DLR's Airborne F-SAR System

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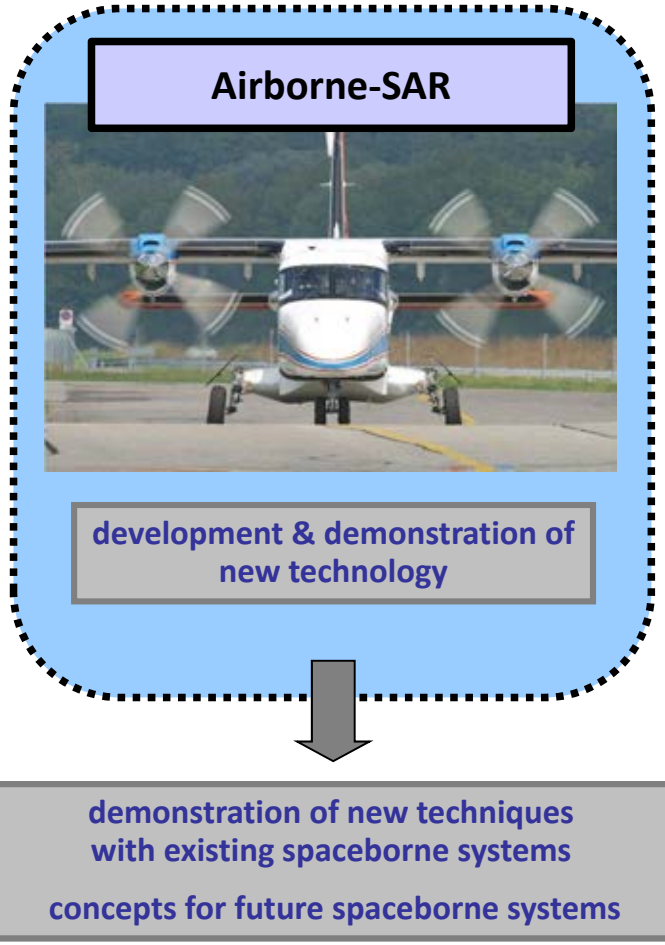
Why Airborne SAR?

Advantages of airborne SAR:

- Higher SNR & resolution than spaceborne sensors
- Flexible operation of the sensor
- Experimental platform for new technology

For the Institute:

- Defining the „state-of-the-art“ in SAR sensor technology
- Prepare future satellite missions
- Test and develop new signal processing algorithms
- Development and demonstration of new products and imaging techniques
- Execution of scientific flight campaigns



The Advanced Airborne Sensor F-SAR

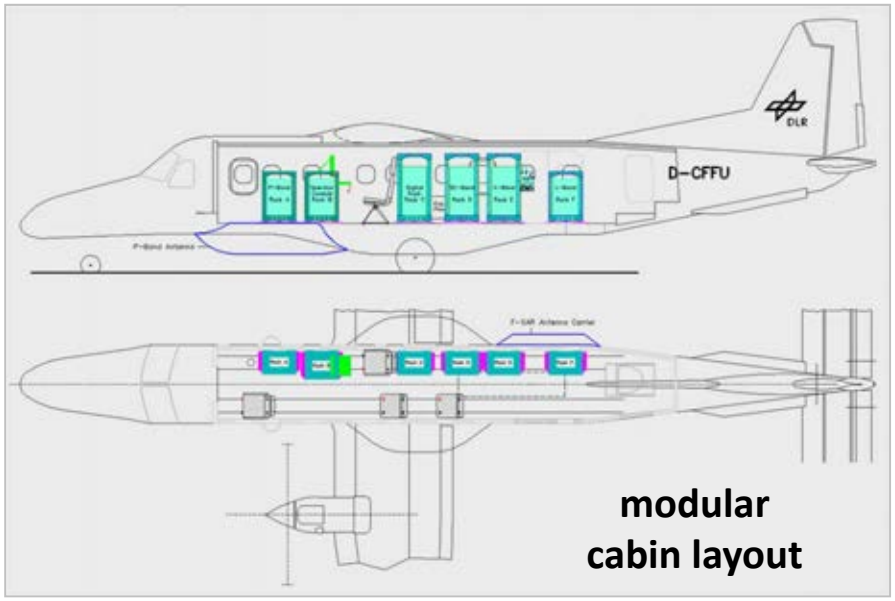
Remarkable features:
- Very high resolution and SNR
- Multispectral operation (up to 4 bands)
- Polarimetry in all bands
- Single-pass interferometry at X and S-band
- Modular sensor design

F-SAR technical characteristics

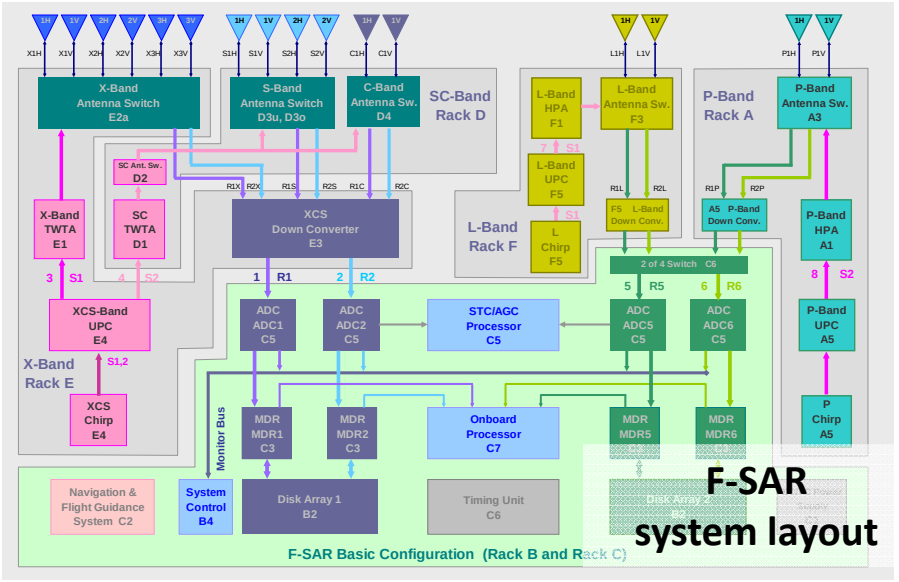
	X	C	S	L	P
RF [GHz]	9.6	5.3	3.2	1.3	0.35
BW [MHz]	800	400	300	150	100
PRF [kHz]	up to 12				
Rg res. [m]	0.2	0.4	0.5	1.0	1.5
Az res. [m]	0.2	0.3	0.35	0.4	1.5
PolSAR	✓	✓	✓	✓	✓
Rg cov [km]	12.5 (at max.bandwith)				
Sampling	8 Bit real; 1000MHz; 4 channels.				

Main Goals:
- Defining the „state-of-the-art“ in SAR sensor technology
- Scientific flight campaigns, preparation of new satellite missions
- New approaches by multispectral & high resolution PolSAR imaging

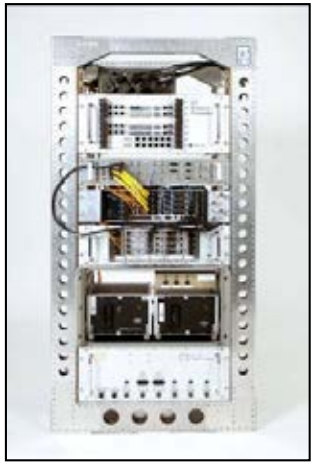
The Advanced Airborne Sensor F-SAR



modular
cabin layout



F-SAR
system layout



F-SAR core modules

X-band
rack

C/S-band
rack

L-band
rack

P-band
rack

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F-SAR „in action“ (mounted on research plane Do228)

DLR

Simulation of Future Spaceborne Products

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

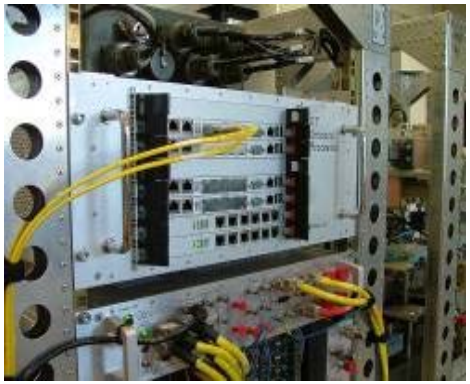
Simulation of Future Spaceborne Products

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

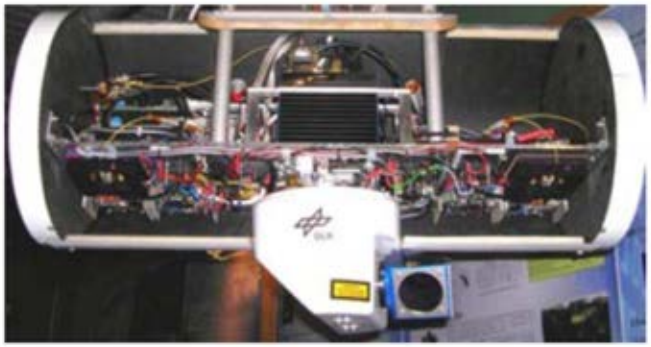
Real-time Situation Monitoring

F-SAR (DLR-HR)

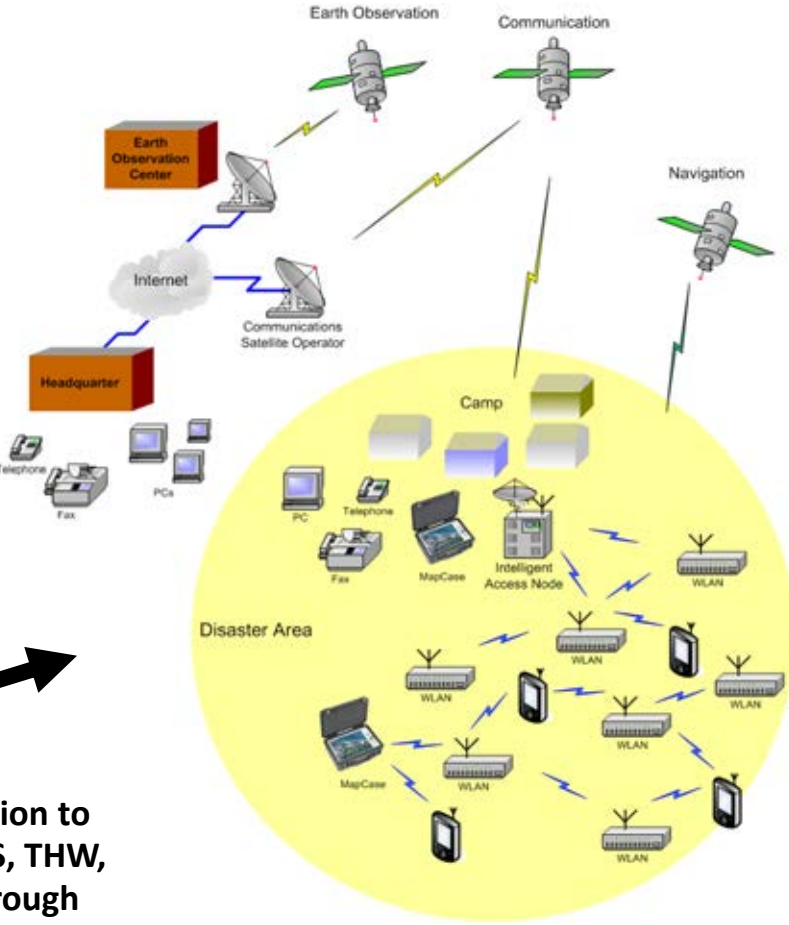
weather independent
day & night capability



real-time onboard processing



data downlink: 1.25 GBit/sec
(DLR-KN) laser / microwave



Data distribution to end-users (BOS, THW, red cross) through central platform

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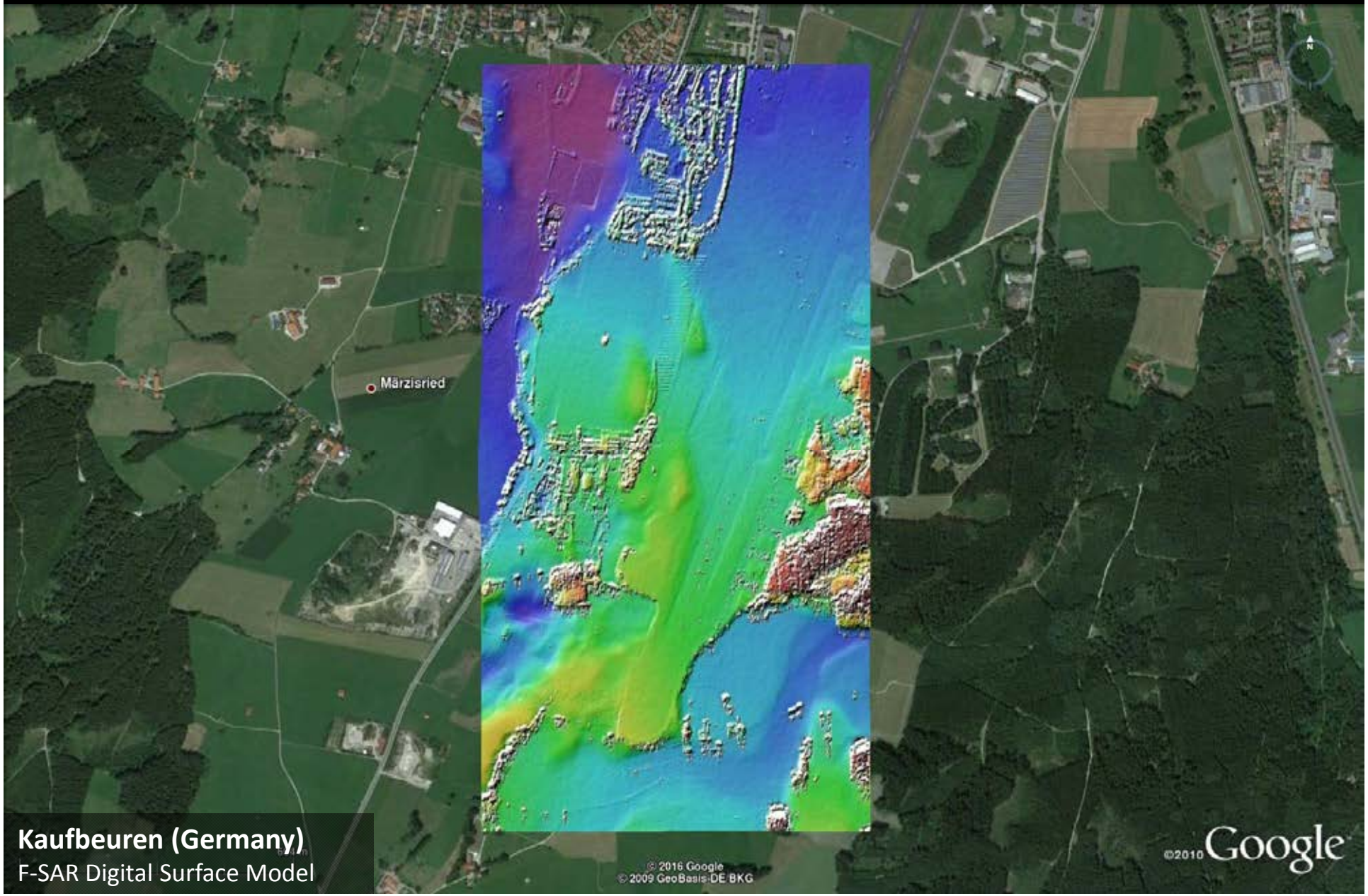
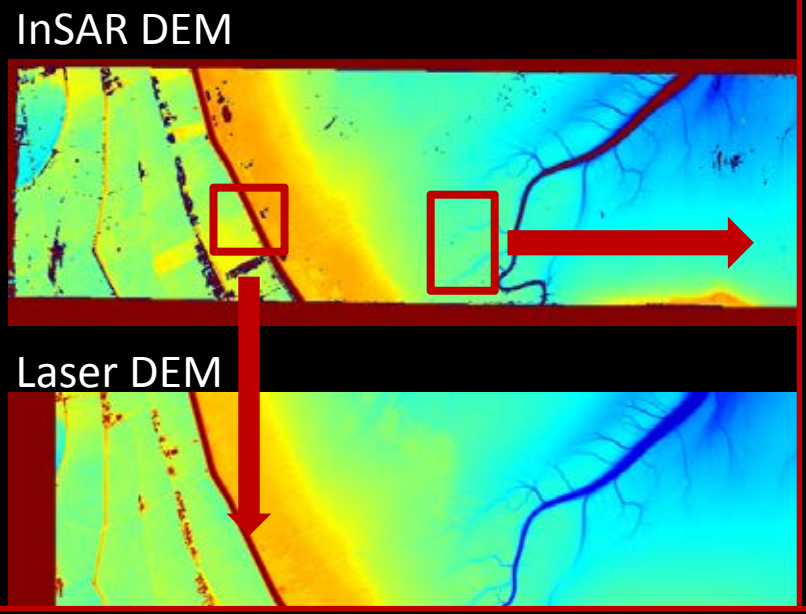
Real-time Situation Monitoring

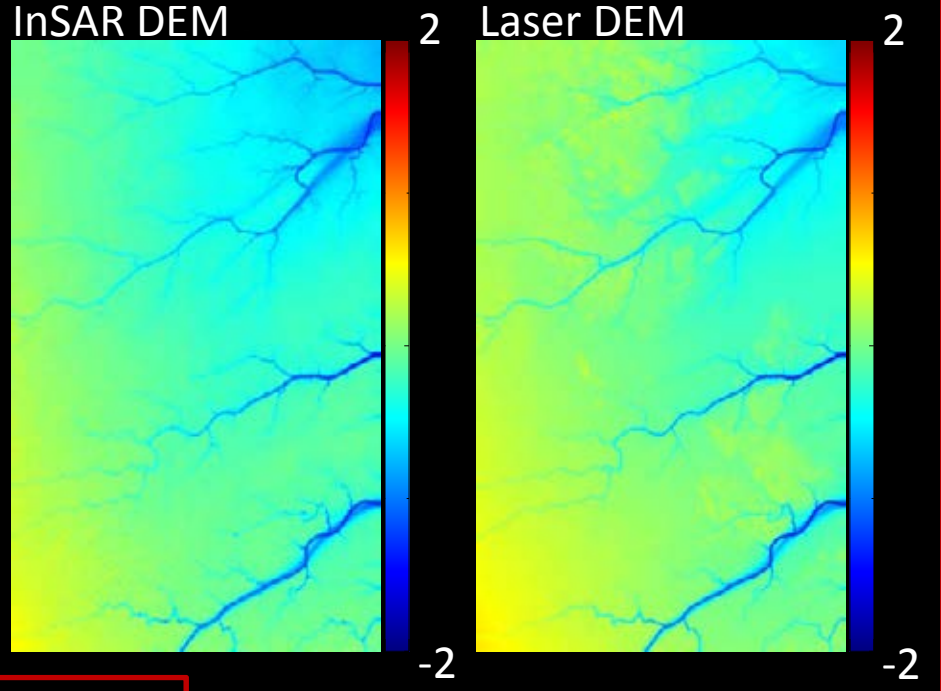
InSAR: Generation of digital elevation models



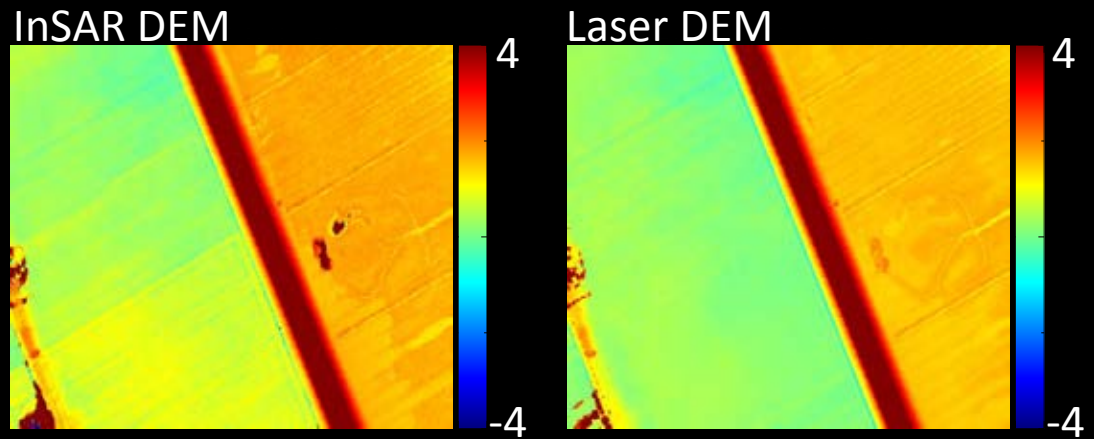
Kaufbeuren (Germany)
F-SAR Digital Surface Model

InSAR: Generation of digital elevation models





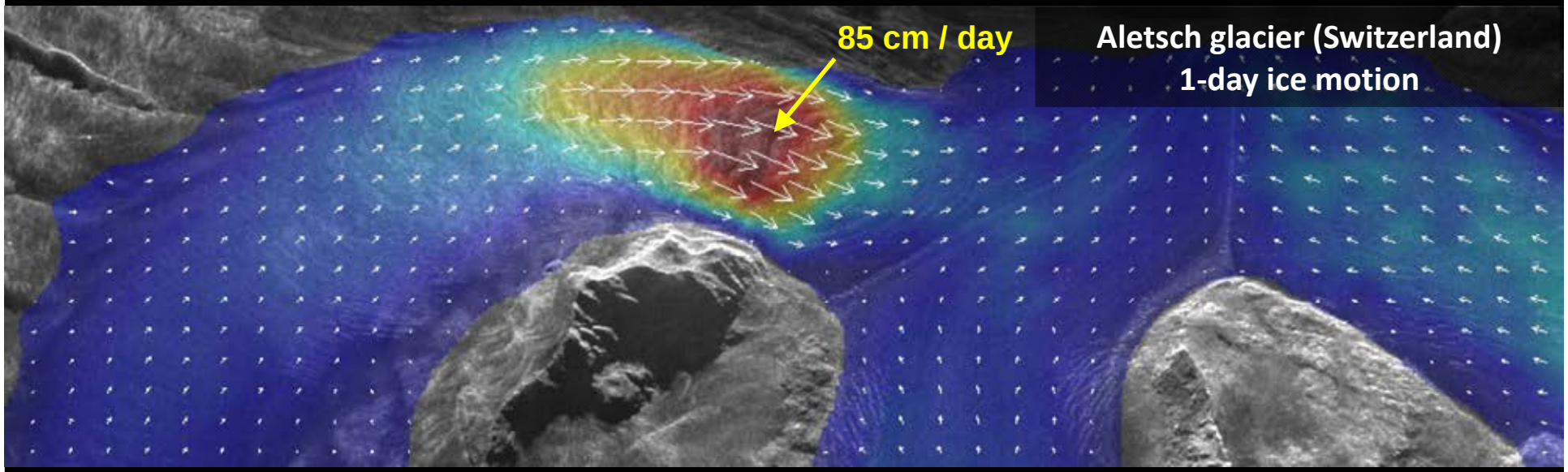
μ = -0.15m σ = 0.11m



μ = 0.21m σ = 0.22m

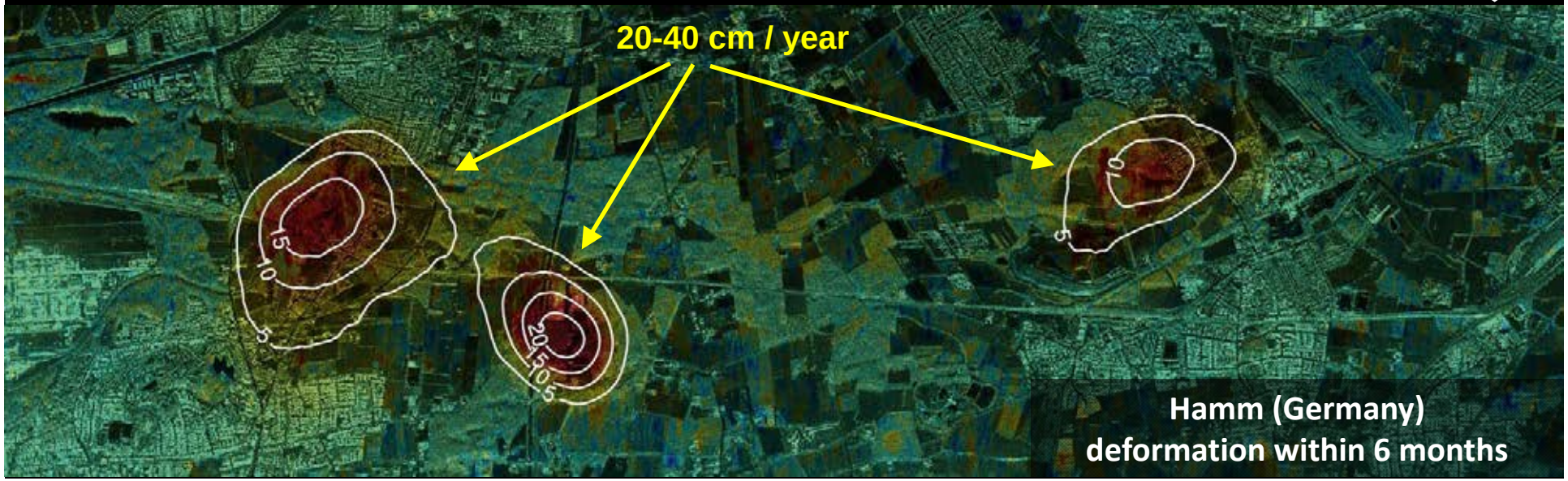
Testsite: Jade Bight
F-SAR Digital Surface Model
vs. ALS Reference Heights

DInSAR: Measurement of Ground Deformation / Motion

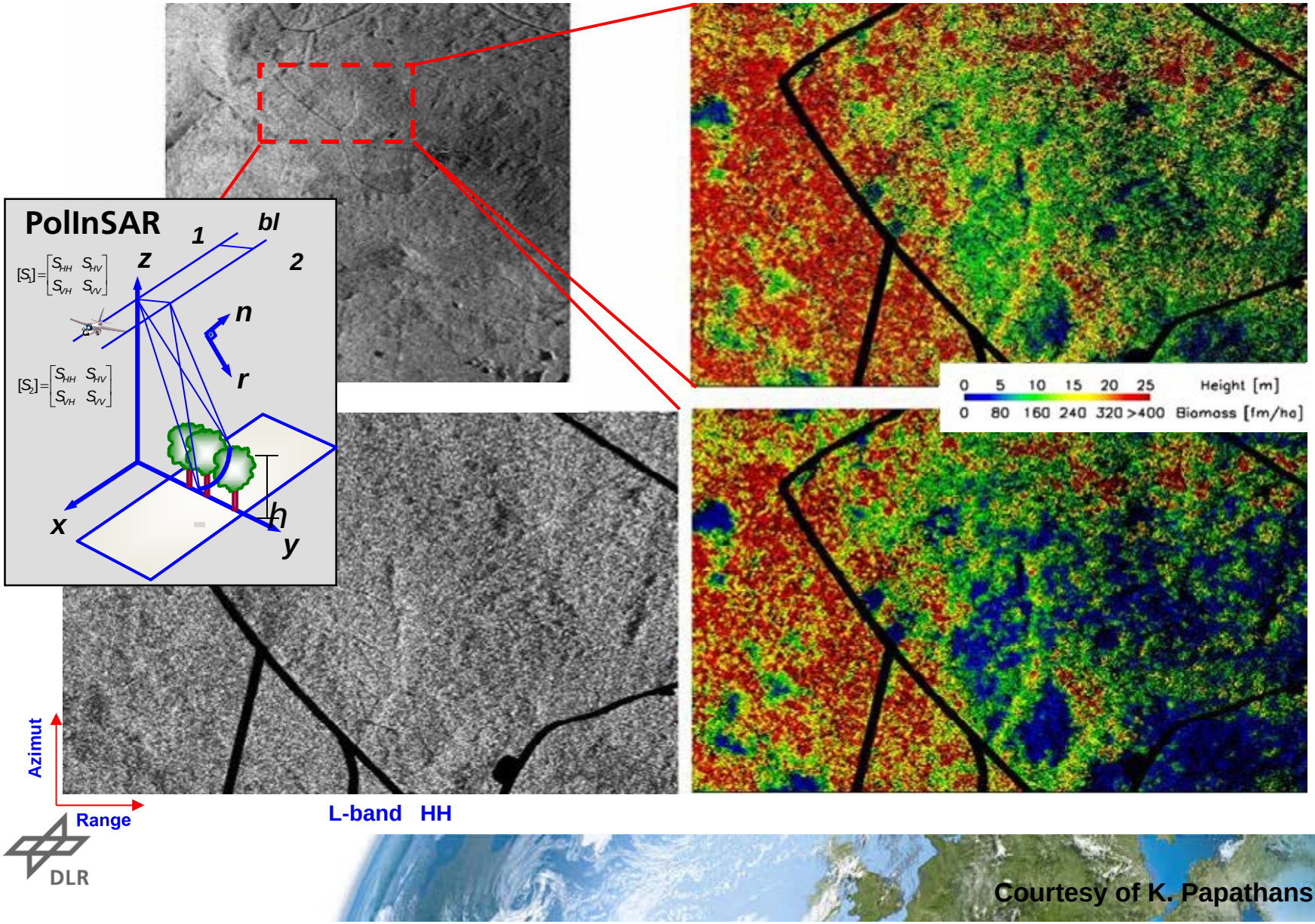


SWISAR campaign (2006 & 2007)

DINSAR campaign (2009)



Polarimetric Interferometry:
Estimation of Forest Height and Biomass



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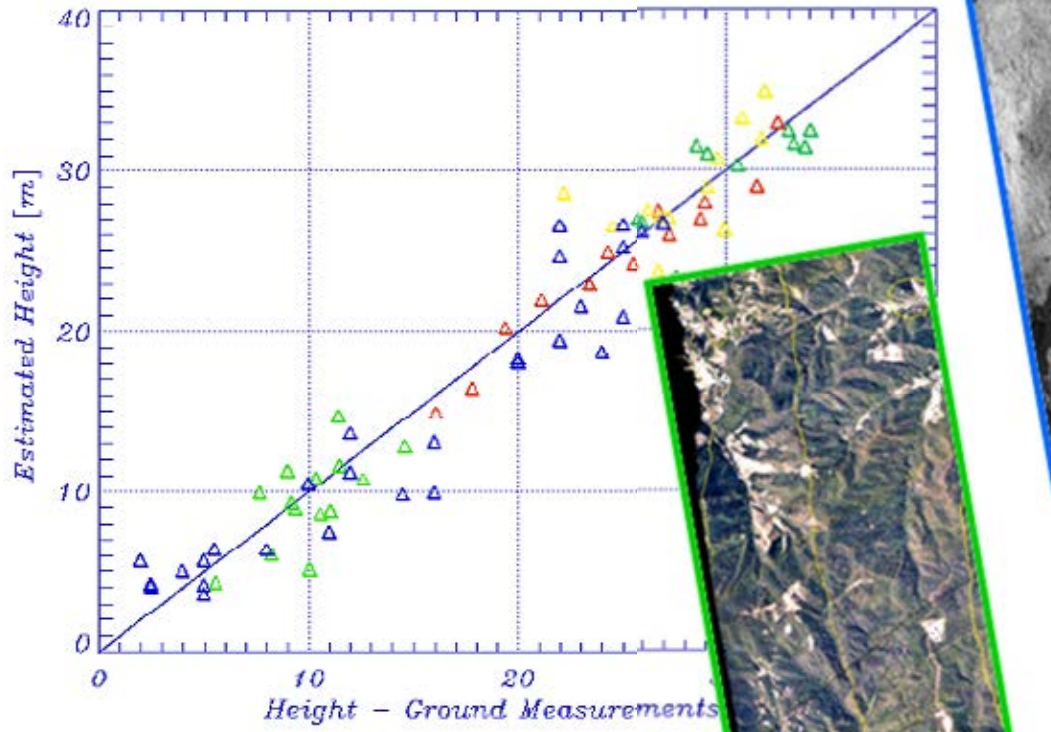
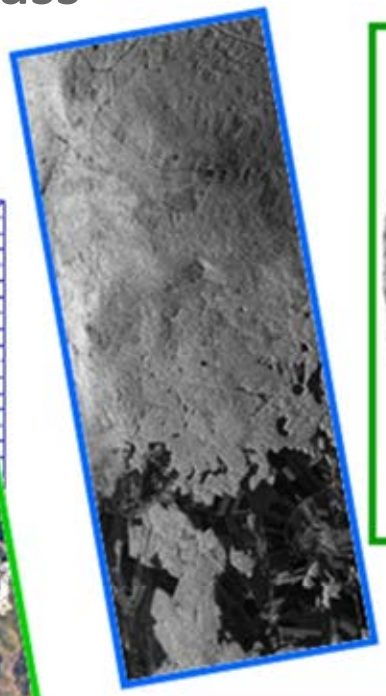
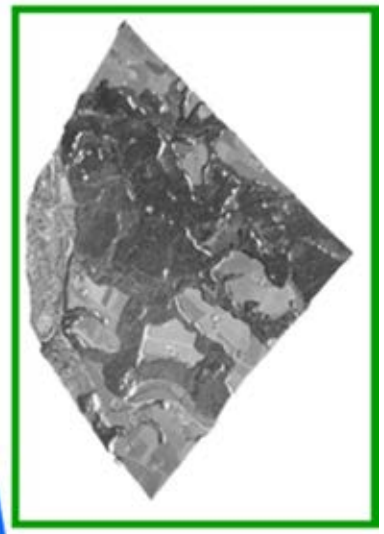
Courtesy of K. Papathanssiou

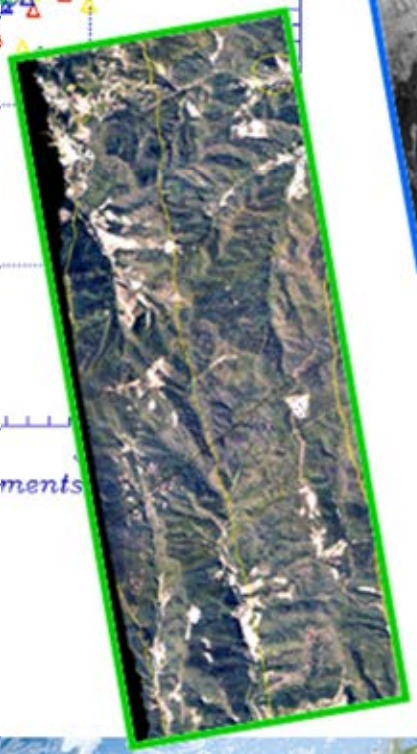
Polarimetric Interferometry:
Estimation of Forest Height and Biomass

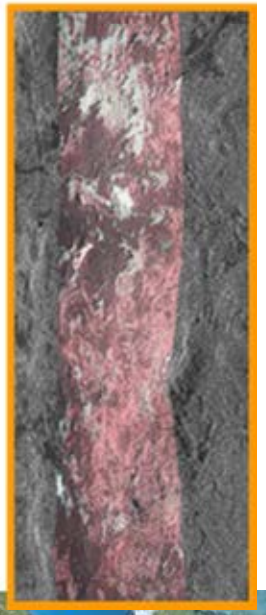
Courtesy of











Fichtelgebirge / Germany
Corridor / Spain
Bayrischer Wald / Germany
Traunstein / Germany
Oberpfaffenhofen / Germany

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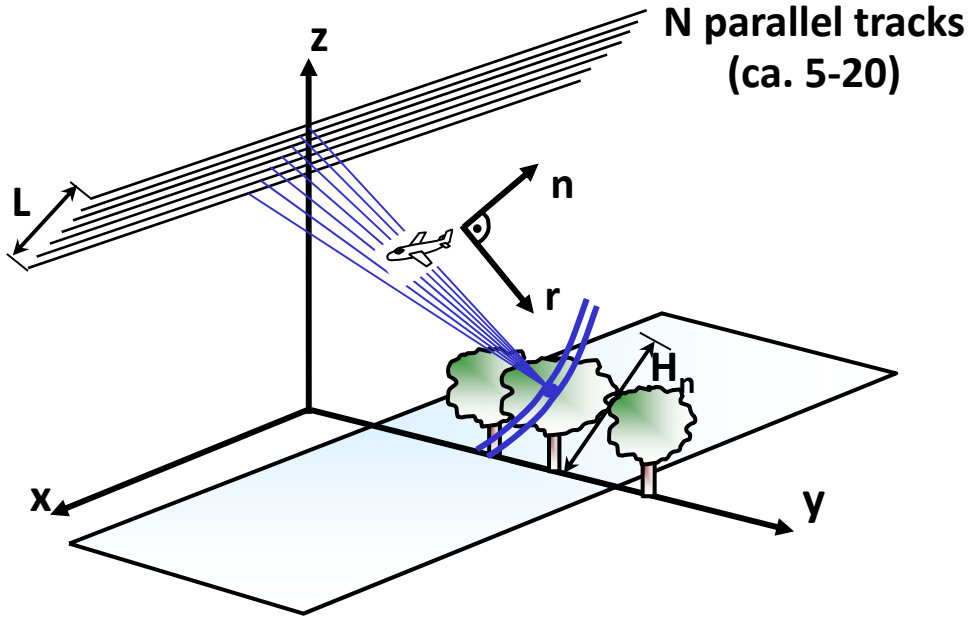
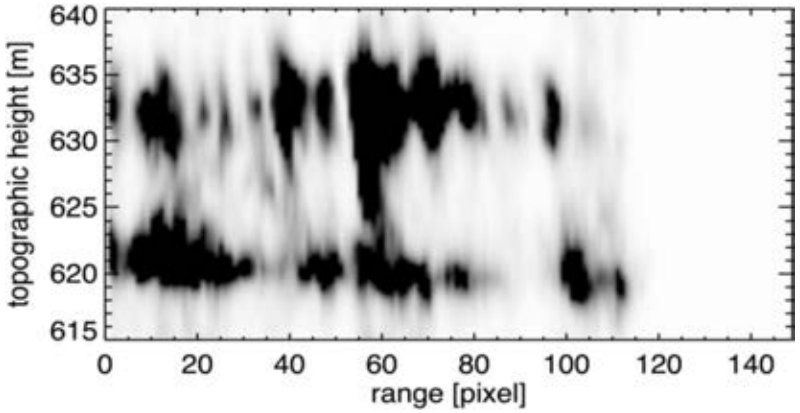
3D SAR Tomography

- **Innovative method for3D-imaging**
- **Possible applications:**
  - Vegetation structure, biomass
  - 3D City models
  - Archeology





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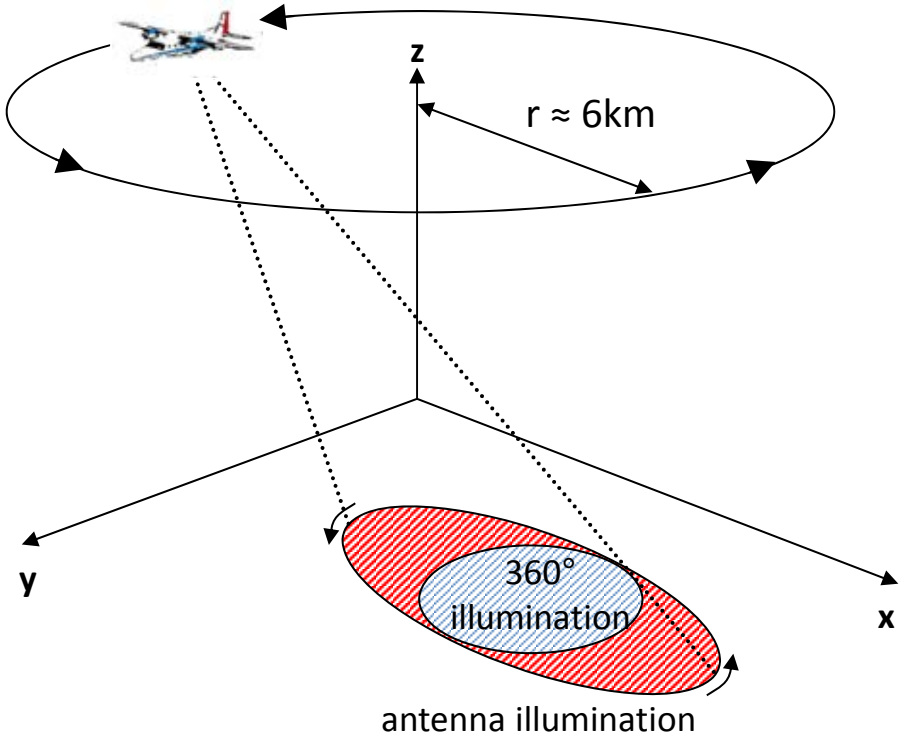
Circular SAR Imaging

- Possibility of extremly high resolution (up to λ/4, i.e. about 6cm at L-band)
- Possibility of “holographic” 3D imaging
- Possibility of continous imaging (“video SAR”)



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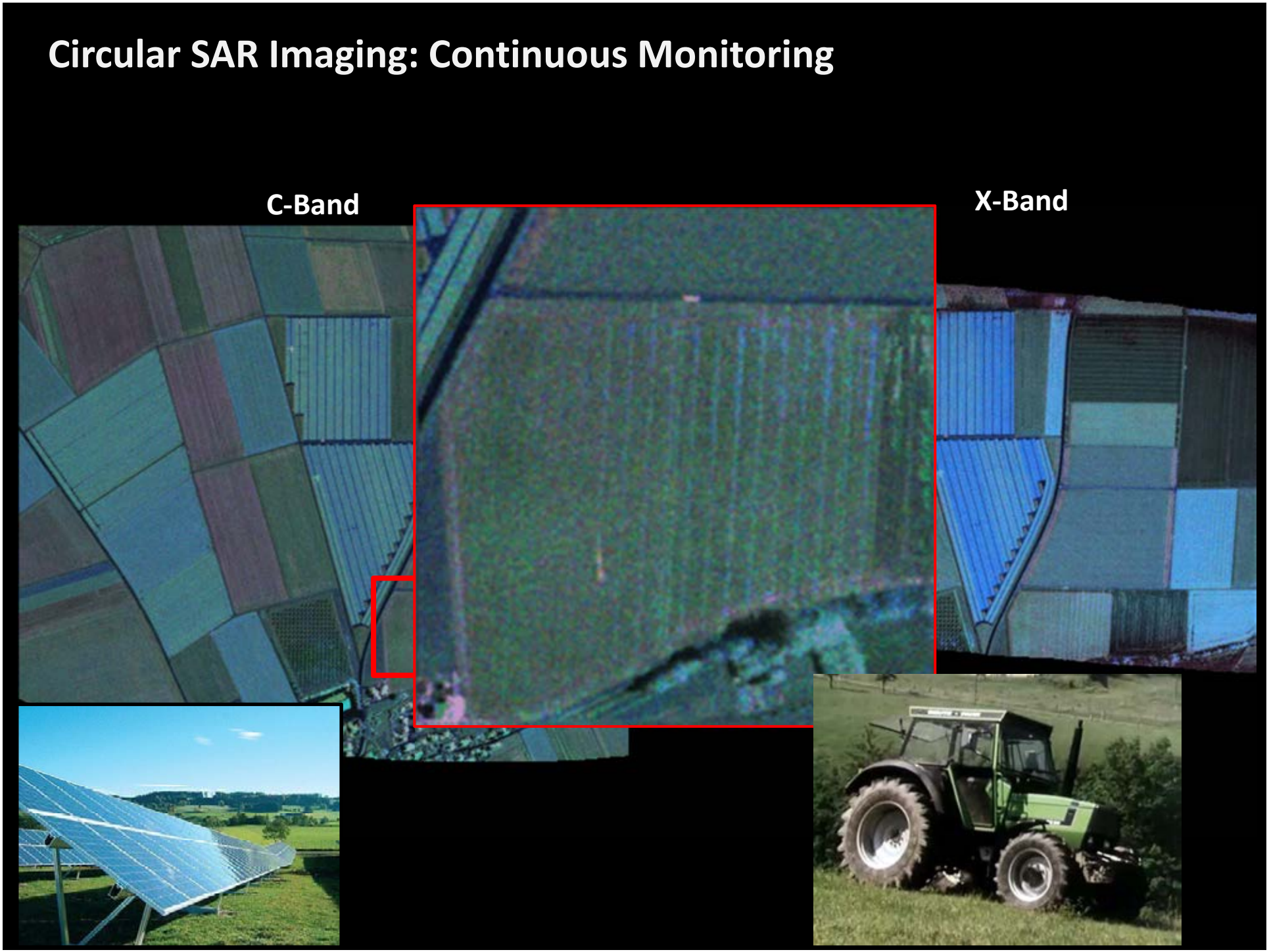
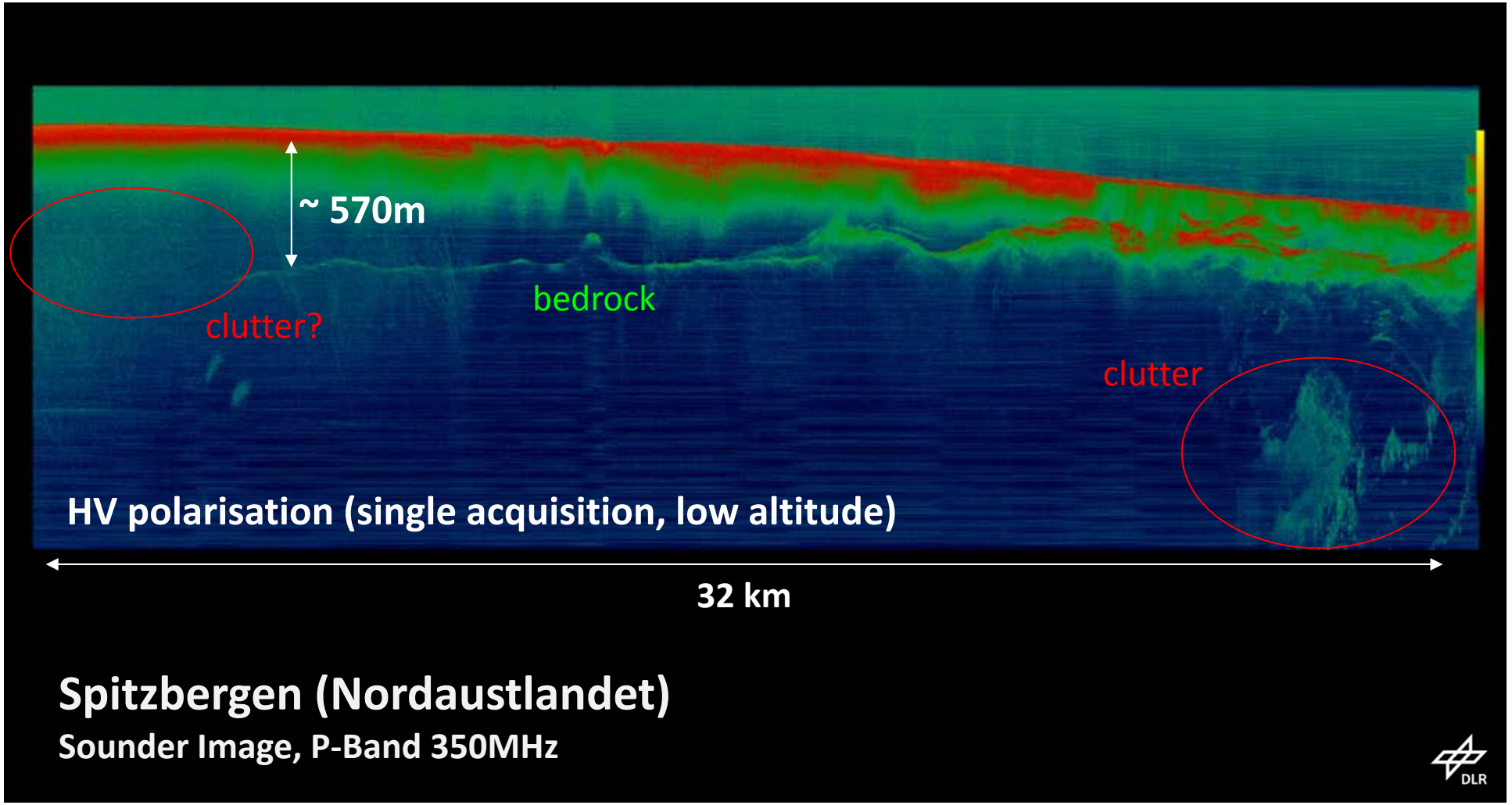
Circular SAR Imaging: Continuous Monitoring



Polarimetric P-band Sounding

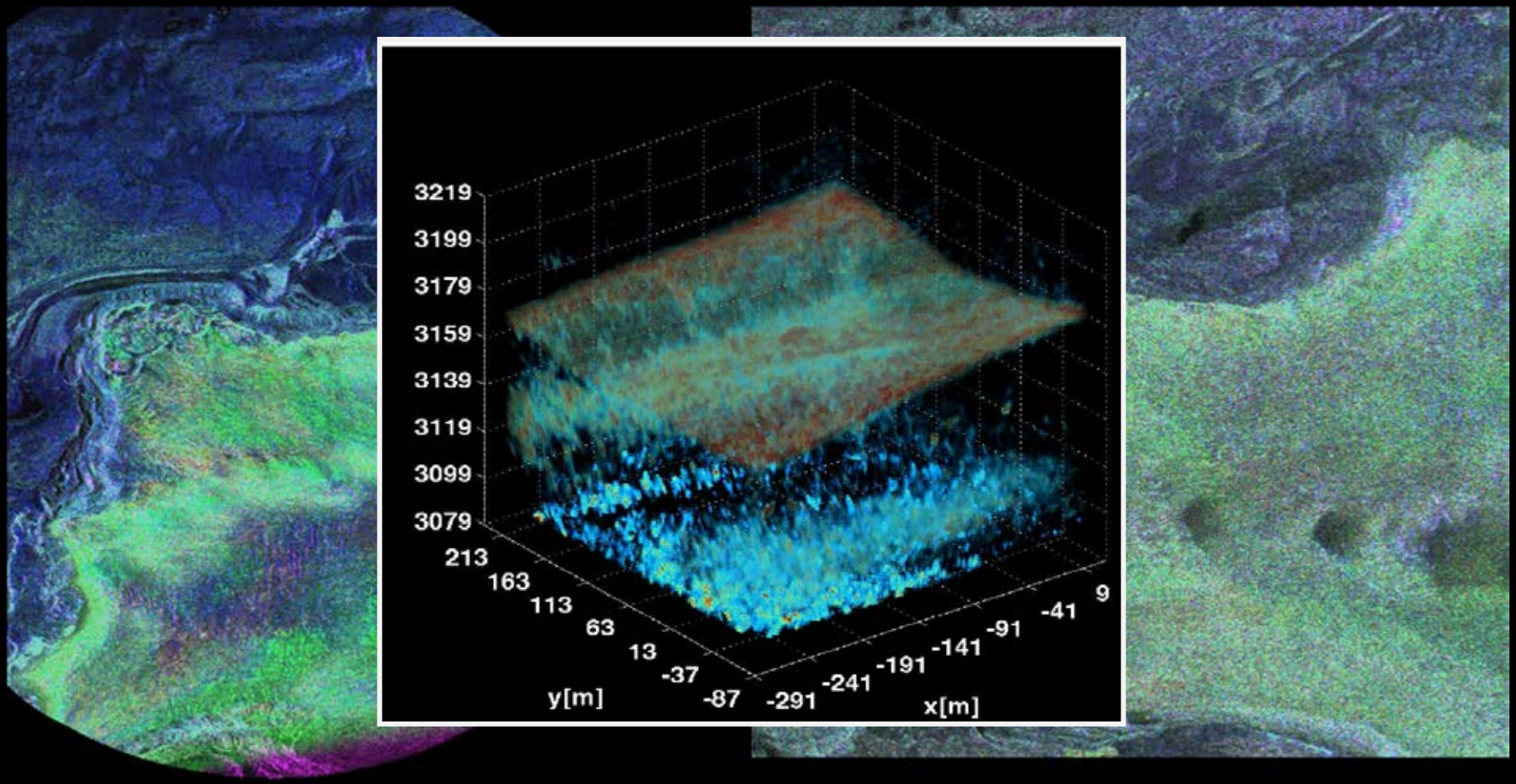
- Dedicated imaging mode for deep sounding of ice / bedrock structure
- Long wavelength can penetrate very deep in dry (i.e. cold) ice.
- Identical antennas as in SAR mode, but nadir-looking by modified feed network.



Holographic Ice Sounding / Multi-circular SAR

L-Band

P-Band



ARCTIC15

F-SAR CAMPAIGN

April - May 2015

Kangerlussuaq / K-Transect

Fully polarimetric HoloSAR images.

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

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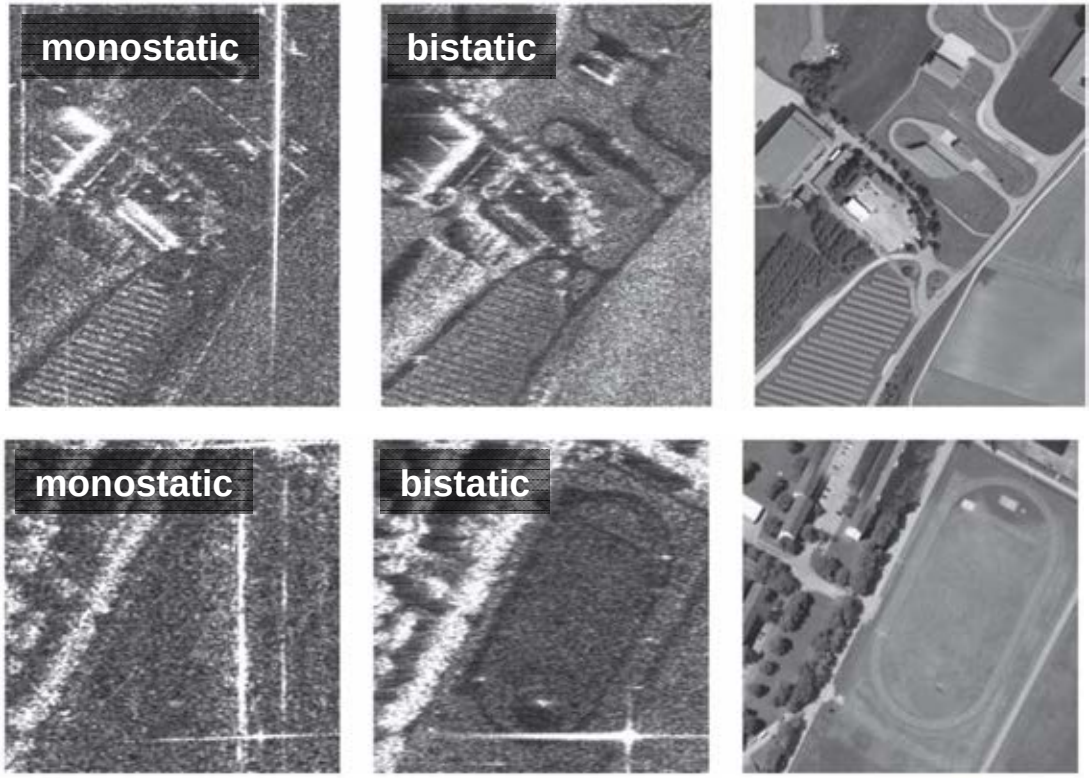
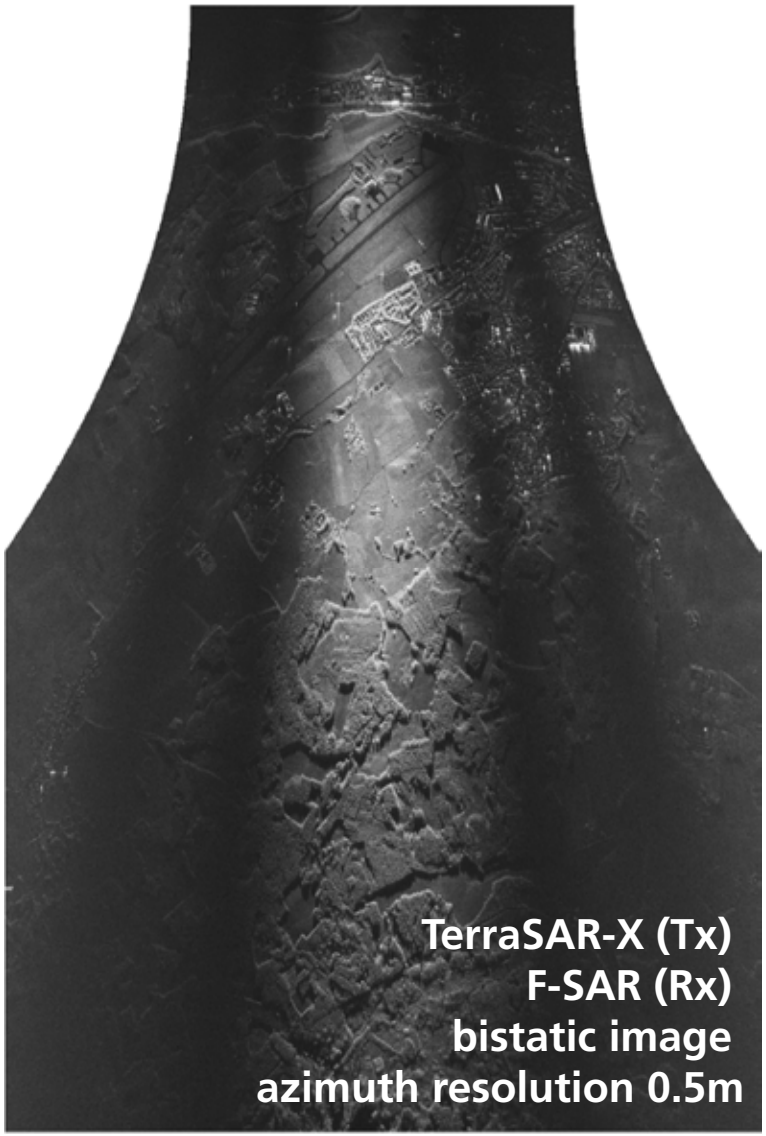
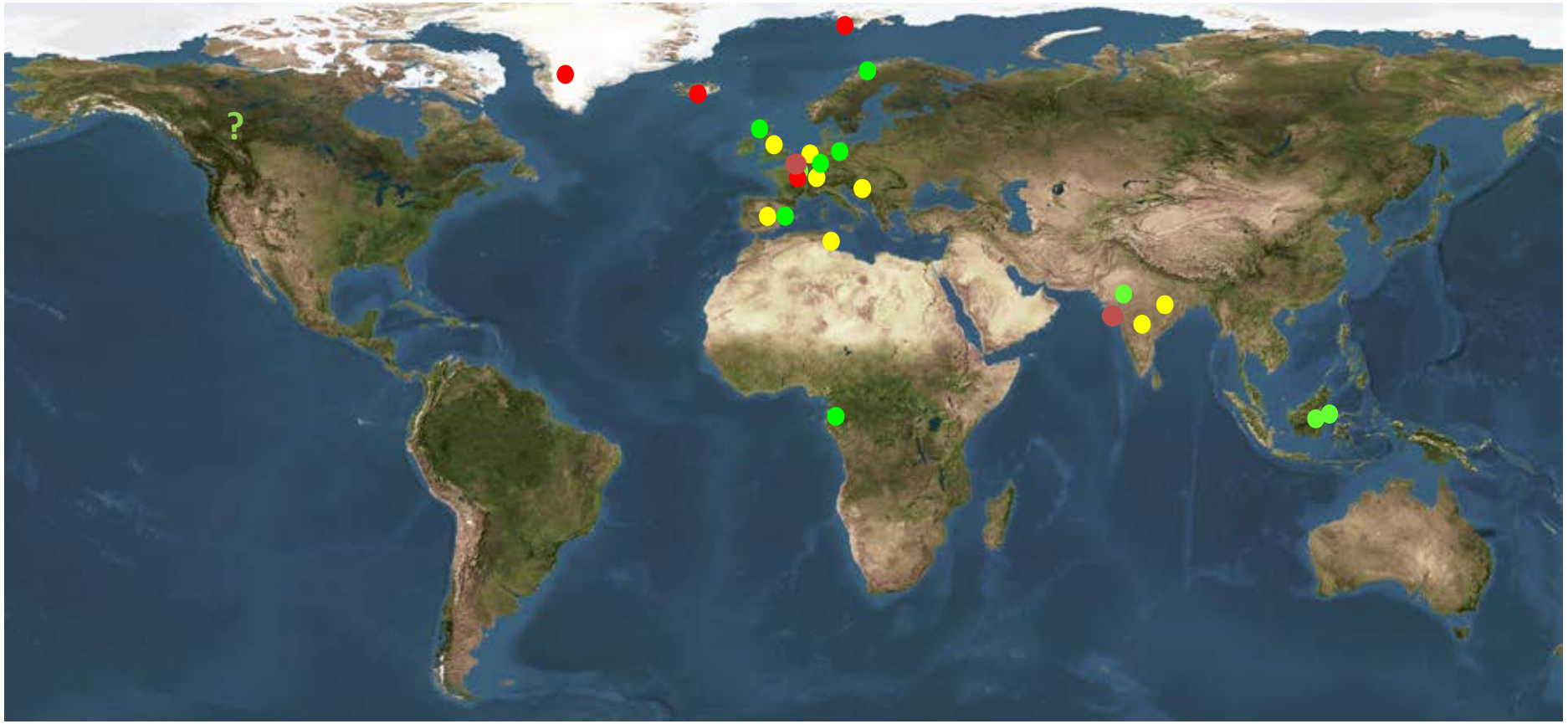
Bistatic SAR Imaging & Processing

- Development of synchronisation techniques in preparation of TanDEM-X
- Development of new processing concepts (BFFB - bistatic fast factorised back-projection)

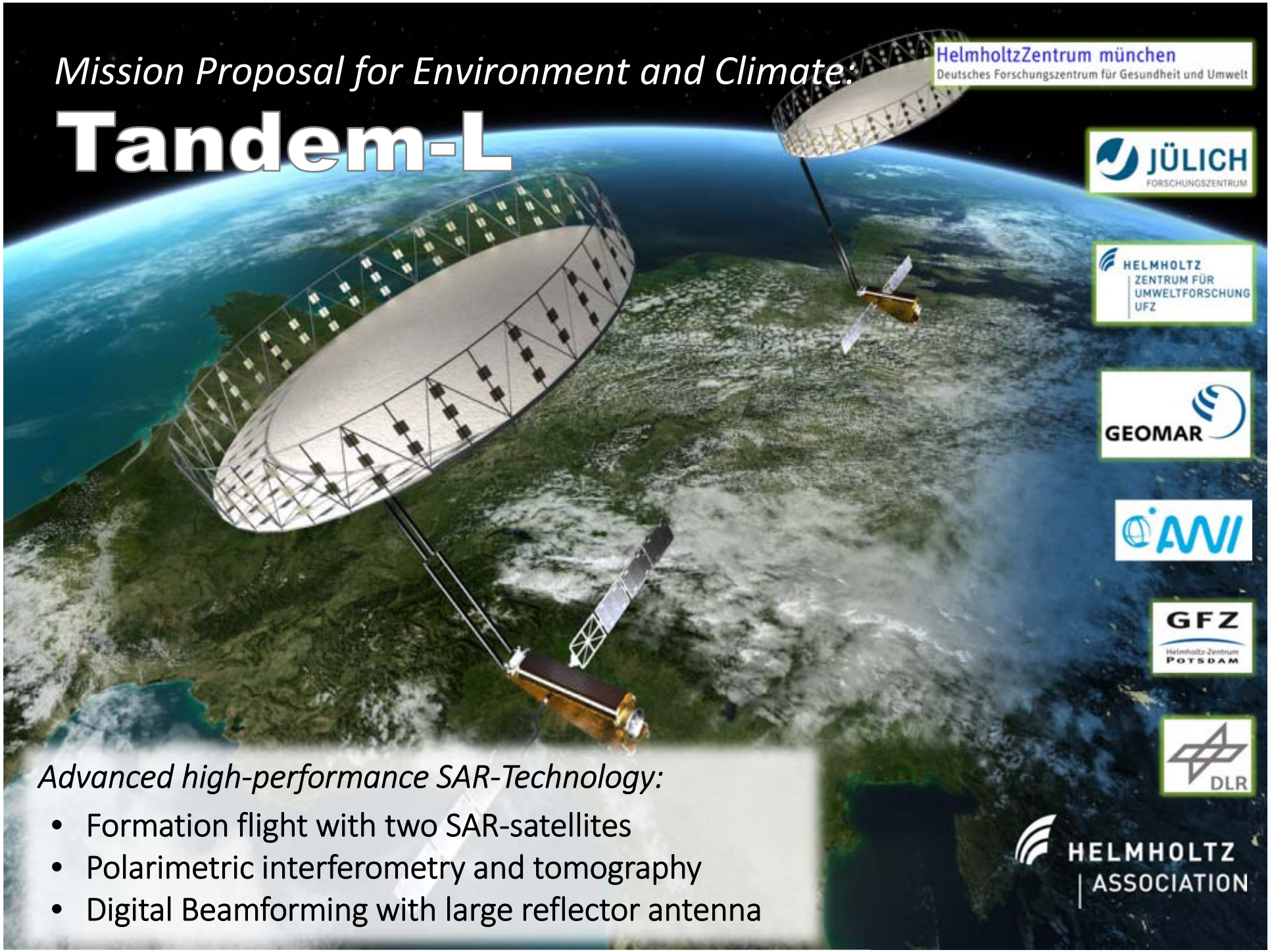




Airborne-SAR Campaigns (since 2001)

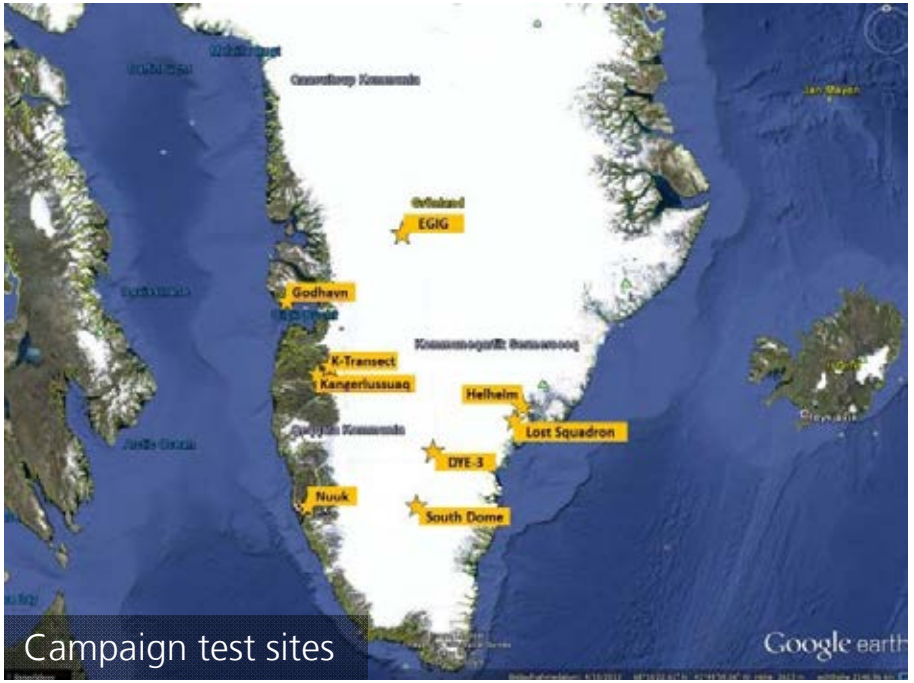


- Agriculture (crop parameters, soil moisture)
- Forestry (forest heights and biomass)
- Surveys over sea and land ice
- Sea topography and oceanography

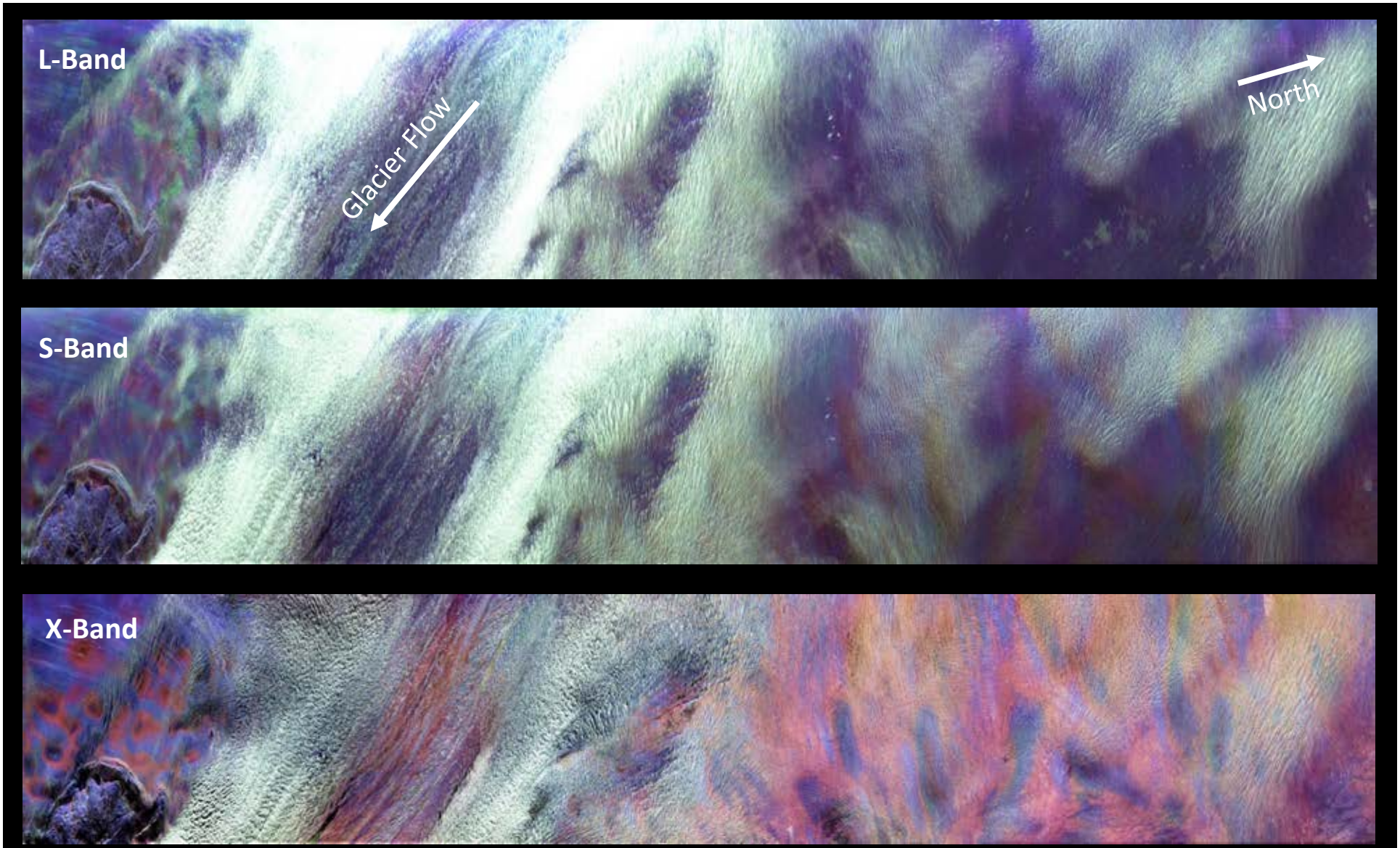

Mission Proposal for Environment and Climate:
Tandem-L
HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt
JÜLICH
FORSCHUNGSZENTRUM
HELMHOLTZ
ZENTRUM FÜR
UMWELTFORSCHUNG
UFZ
GEOMAR
AWI
GFZ
Helmholtz-Zentrum
POTSDAM
DLR
Advanced high-performance SAR-Technology:
• Formation flight with two SAR-satellites
• Polarimetric interferometry and tomography
• Digital Beamforming with large reflector antenna
HELMHOLTZ
ASSOCIATION

F-SAR Campaign ARCTIC/DALOX (May 2015)

- **11 test-sites** in Greenland
- Analysis of several novel methods for the **estimation of snow and ice parameters**
- Evaluation of high-resolution SAR for **security applications** in Arctic environments
- Study of the stongly varying penetration capabilities of the different bands into snow and ice
- Demonstration of multi-spectral SAR data recording in 4 frequency bands
- Acquisition of unique data sets for further research



Campaign test sites



ARCTIC15

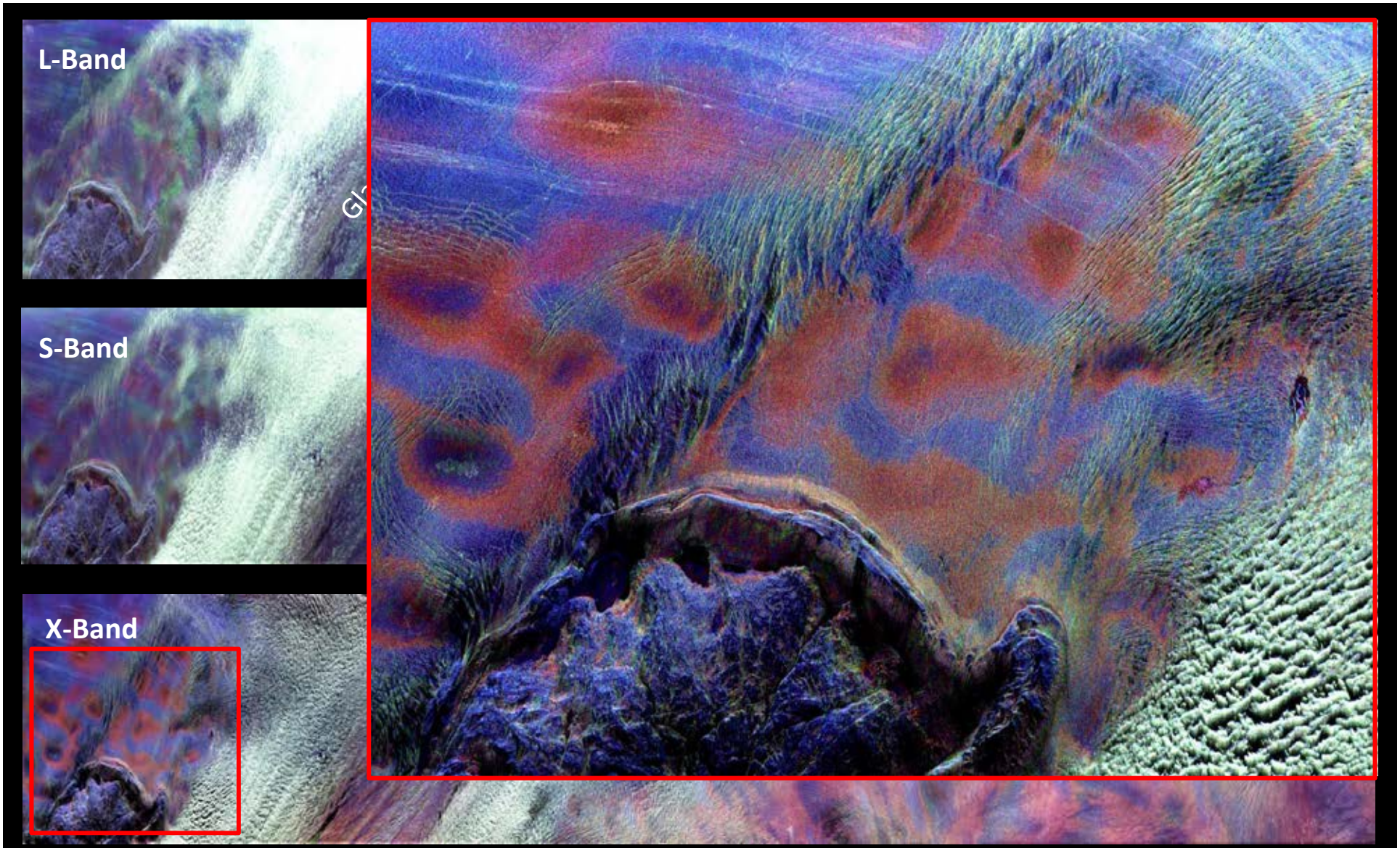
F-SAR CAMPAIGN
April - May 2015

Helheim Glacier, differences in L-, S- and X- band.

Fully polarimetric images.

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

DLR



ARCTIC15

F-SAR CAMPAIGN
April - May 2015

Helheim Glacier, differences in L-, S- and X- band.

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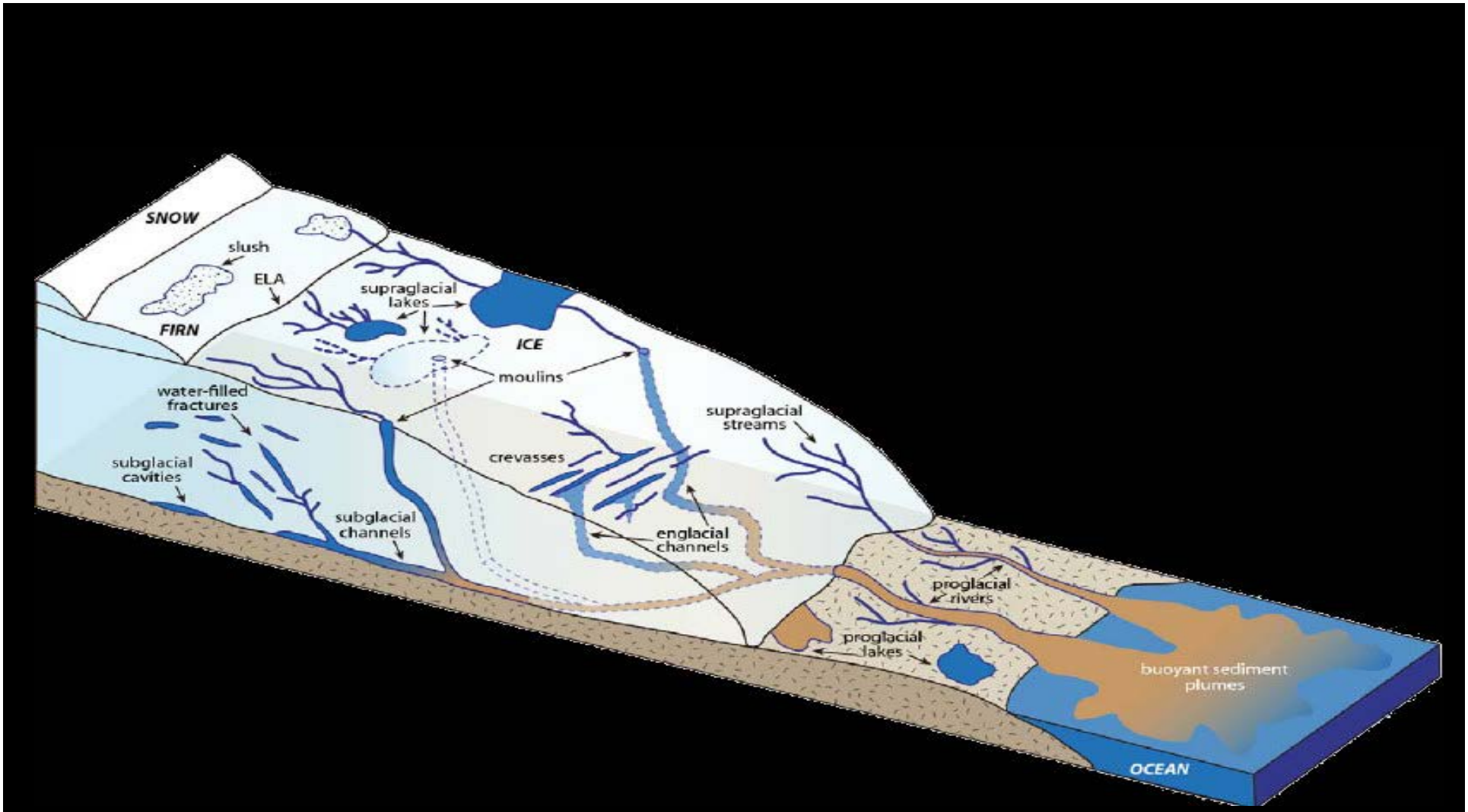

ARCTIC15

F-SAR CAMPAIGN
April - May 2015

K-Transect - Percolation zone

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

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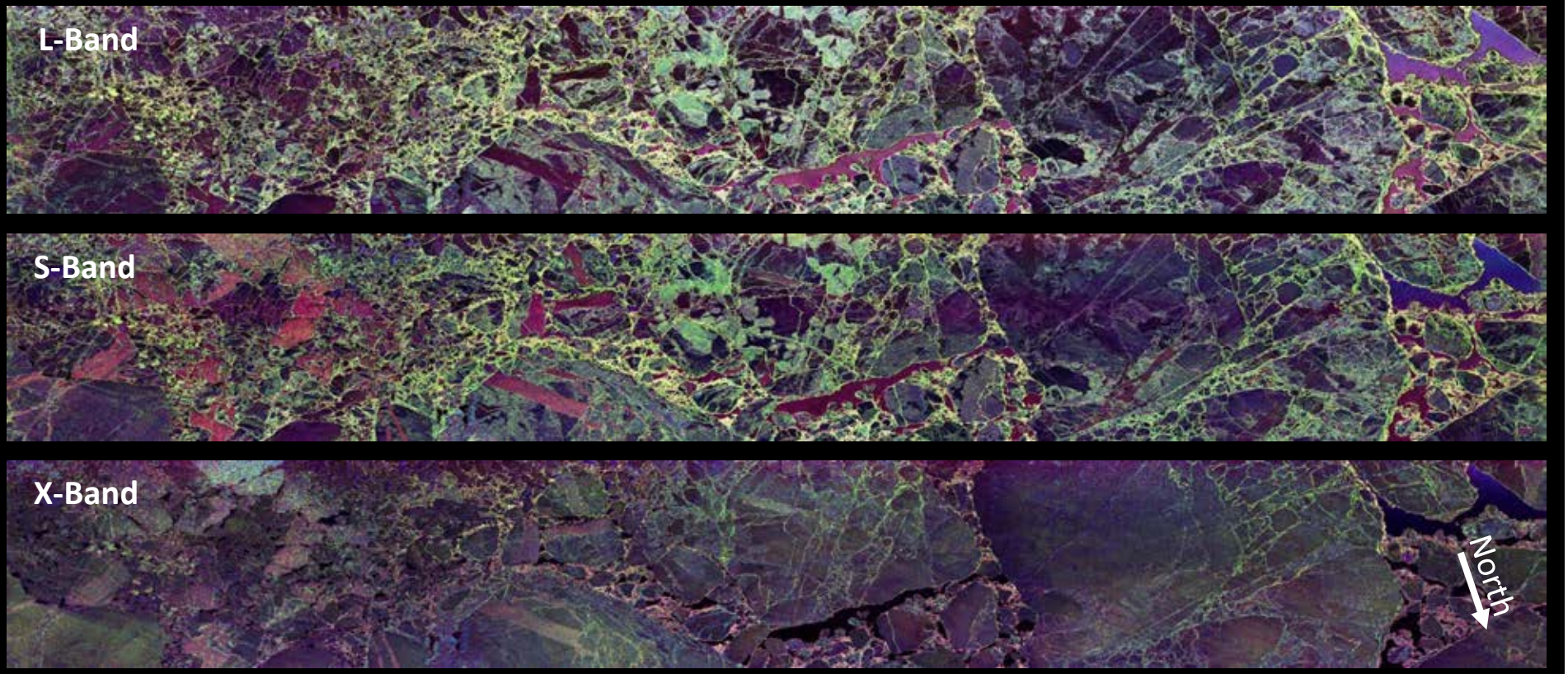

ARCTIC15

F-SAR CAMPAIGN
April - May 2015

Sea Ice between Greenland and North America

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

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ARCTIC15

F-SAR CAMPAIGN

April - May 2015

Godhavn, X-band detail image, 25cm resolution

Fully polarimetric images.

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

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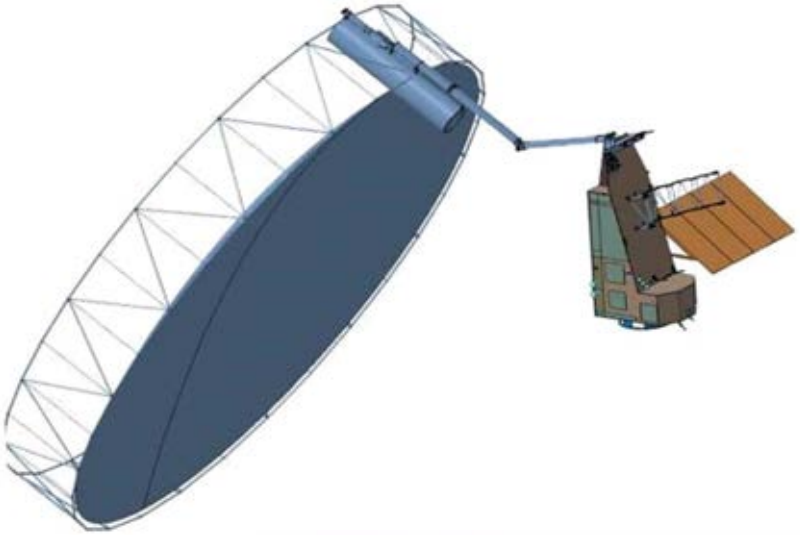
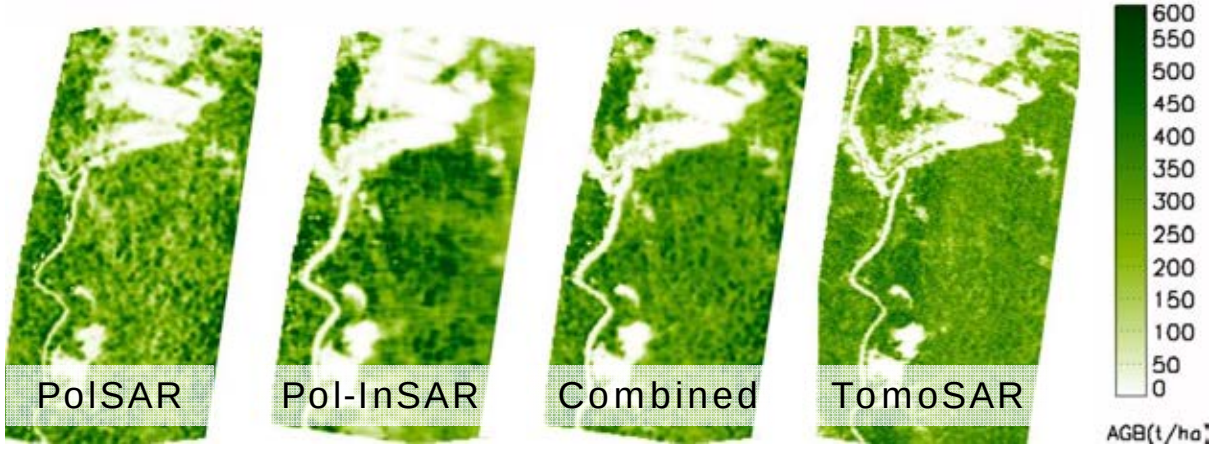
BIOMASS: ESA Earth Explorer Mission

ESA EE-7 to map **forest above-ground biomass** and **its changes**



System:

- Fully-polarimetric P-band SAR
- 12 m reflector antenna
- Strip-map acquisition mode with 6 MHz bandwidth
- Spatial resolution: 60 x 50 m with 6 ENL
- Launch planned for 2021



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AfriSAR Campaign 2016

Goals:

- Preparation of ESA‘s BIOMASS mission
- Algorithm development for Tandem-L
- Various test-sites in Gabun (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
- Parallele flights by UAVSAR and LVIS 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

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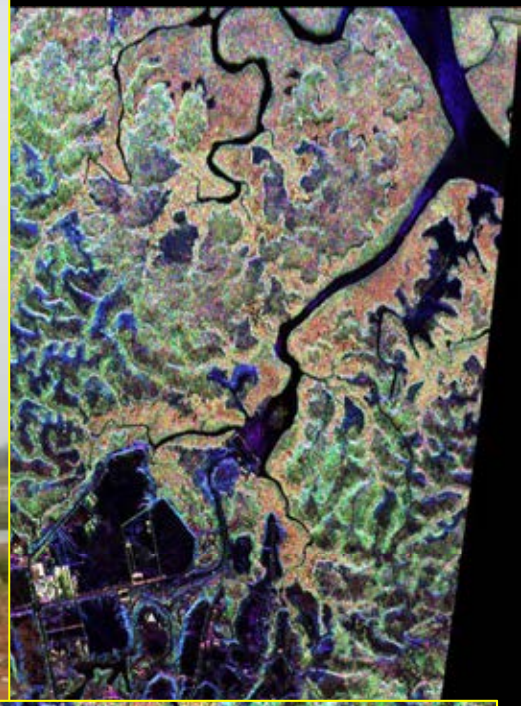
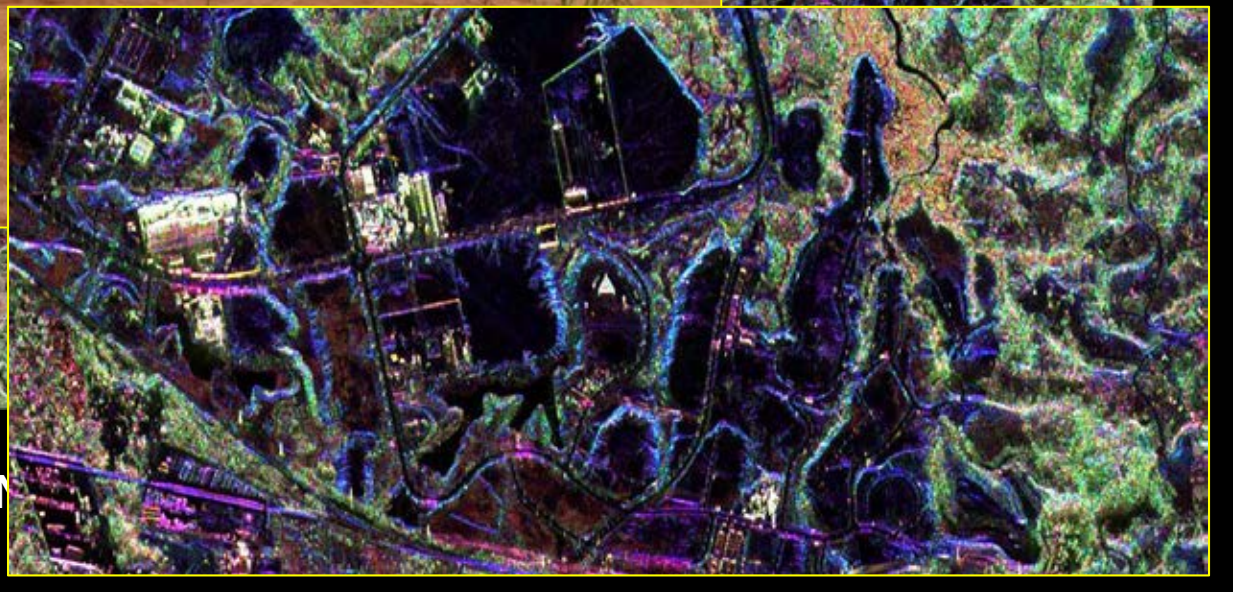
AfriSAR Kampagne: Kalibrierung





surface

double

volume

L-Band

AfriSAR Campaign: Results

surface
double
volume

Pongara test site: mangroves
(0° 9'15.29"N, 9°28'46.56"E)

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AfriSAR Campaign: P-Band Mosaic (7 tracks)

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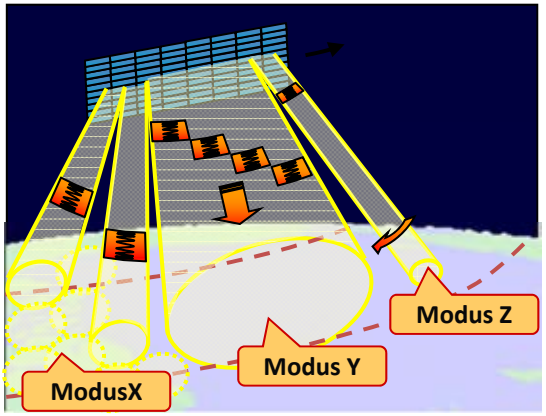
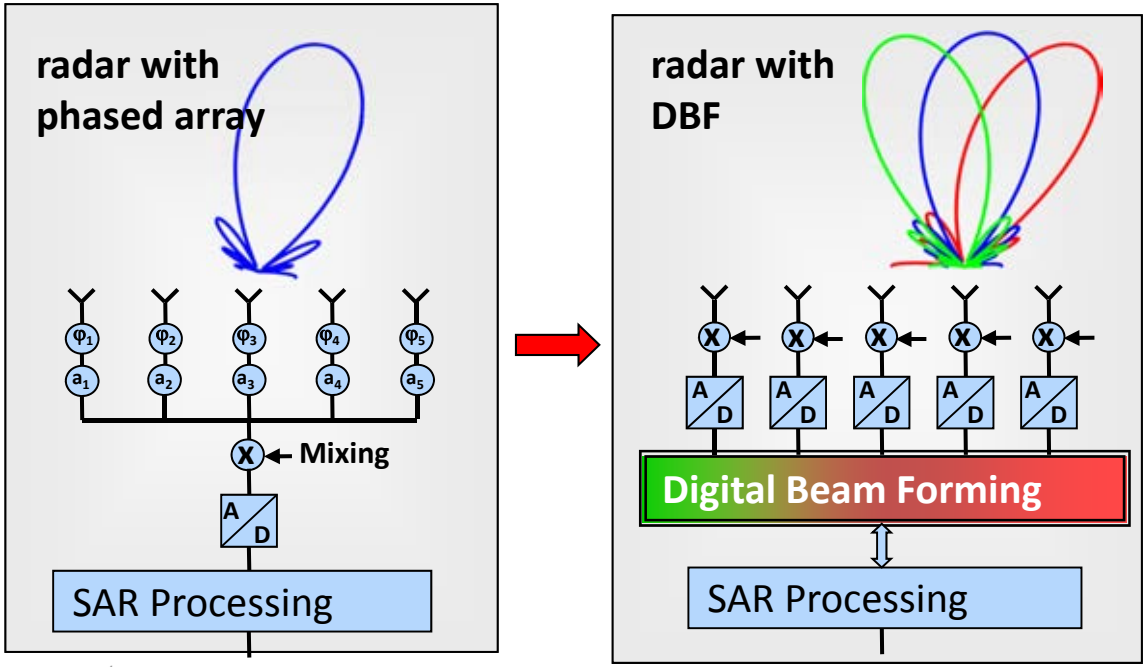
Current Developments: Digital Beamforming (DBF) Extension



Future Requirements	imaging mode (quad pol)		
	Mode X	Mode Y	Mode Z
Resolution	**5 m**	**1 m**	**<< 1 m**
Swath	**400 km**	**100 km**	**30 km**
Orbit Duty Cycle	**30 Minutes per Orbit**		



Possibilities:

- Better radiometric accuracy
- Moving target detection
- Ambiguity suppression
- RFI suppression
- Adaptive & hybrid SAR imaging modes
- …

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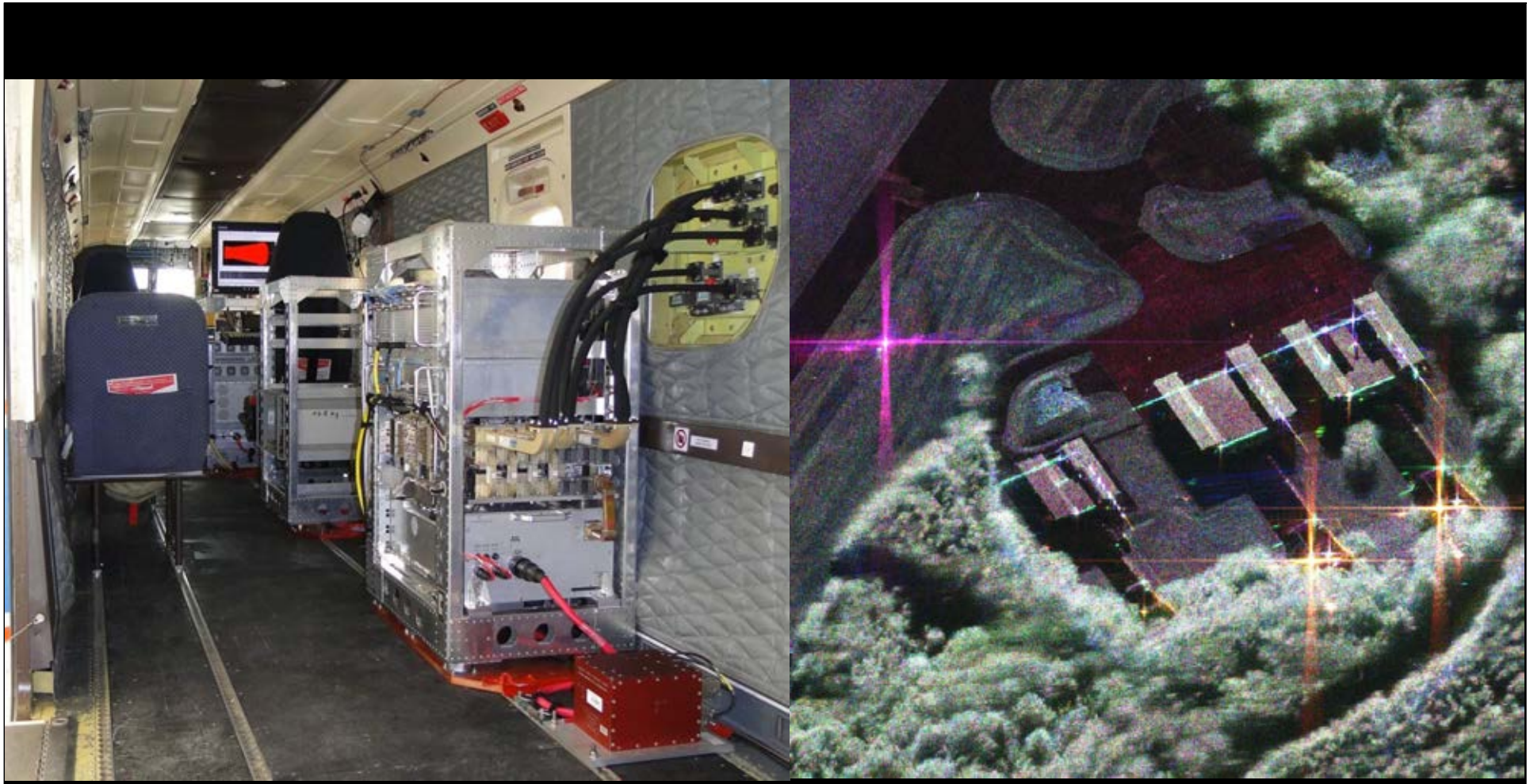
F-SAR: Next Steps…



DBF-SAR: First X-band in-flight results (April 2017)

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