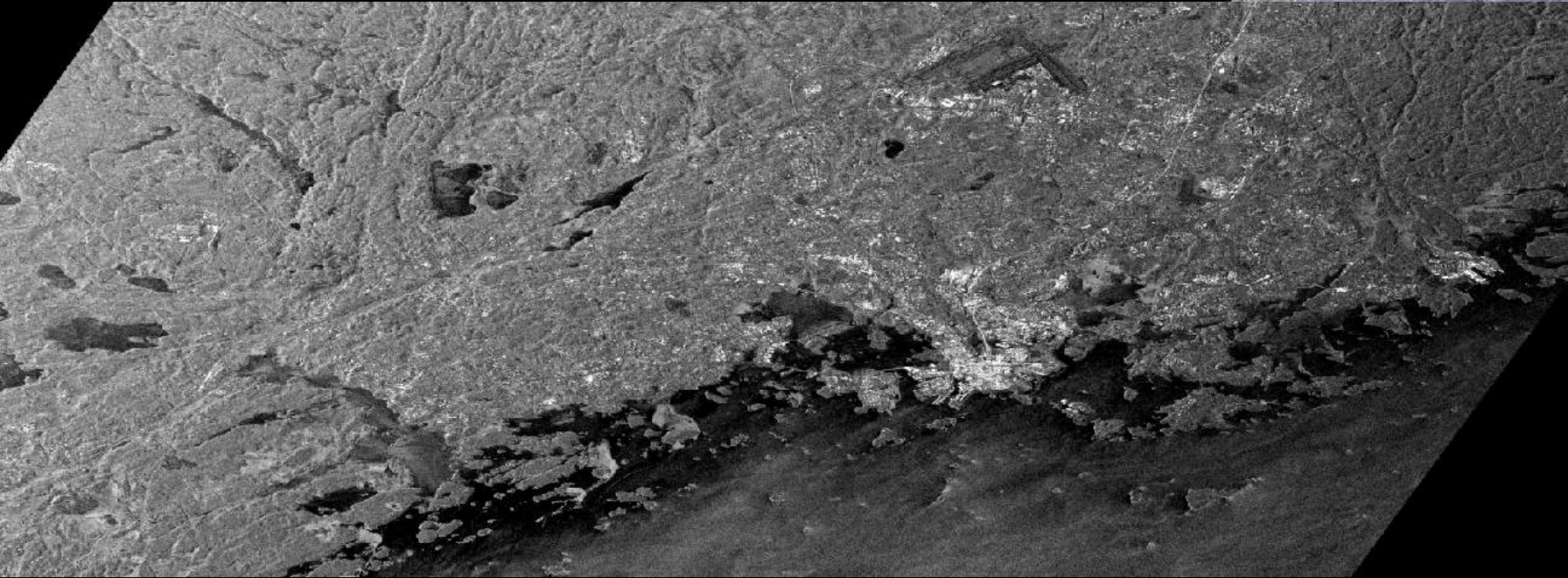
Sentinel-1 scene 2/2/2018
X1 scene 30/1/2018 
same winter conditions



©ICEYE 2018

Helsinki

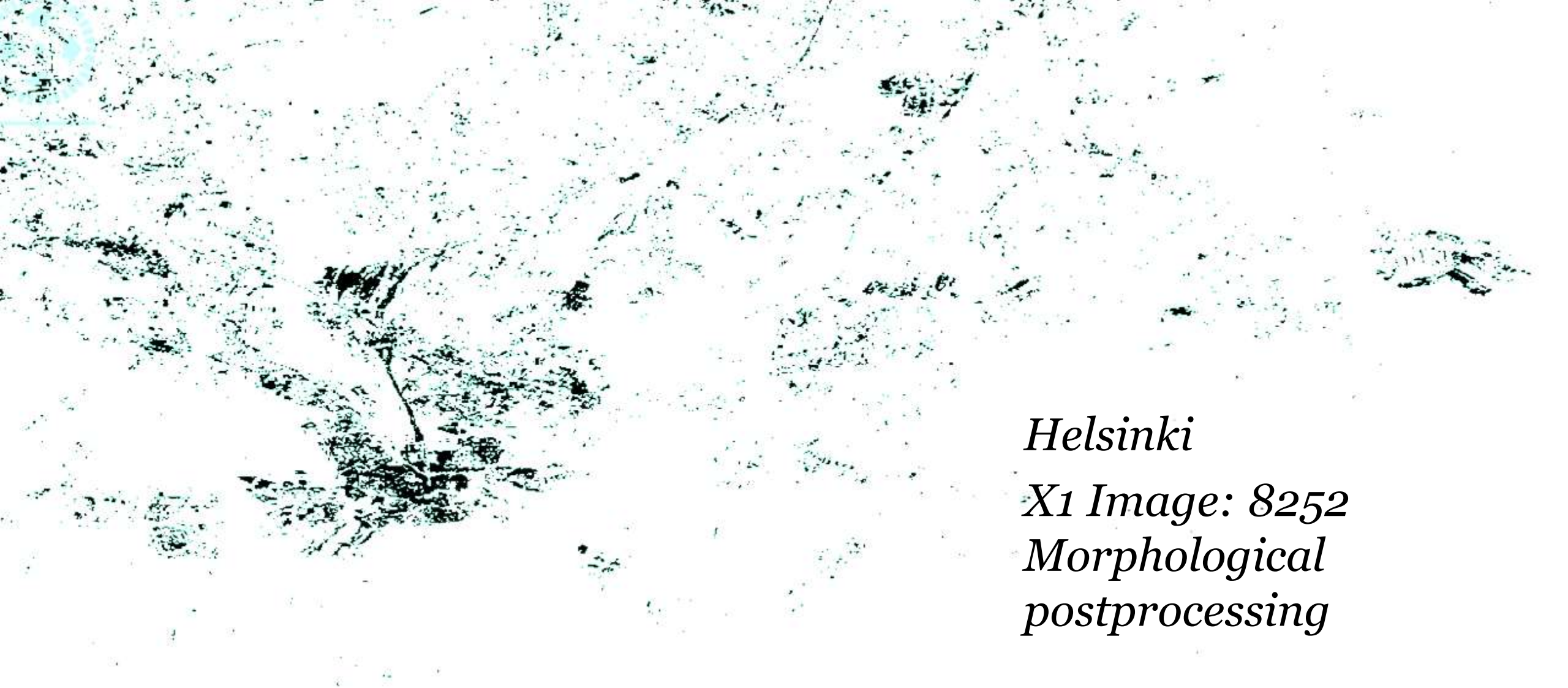
X1 Image 1/30/2018





Helsinki

X1 Image 1/30/2018



Helsinki

X1 Image: 8252

*Morphological
postprocessing*



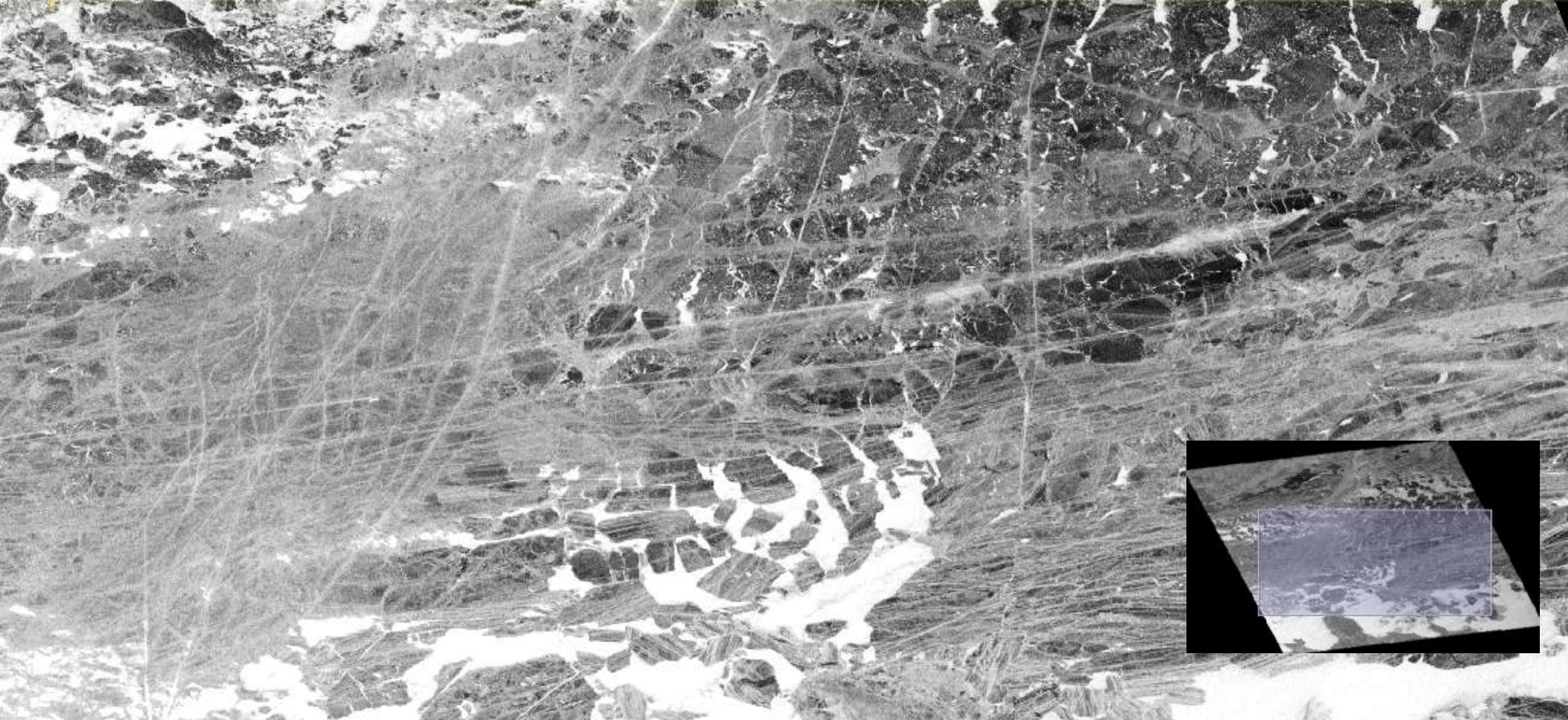
Helsinki

X1 Image: 8252



Helsinki

X1 Image: 8310





Iceye X1

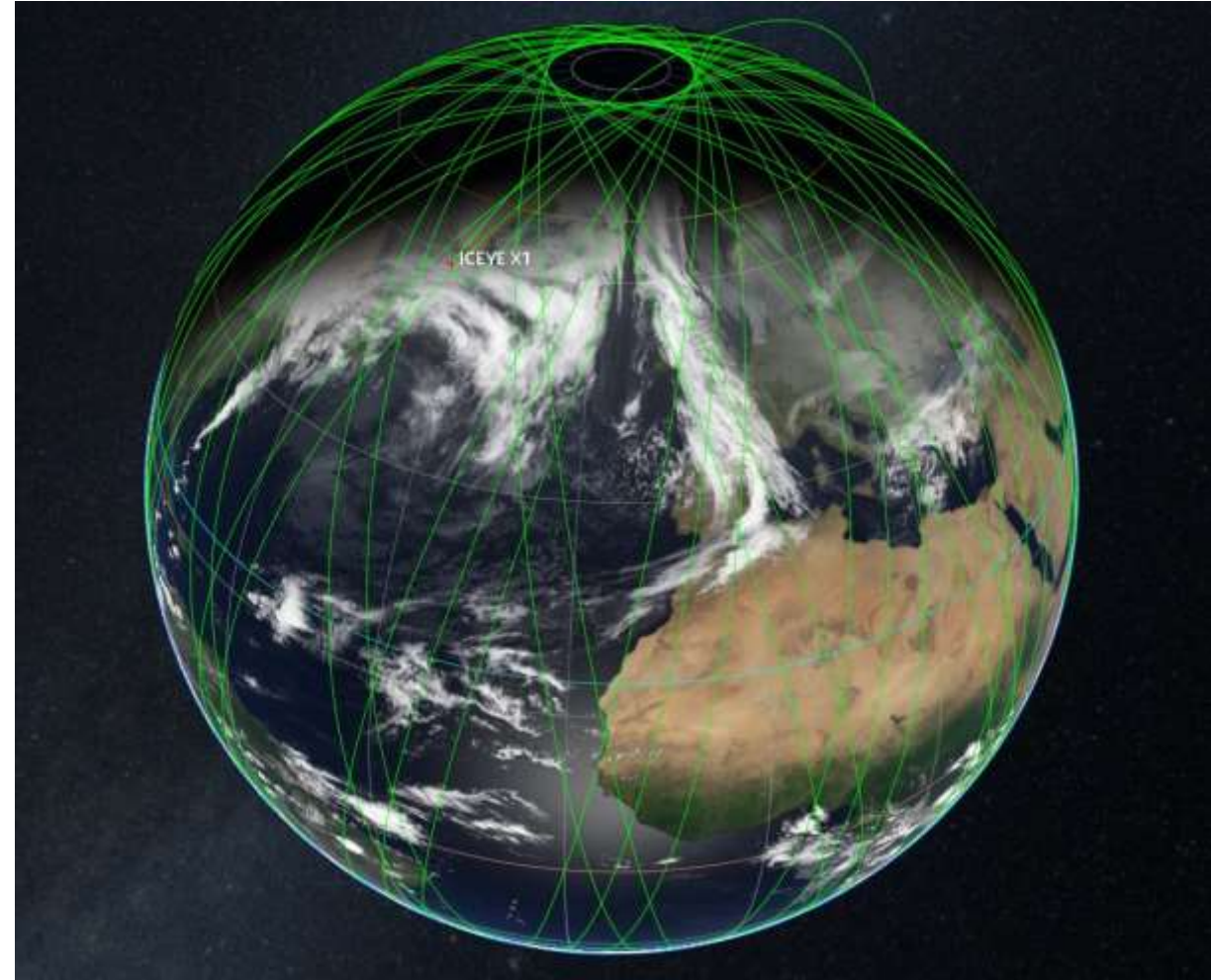


Sentinel 1

Constellation

The proof-of-concept satellite demonstrated the capability of small spaceborne SAR. True value of small SAR is in satellite constellation.

X2 and X3 satellites with improved capability are launched 2018



PLANNED CONSTELLATION PERFORMANCE

ICEYE

WORLD'S LARGEST
SAR SATELLITE
CONSTELLATION

- **3h Response Time** Around the Globe
- **Radar Instrument:**
Reliable Imaging Through Clouds,
Day and Night time
- **Over 7M km² of daily coverage,**
3x3 meter resolution
- **Full range** of imaging angles and times

LARGE AREAS & HIGH
SPEED



24h ICEYE
Constellation



PLANNED INDUSTRY DATA APPLICATIONS

MARITIME
SURVEILLANCE

ICE
MONITORING

OIL SPILL
DETECTION

INFRASTRUCTURE
MONITORING

ECONOMIC
ACTIVITY
MONITORING

FORESTRY

DISASTER &
RESCUE
MANAGEMENT

AGRICULTURE

PREVENTION &
MONITORING
OF
ILLEGAL
FISHING

ICEYE

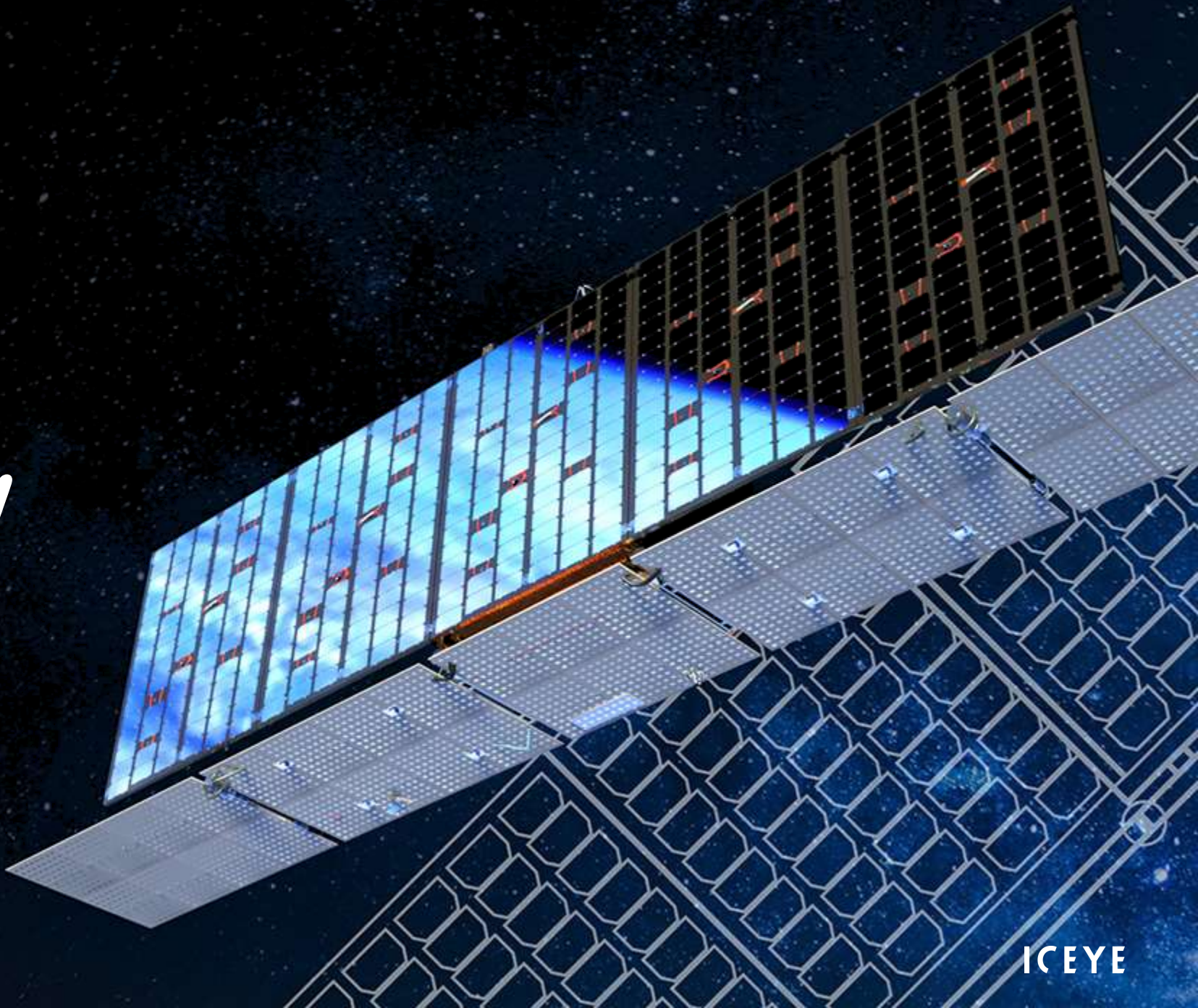
Conclusions

- **A SAR satellite under 100 kg delivers good SAR data, suitable for variety of applications**
- **A comparison with Sentinel and TanDEM-X satellites was performed**
 - All tested simple application scenarios delivered decent results
- **Improvement needs (work in progress)**
 - Improved dynamic range
 - Improved radiometric correction
 - Improved Geo-rectification
- **Further steps include integration of data products to COTS GIS software and a series of pilots based on user requirements assessment.**

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Thank you!



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