DLR'S AIRBORNE SAR RESEARCH: PREPARING FUTURE SATELLITE MISSIONS

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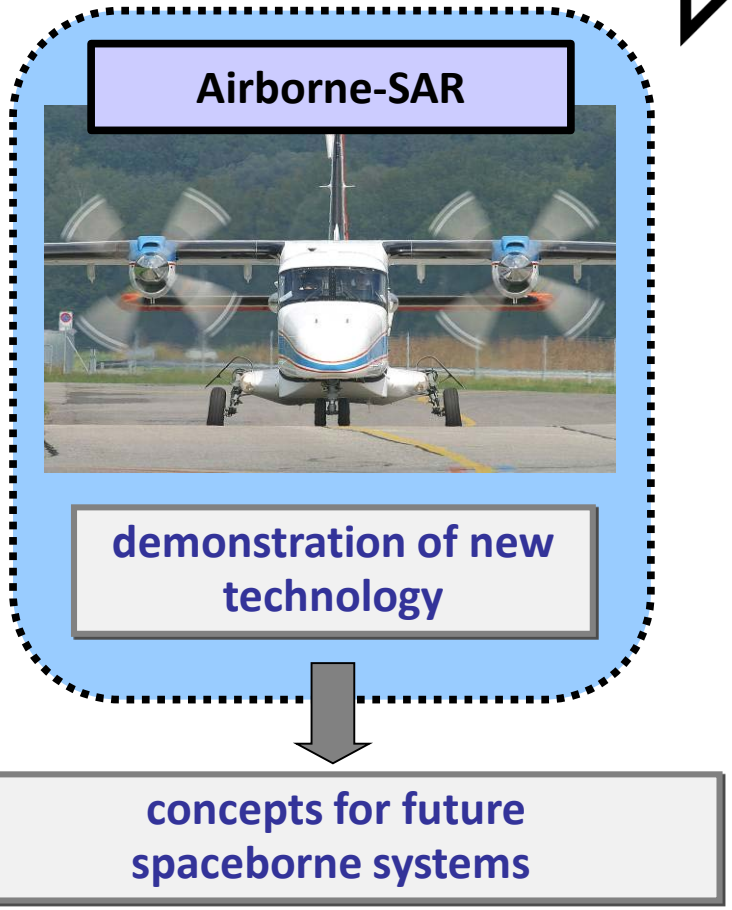
Why Airborne SAR?

- Pushing “state-of-the-art” in SAR sensor technology
  - Test new sensor technology
  - Achieve highest possible data quality
  - End-to-end expertise in airborne SAR
- Preparing future satellite missions
  - Research new imaging modes
  - Simulate data of upcoming spaceborne sensors
  - Test new signal processing algorithms
- Execution of scientific flight campaigns
  - Generation of unique data sets for further research
  - Development new information products and applications



Side looking airborne radar (SLAR)
mid 70’s – end 80’s

→

Dual frequency scatterometer (2-FS)
beginning to end 80’s

→

Experimental synthetic aperture radar (E-SAR)
1986 to 2009

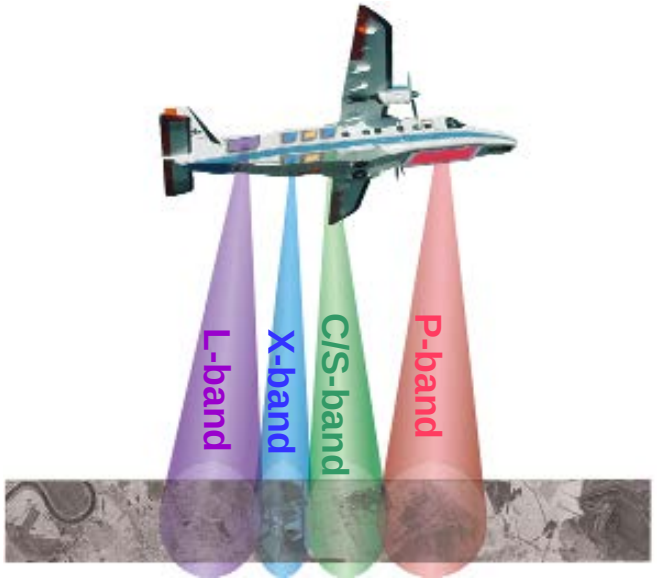
→

Advanced synthetic aperture radar (F-SAR)
since 2006 / 2012

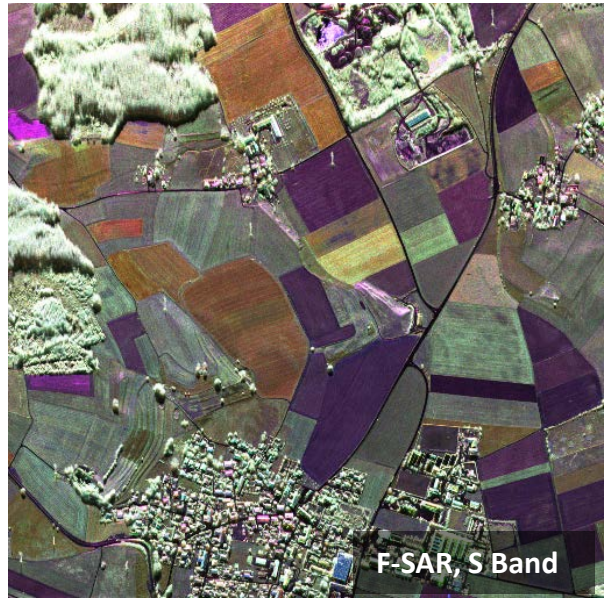
→

The Advanced Airborne Sensor F-SAR

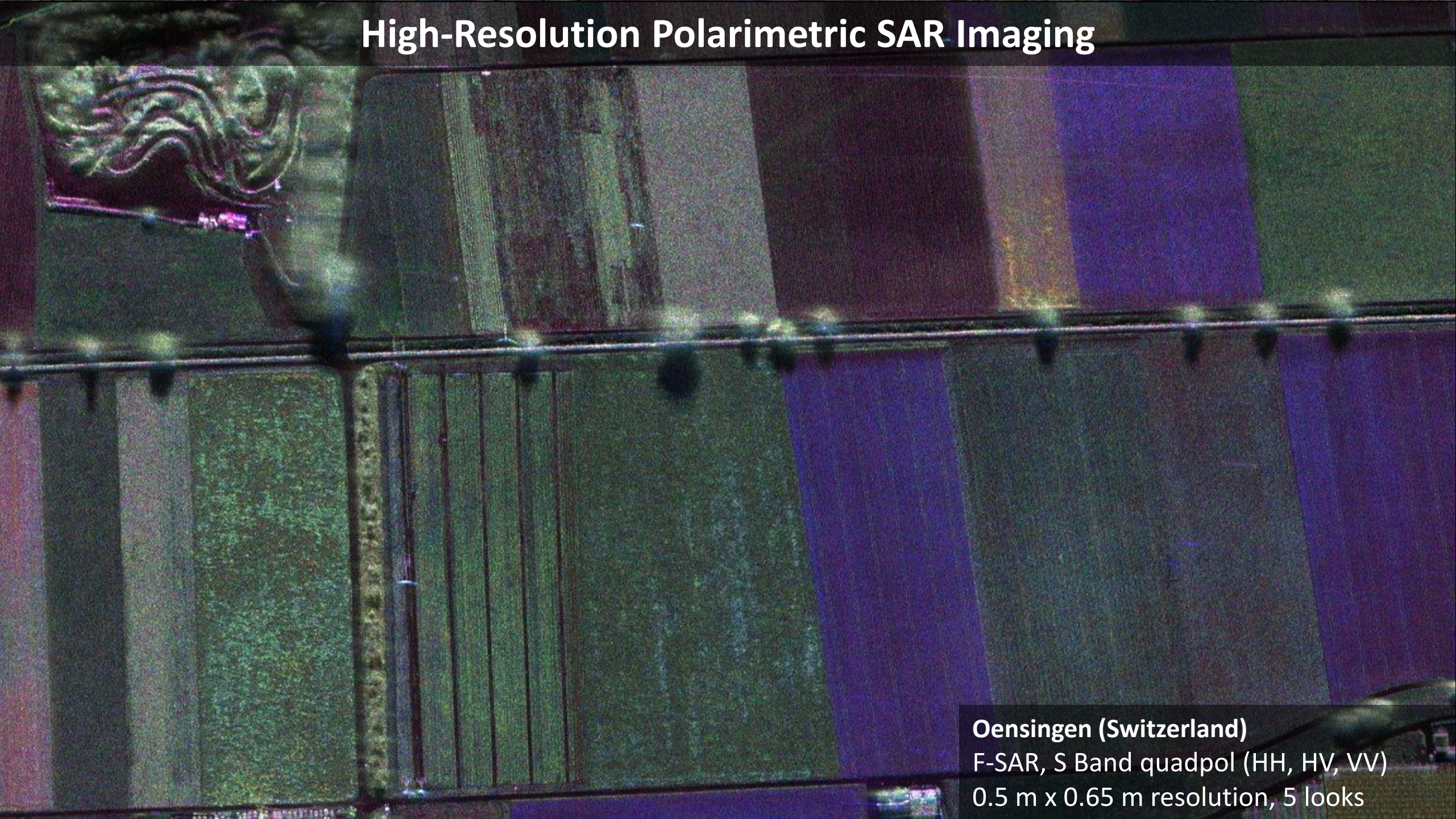
Remarkable features:
- Very high resolution and SNR
- Multispectral operation (up to 4 bands)
- Polarimetry in all bands
- Single-pass interferometry at X and S-band
- Modular sensor design
- Real-time processing & data down-link



	X band	C band	S band	L band	P band
Radar frequency [GHz]	9.60	5.30	3.25	1.325	0.435
Bandwidth [MHz]	760	384	300	150	50
PRF [kHz]	5	5	5	10	10
Transmit power [kW]	2.50	2.20	2.20	0.90	0.90
Range resolution [m]	0.25	0.5	0.67	1.35	4.0
Azimuth resolution [m]	0.2	0.3	0.35	0.4	1.5
Ground range coverage	From 600 m to 6 km depending on flight altitude				
Sampling	8 bit complex, 500MHz, 2+2 recording channels				

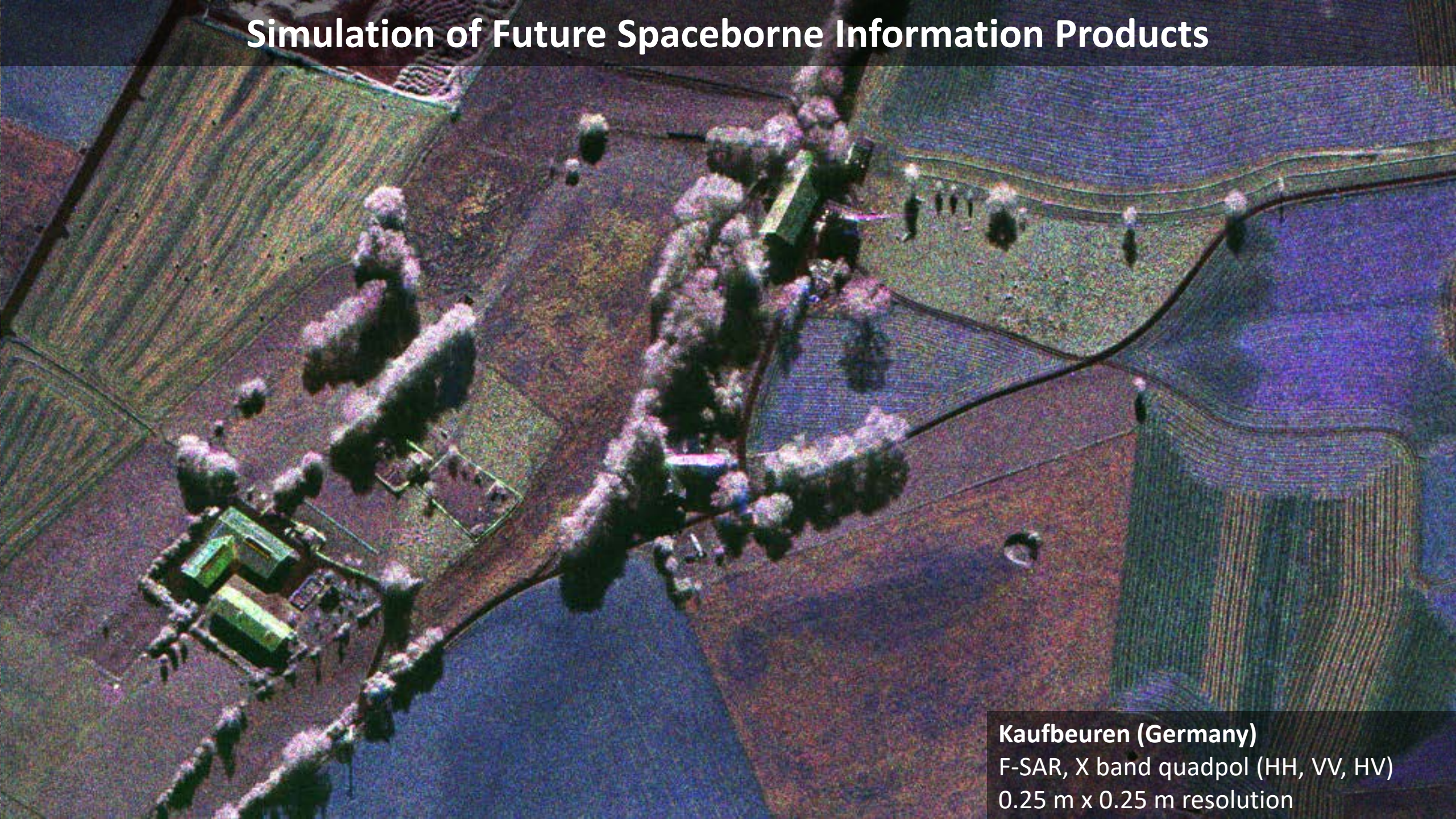


High-Resolution Polarimetric SAR Imaging



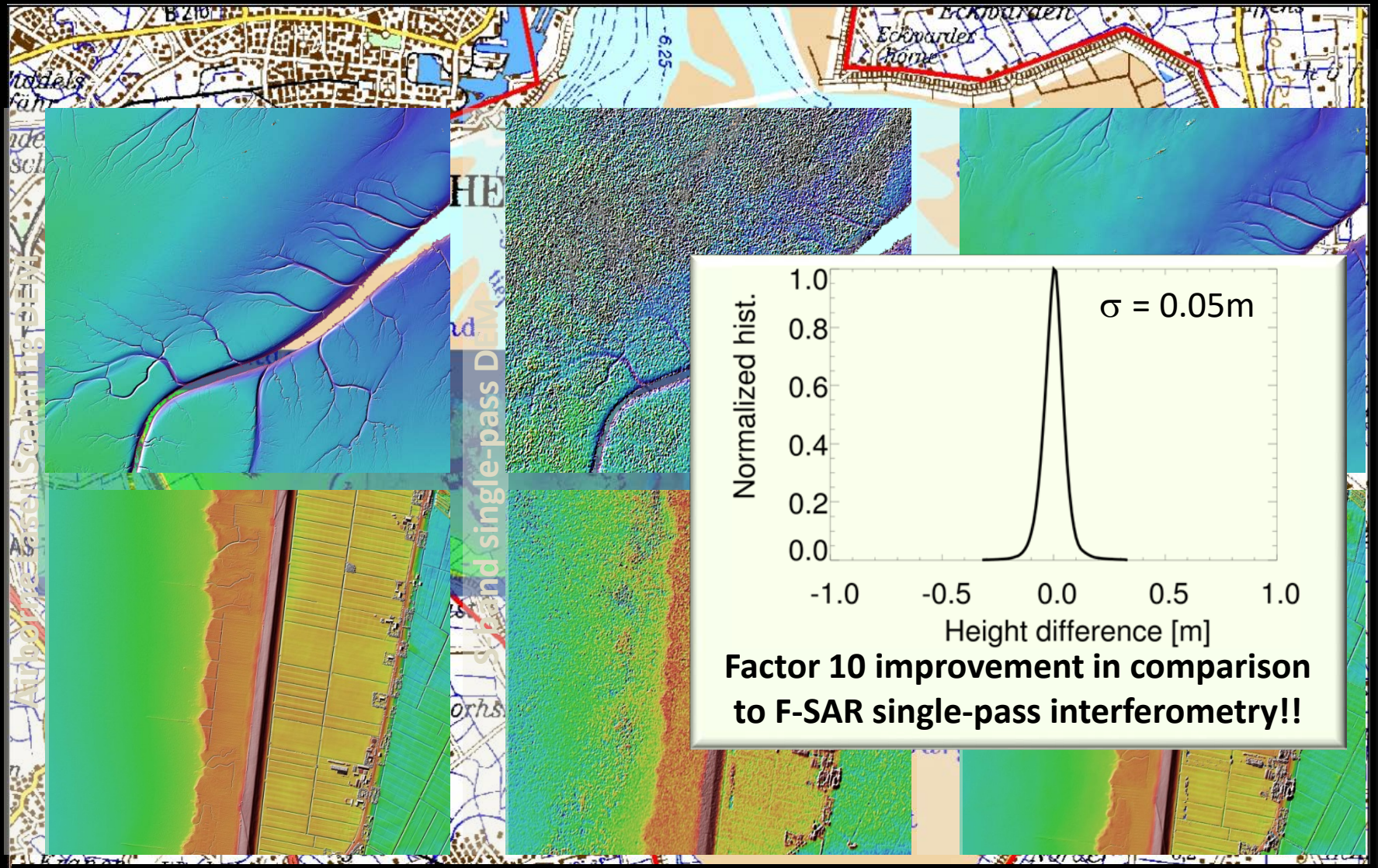
Oensingen (Switzerland)
F-SAR, S Band quadpol (HH, HV, VV)
0.5 m x 0.65 m resolution, 5 looks

Simulation of Future Spaceborne Information Products



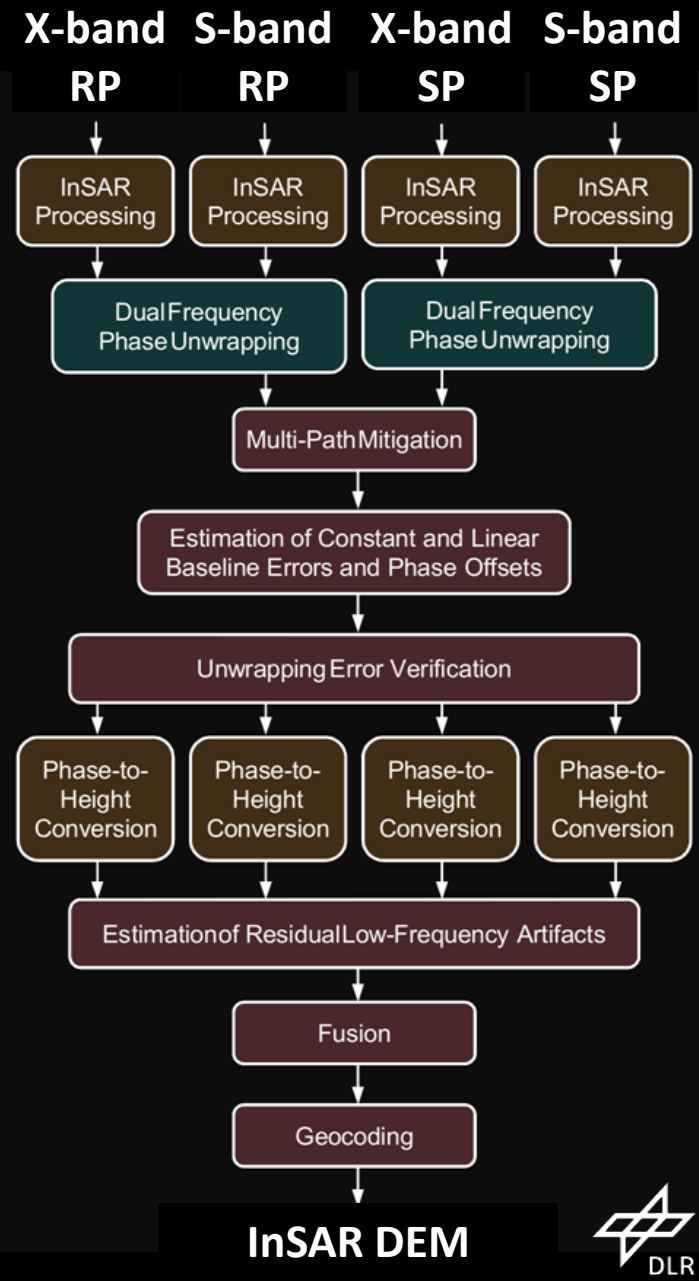
Kaufbeuren (Germany)
F-SAR, X band quadpol (HH, VV, HV)
0.25 m x 0.25 m resolution

High-Precision DEM Generation: Dual-Baseline Dual-Frequency InSAR



Testsite: Jade Bight, Germany

F-SAR Digital Surface Model vs. Airborne Laser Scanning Reference Heights



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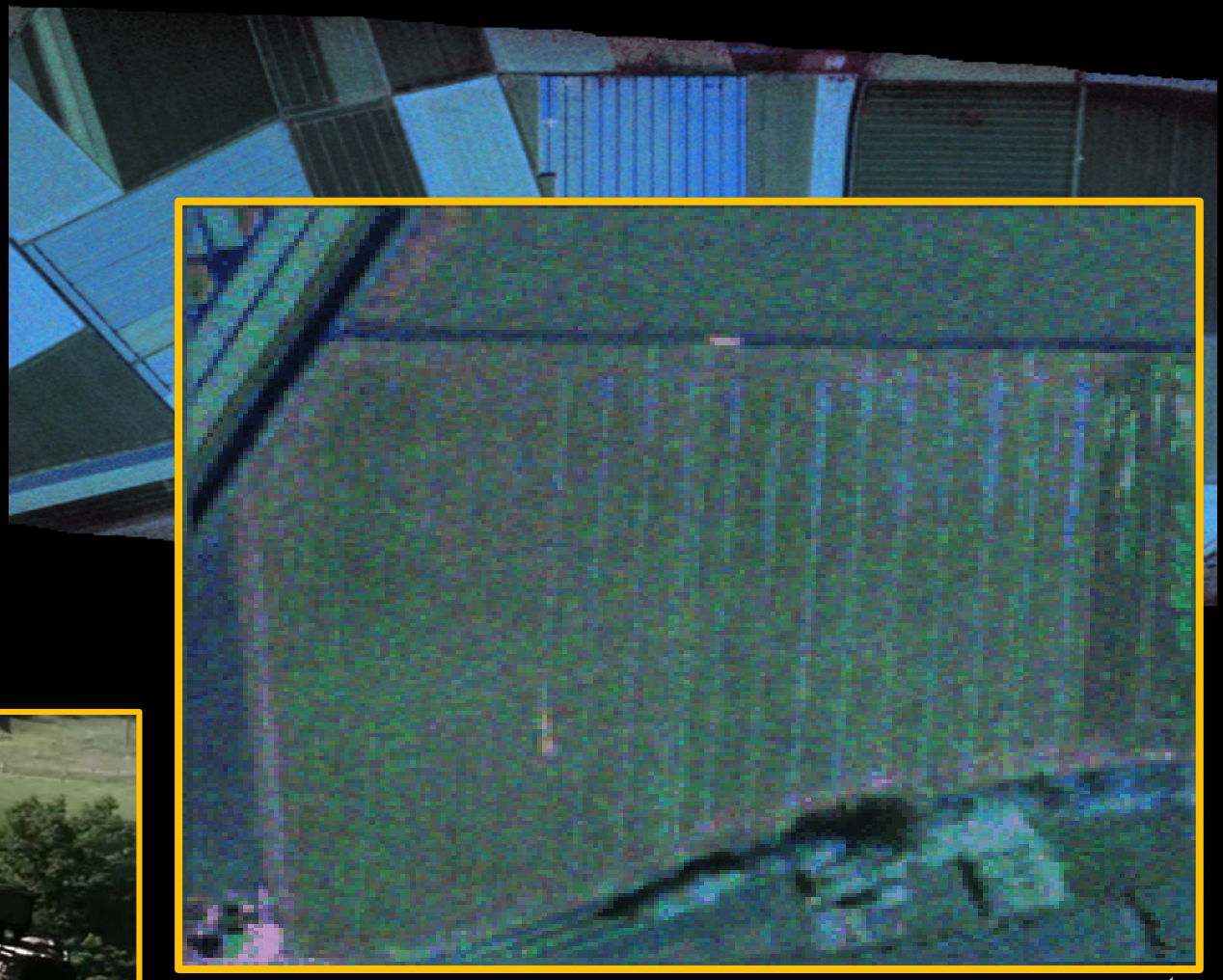
Circular SAR Imaging: Continuous Monitoring / VideoSAR

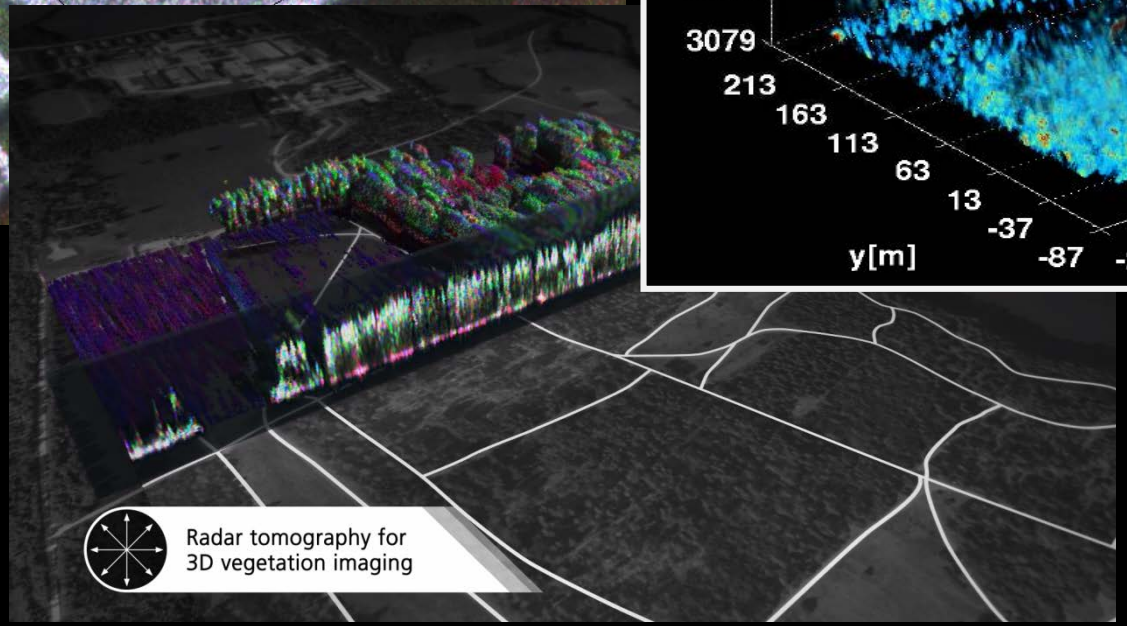
C band

X band

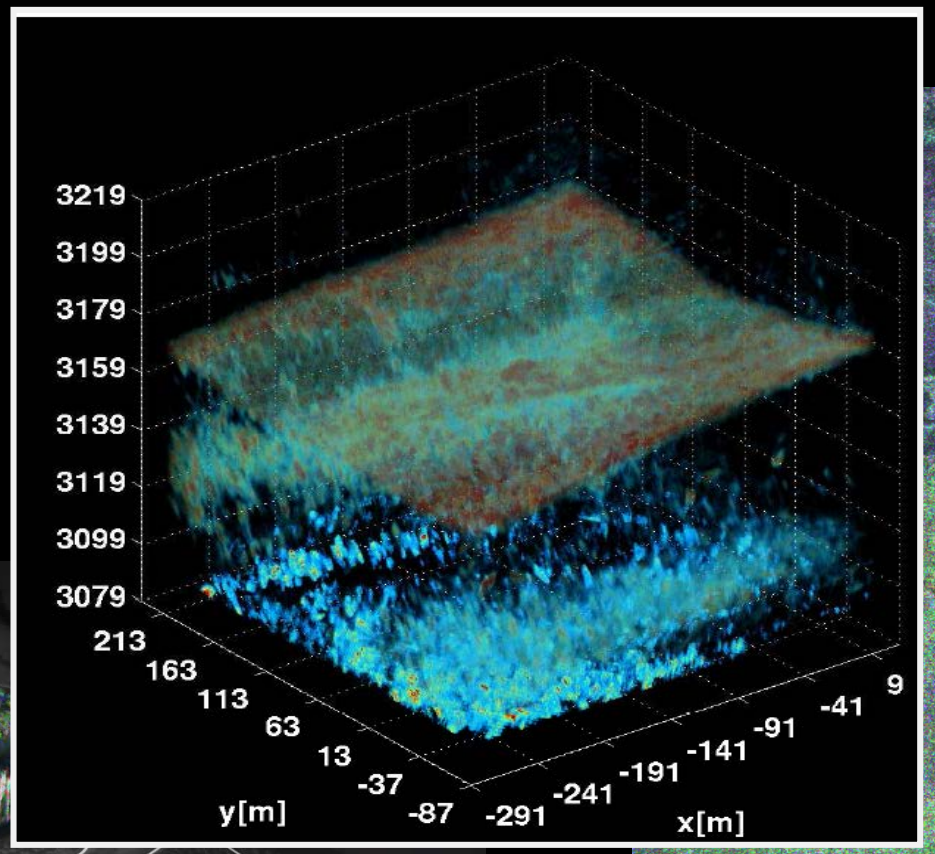


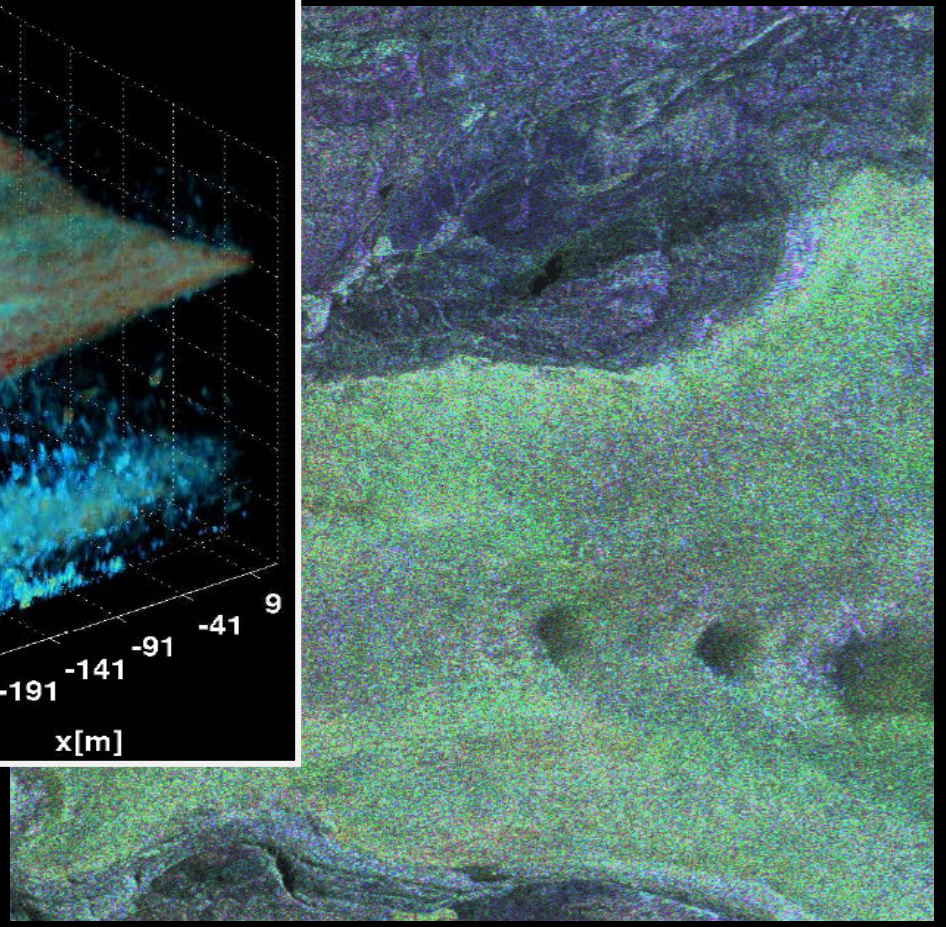
3D Imaging: Tomographic & Holographic SAR

Multi-baseline SAR Tomography



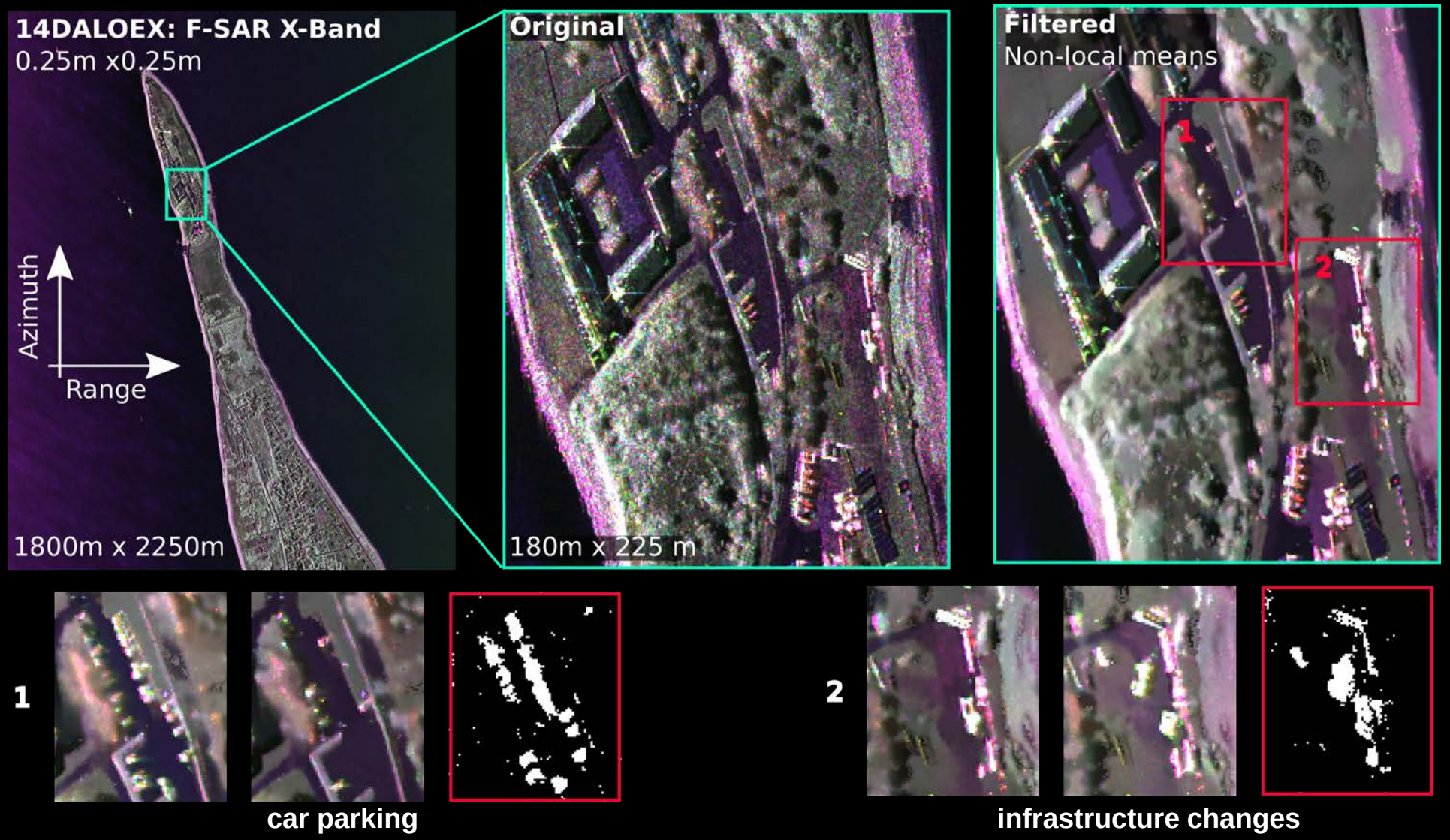
Multi-circular SAR Holography





Testsite: Kangerlussuaq / K-Transect (Greenland)
Fully polarimetric HoloSAR images (P band).

PolSAR Change Detection for Security Applications



Constant-False-Alarm-Rate (CFAR) Detector @95%

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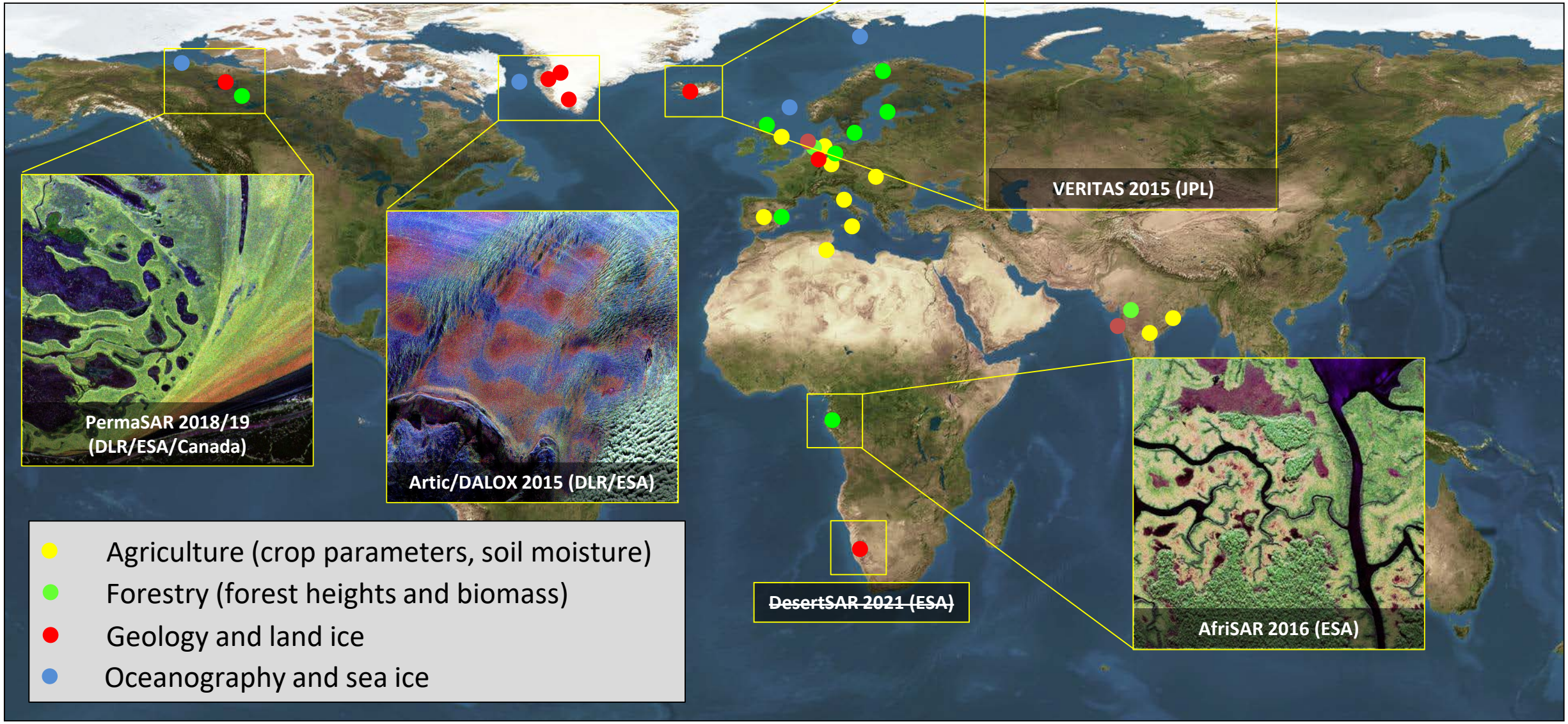
Airborne-SAR Campaigns (since 2001)



F-SAR Campaign AfriSAR 2016

Goals:

- Preparation of ESA's **BIOMASS mission**
- Algorithm development for **Tandem-L** forest products
- Various test-sites in Gabon (tropical rain forest)
- Cooperation with **ESA, NASA/JPL, NASA/Goddard, ONERA**
- Extensive ground-truthing

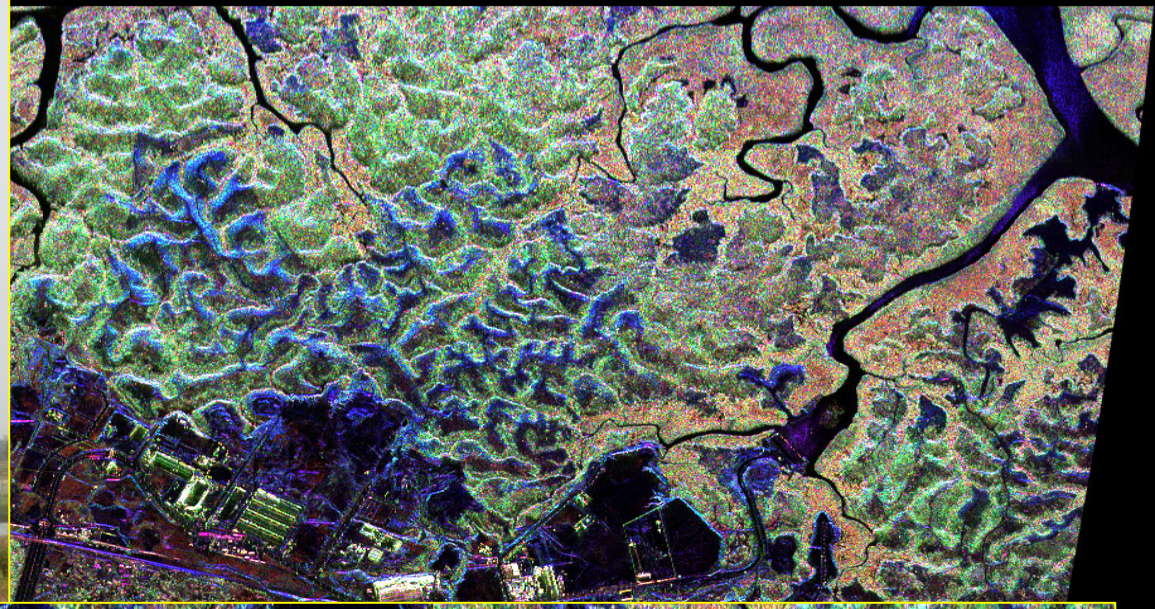
Execution:

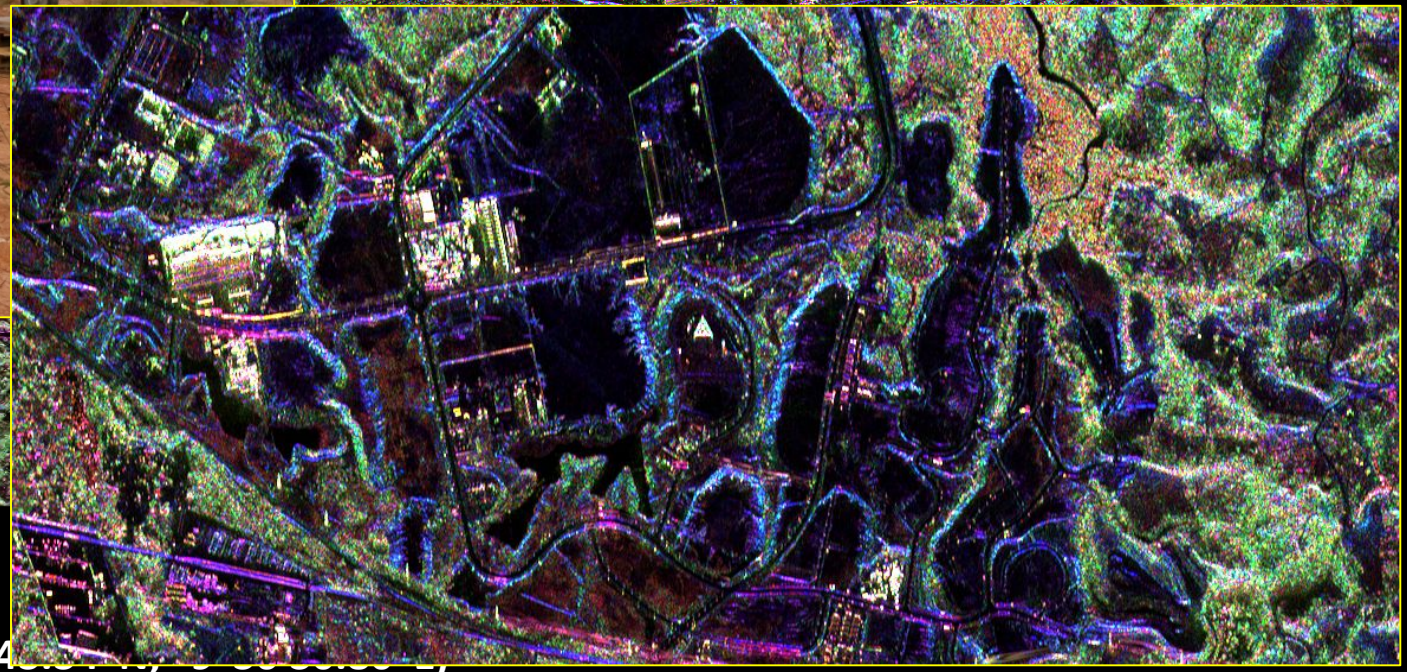
- Flight campaign by ONERA in July 2015
- F-SAR campaign in February / March 2016
- Parallel flights by UAVSAR and LVIS (NASA) in March 2016

Results:

- SAR acquisitions in L and P band quadpol
- Reflectivity, PolInSAR, tomography
- Simulation of BIOMASS products
- Estimation of forest heights and biomass
- Evalutation and development of BIOMASS and Tandem-L algorithms

AfriSAR Campaign: Calibration





surface
double
volume

L band

Nkok
(0°22'4

AfriSAR Campaign: P-Band Mosaic (7 tracks)

surface

double

volume

P-Band

Lopé test site: rain forest / savannah

(0°12'41.06"S, 11°33'11.58"E)

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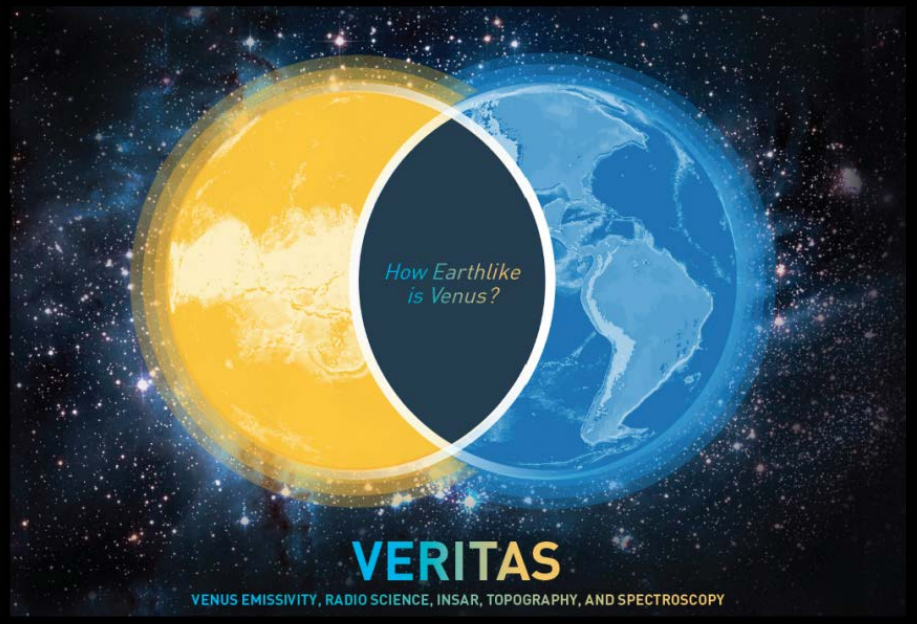
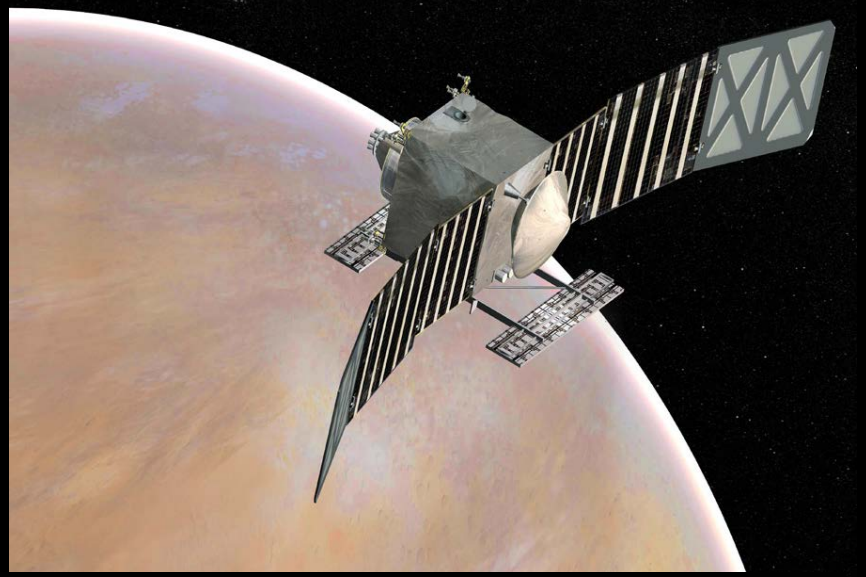
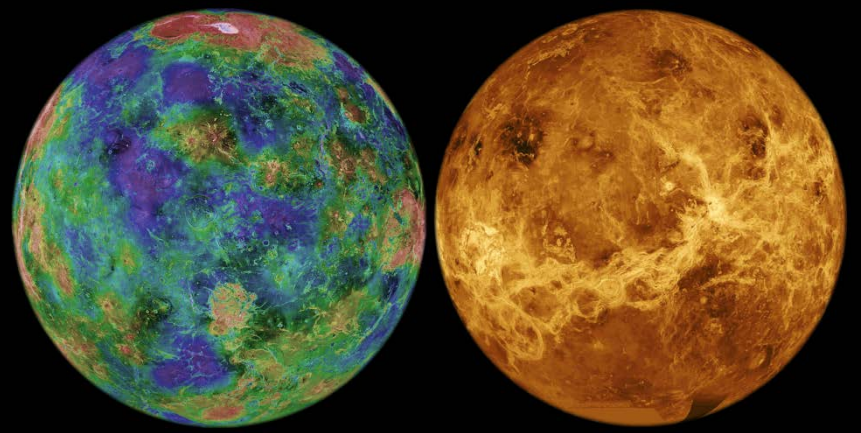
VERITAS

Venus **E**missivity, **R**adio Science, **I**nSAR **T**opography, **A**nd **S**pectroscopy

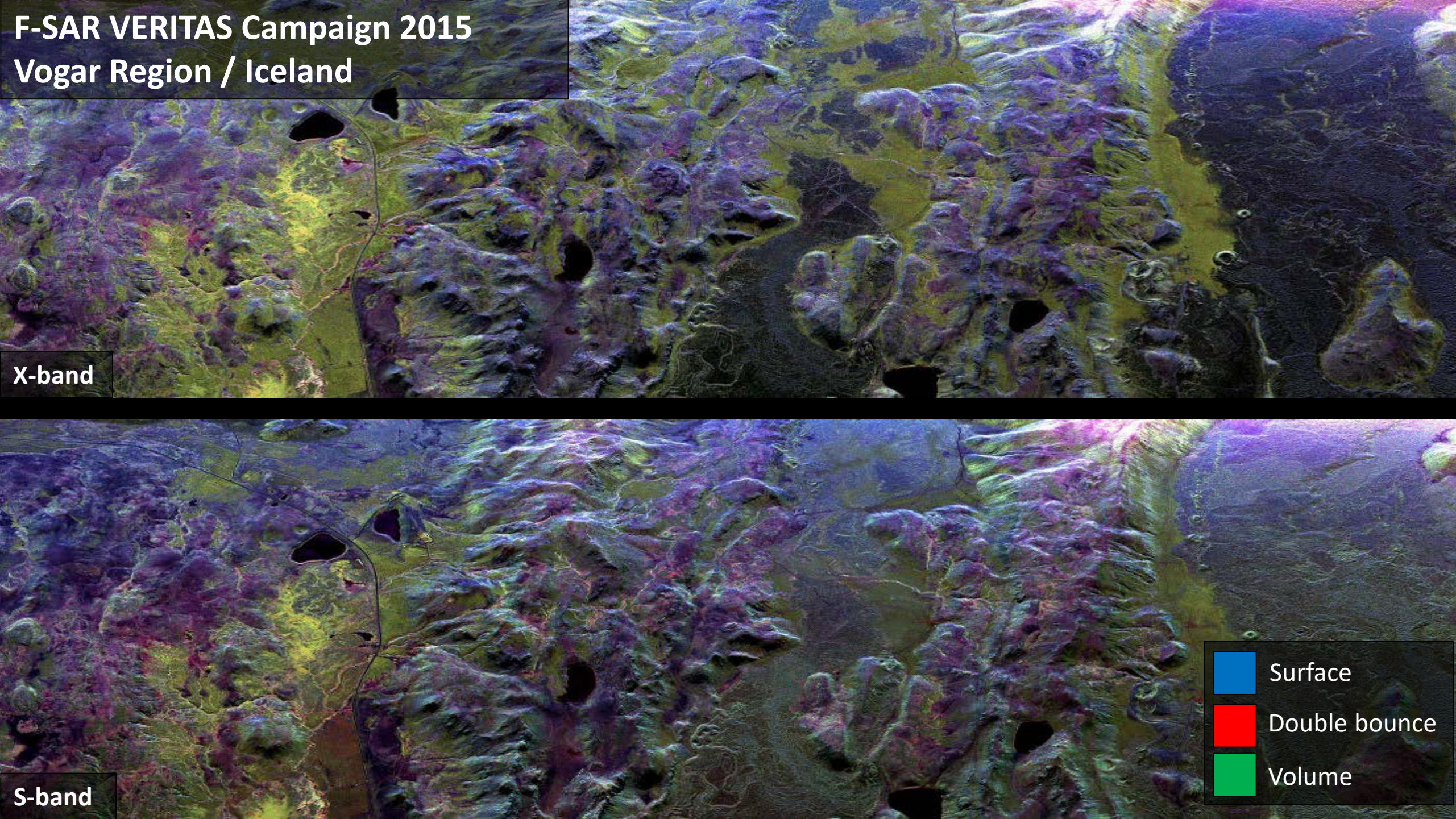




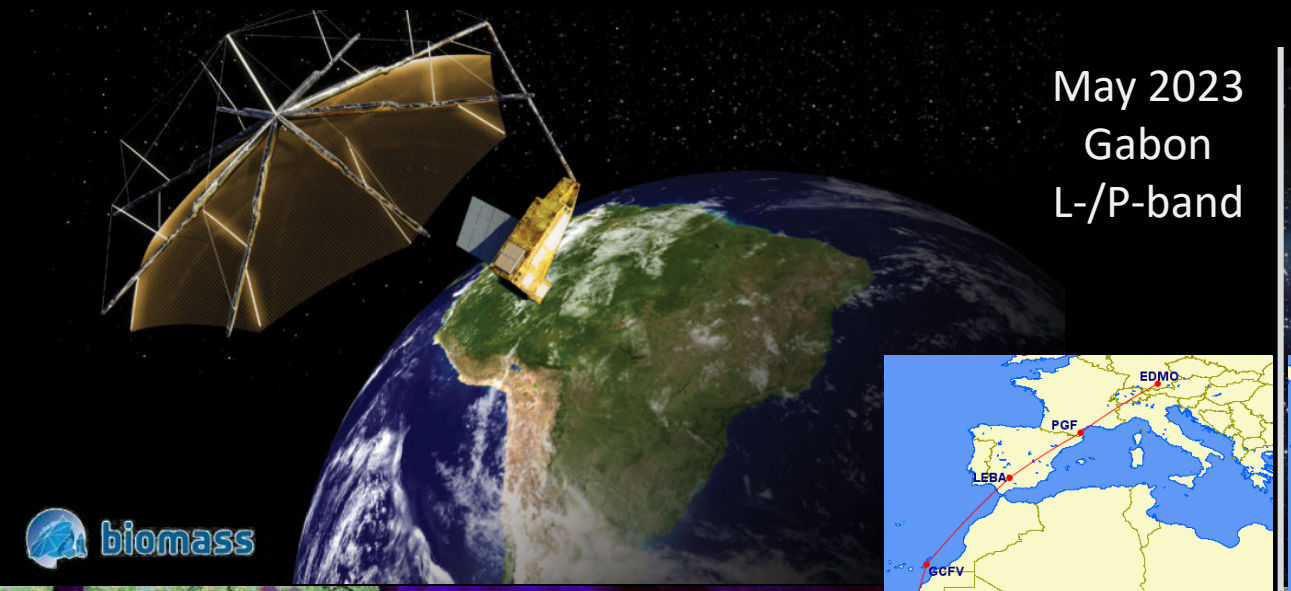
Radar-Reflectivity Map
Magellan Mission (1989-94)



Venus Elevation Model and Reflectivity


F-SAR VERITAS Campaign 2015
Vogar Region / Iceland
X-band
S-band
Surface
Double bounce
Volume

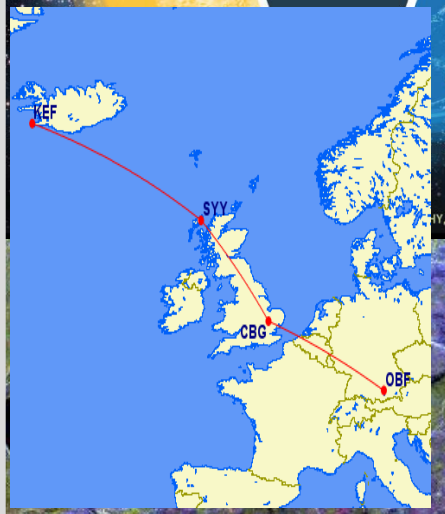
F-SAR Campaigns'23: GABONX, VERITAS



May 2023
Gabon
L-/P-band

Mangroves in Gabon, AfriSAR campaign 2016

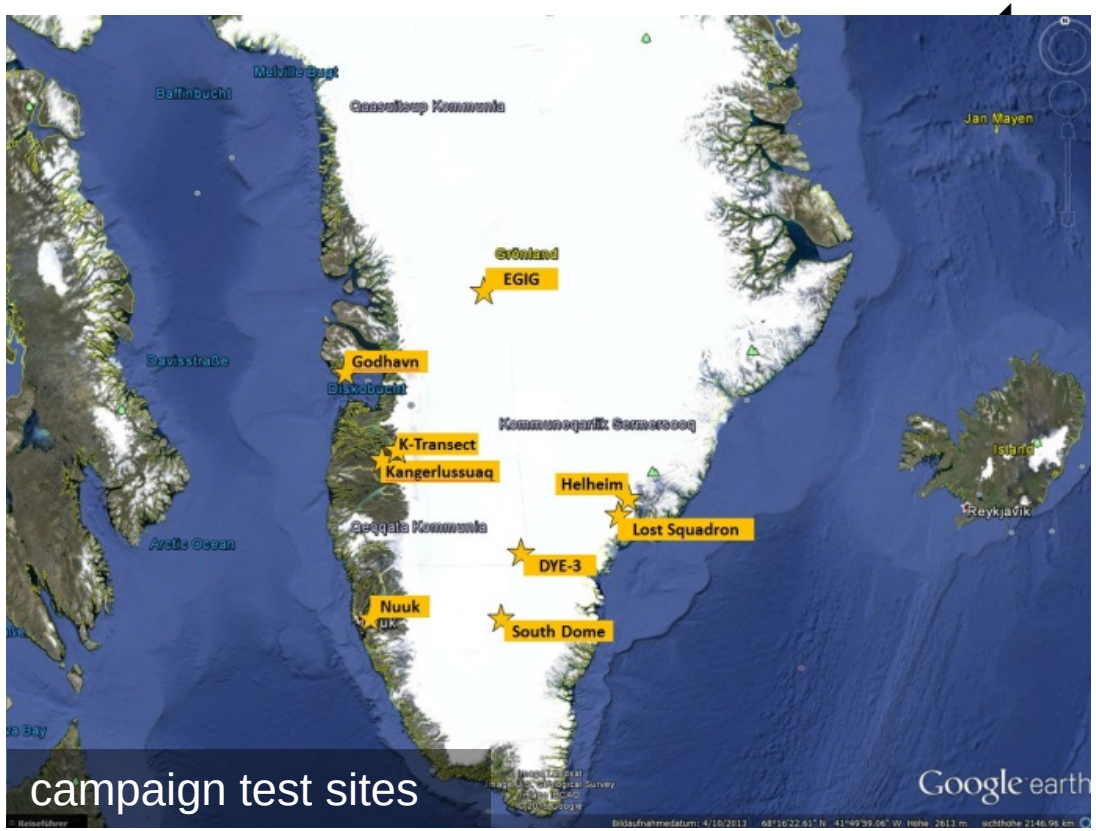
August 2023
Iceland
X-/S-band

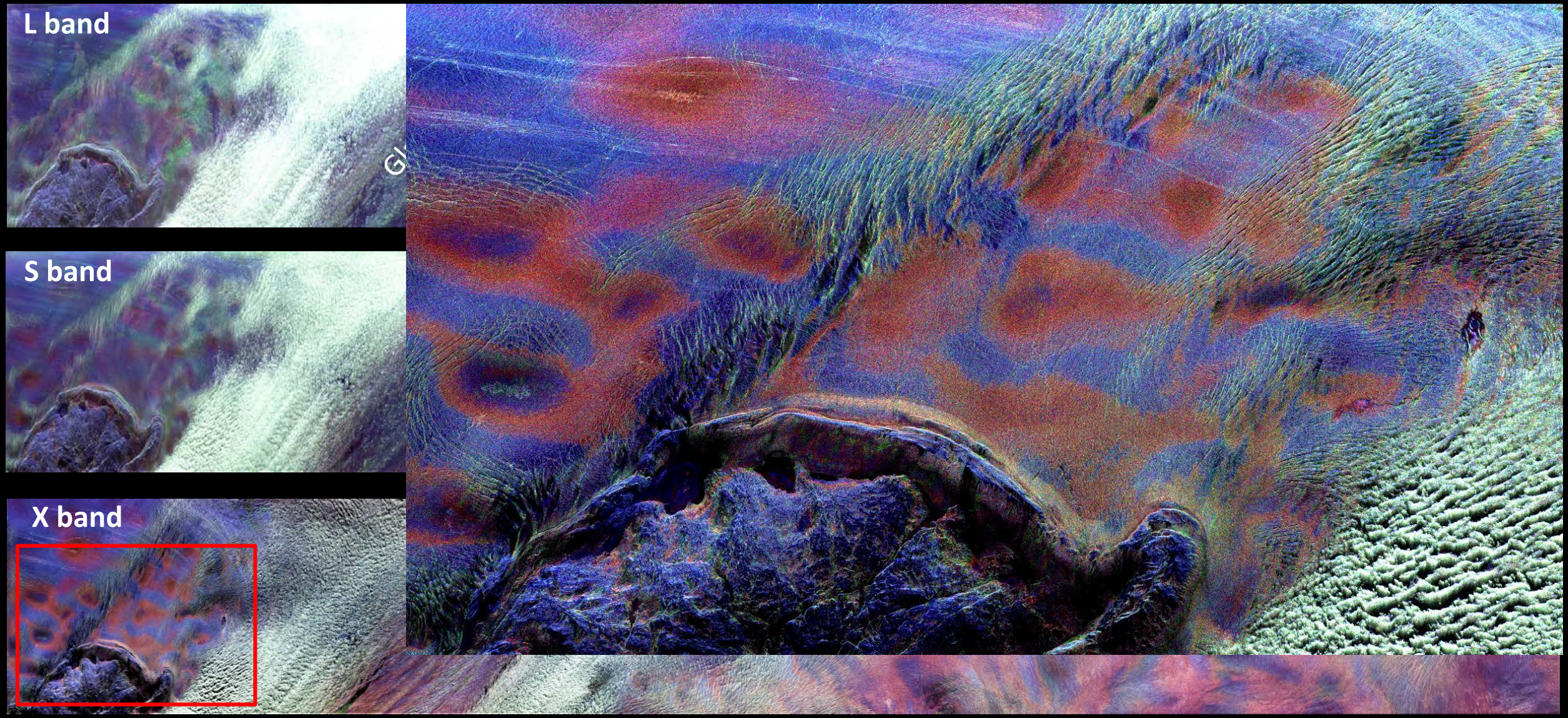


Volcanic surfaces in Iceland, Veritas campaign 2015

F-SAR Campaign ARCTIC/DALOX (May 2015)

- **11 test-sites** in Greenland
- DALOX: Evaluation of high-resolution SAR for **security applications** in Arctic environments
- ARCTIC: Analysis of several novel methods for the **estimation of snow and ice parameters** in preparation of **Tandem-L**
- Study of the strongly varying penetration capabilities of the different bands into snow and ice
- Acquisition of unique data sets for further research





ARCTIC15

F-SAR CAMPAIGN
April - May 2015

Helheim Glacier, differences in L, S and X band.
Fully polarimetric images.
Pauli decomposition R,G,B = HH-VV, HV, HH+VV.

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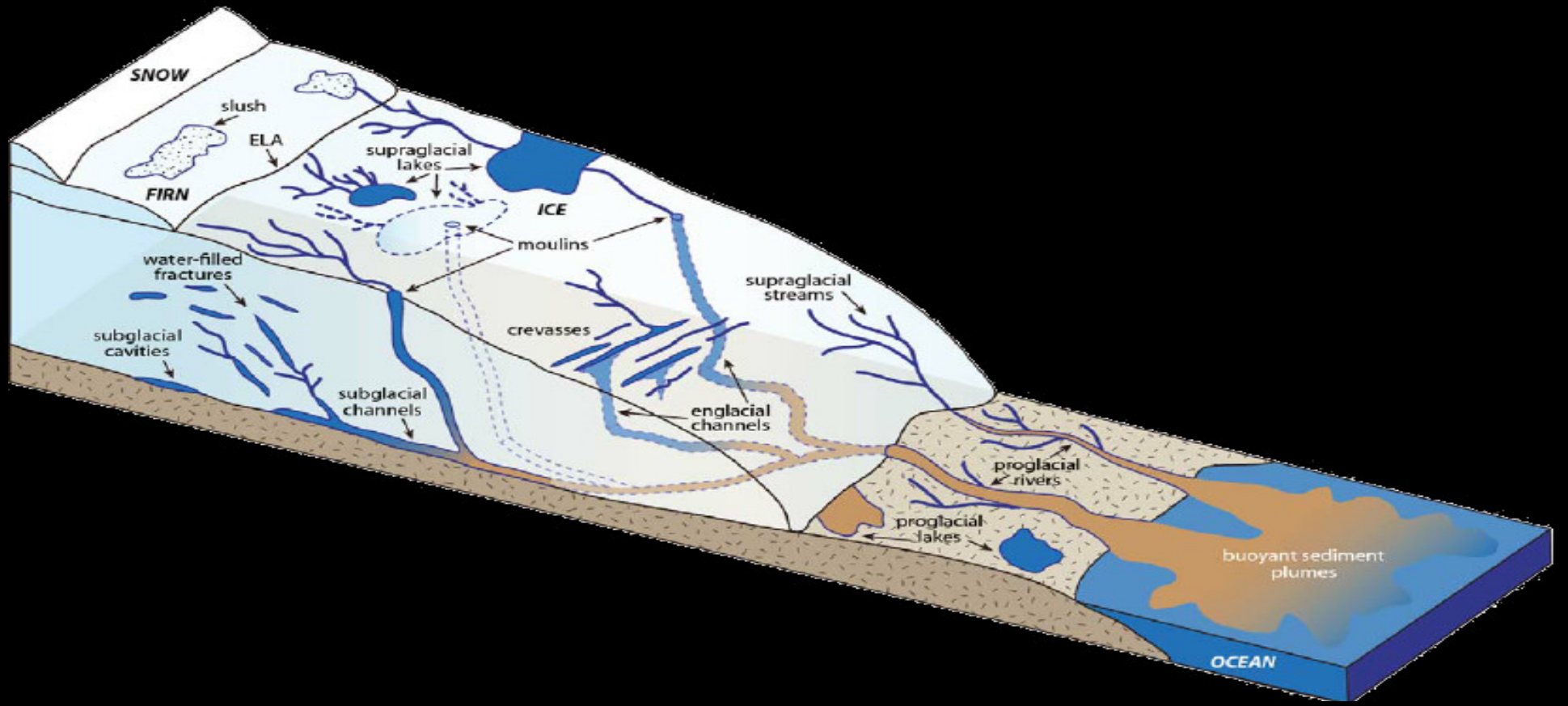


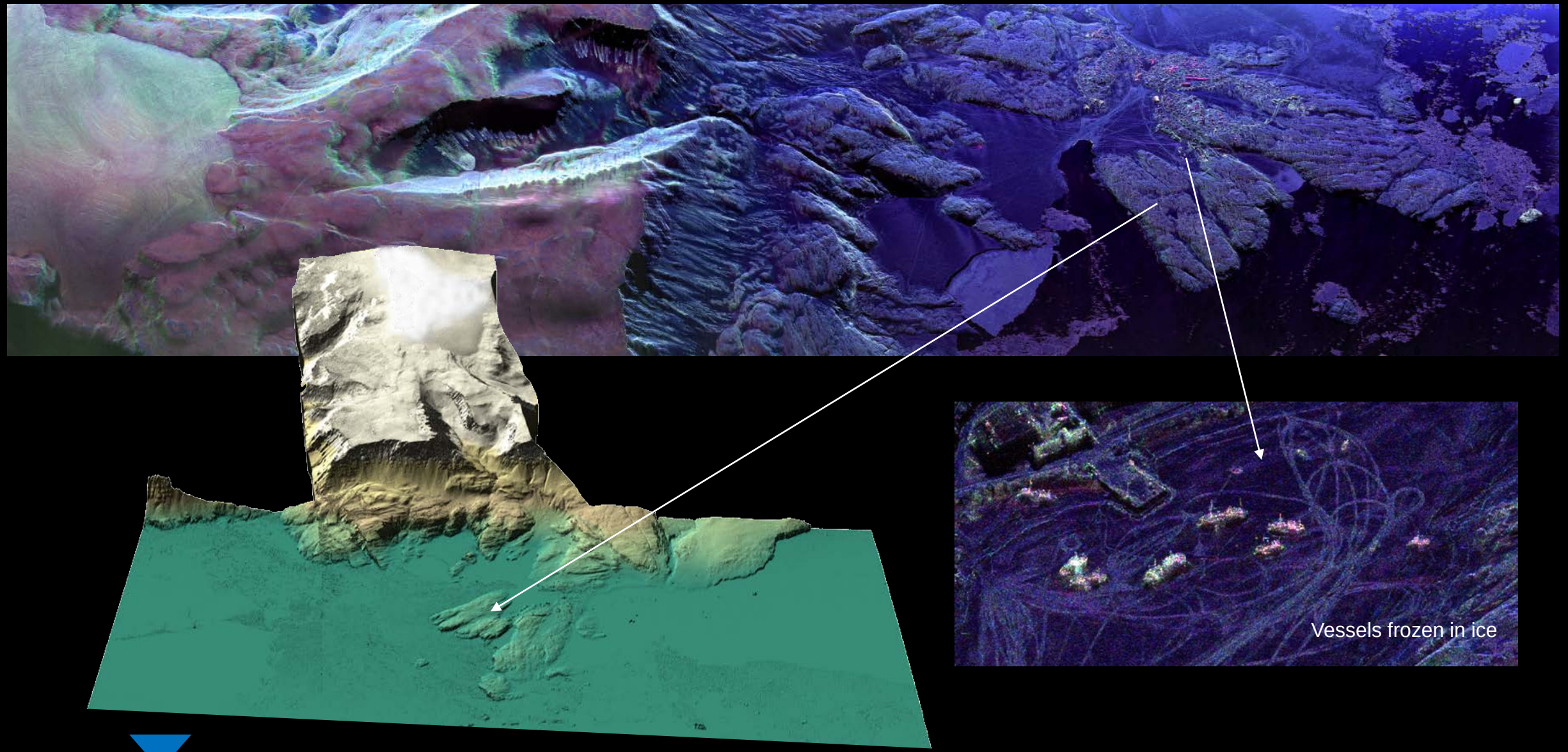
ARCTIC15

F-SAR CAMPAIGN
April - May 2015

K-Transect - Percolation zone

Fully polarimetric images.
Pauli decomposition R,G,B = HH-VV, HV, HH+VV.

DLR



F-SAR CAMPAIGN
April - May 2015

ARCTIC15

Greenland

Disko island near the Greenland coast, a high plateau (left) covered with snow and ice and the city of Godhavn (right).

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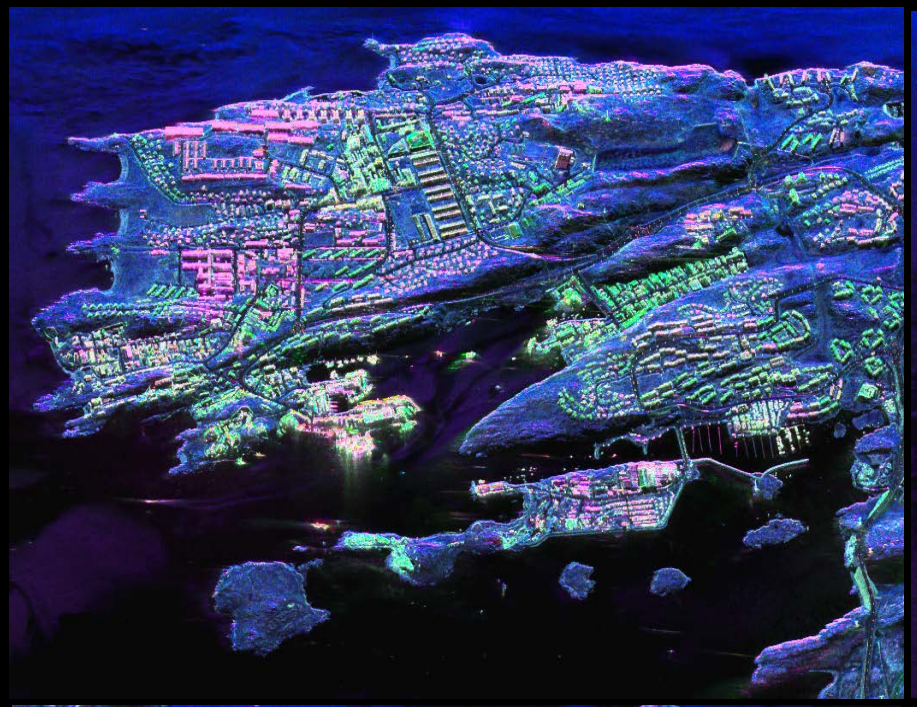
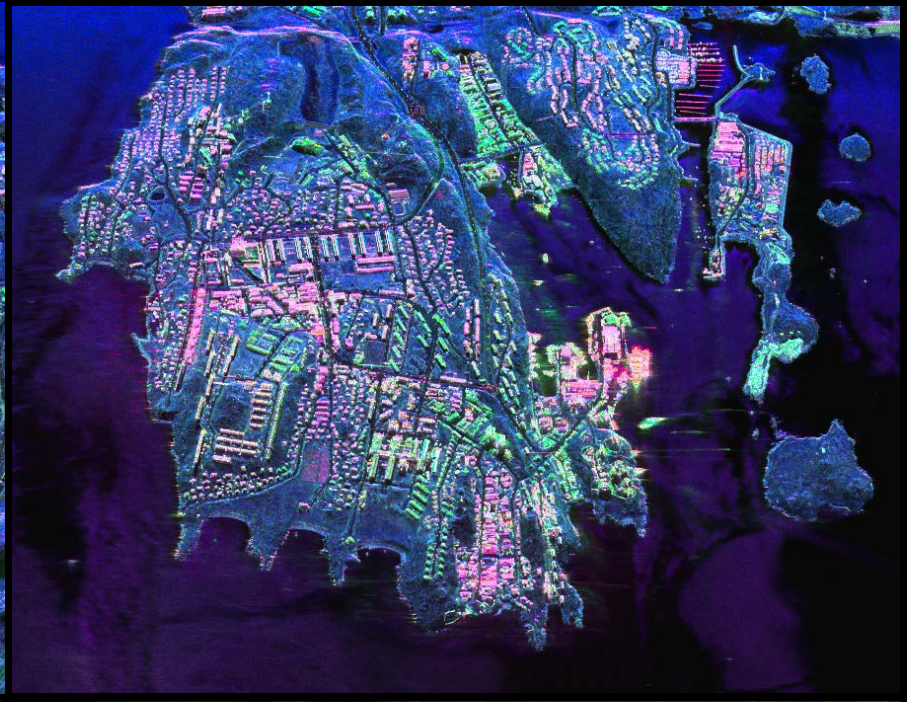
Nuuk, seen from 4 aspect angles

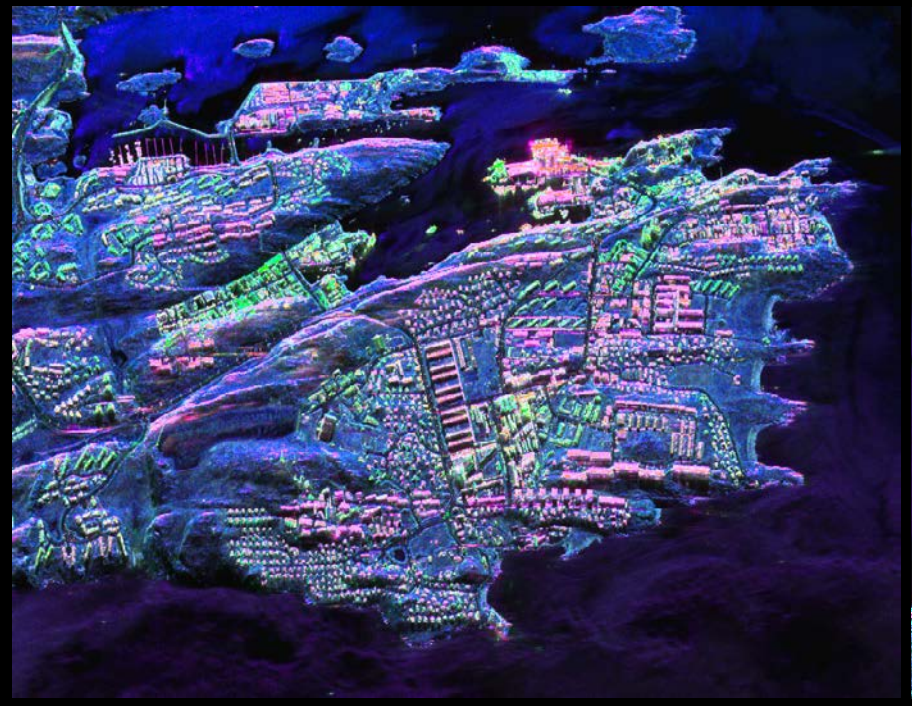
Fully polarimetric images.
L-band, Pauli decomposition
R,G,B = HH-VV, HV, HH+VV.

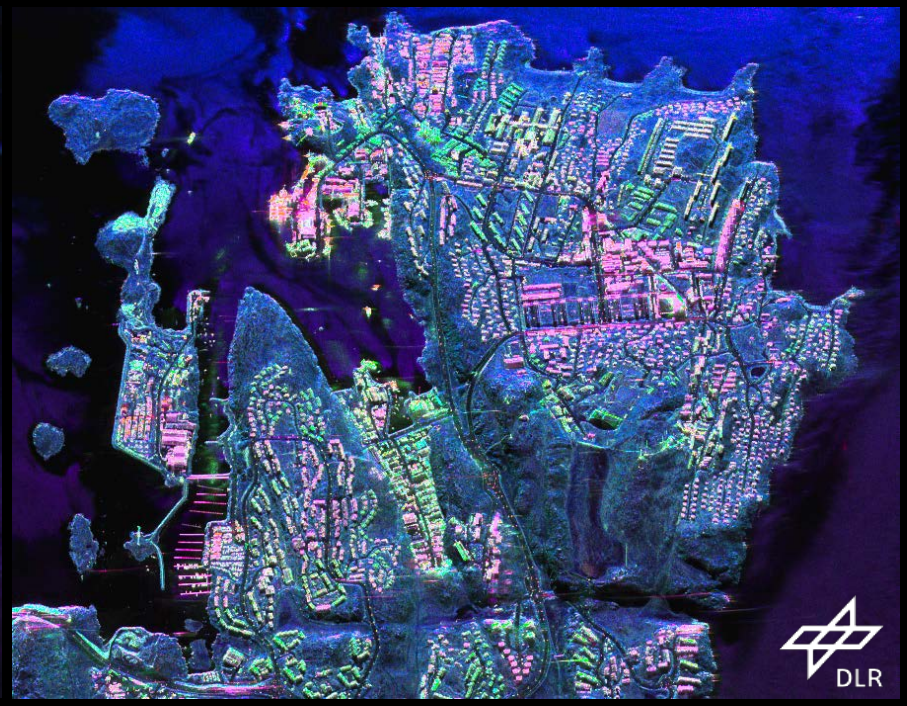
ARCTIC15

F-SAR CAMPAIGN
April - May 2015









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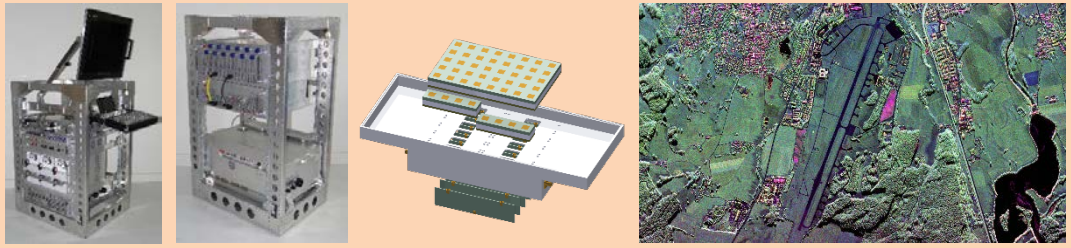
Ongoing hardware upgrades

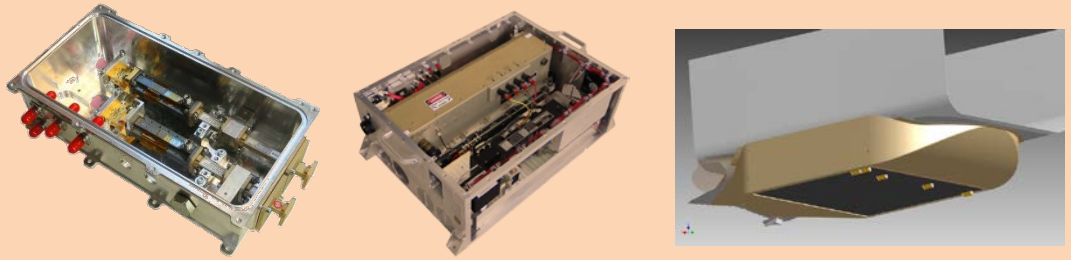
DBFSAR

- *Goal: 12-channel X-band DBF, 1.8GHz bandwidth*
- Operational in GMTI mode since 2018
- Full DBF configuration will become available in 2024



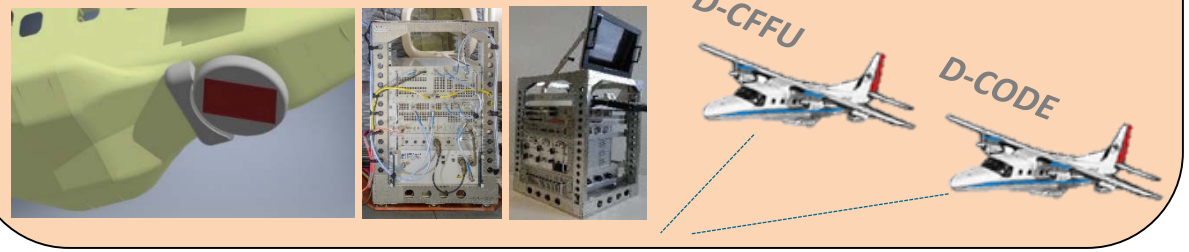
Ka-Band PolInSAR demonstrator

- *Goal: Ka-Band polarimetric interferometer with 3 simultaneous baselines, 500-1000MHz bandwidth*
- Ongoing work, flight tests expected in 2025



DuoLIM

- *Goal: airborne bistatic configuration at L-band*
- In support of Tandem-L & ROSE-L
- First flight tests in 2023, to be completed in 2024



DuoXCSim (GI draft, start in 2024 - tbd):

- *Goal: extension of DuoLIM to X-, C- & S-band*
- In support of the Harmony mission
- Only proposal... Possible implementation 2024ff.

Summary

Current status:

- Airborne SAR is (and stays) an essential tool to design and prepare future satellite missions!
- Many successful scientific data acquisition campaigns (supporting TerraSAR-X, TanDEM-X, BIOMASS, Tandem-L, Hydroterra, Harmony, ROSE-L, Sentinel-1, VERITAS, etc.)
- Development of new imaging techniques and applications (Inteferometry, PolinSAR, Tomography, Holography, etc.)
- Expertise in high-precision SAR processing and calibration

Looking forward:

- Several scientific airborne campaigns (internal & external) are already scheduled (or at least intended) (BIOMASS, VERITAS / EnVision, ROSE-L, Harmony, etc.)
- A new digital backend “DBFSAR” extends F-SAR capabilities (digital beamforming, higher resolution)
- A Ka-band PolInSAR subsystem is under development (shorter wavelength, SKADI)
- A new bistatic airborne L-band system “DuoLIM” will be finished next year (Tandem-L)

Kaufbeuren (Germany)
DBFSAR, X Band quadpol
0.25 m x 0.25 m resolution