ALOS-Next/Tandem-L:

Monitoring Earth's Dynamics with PolinSAR

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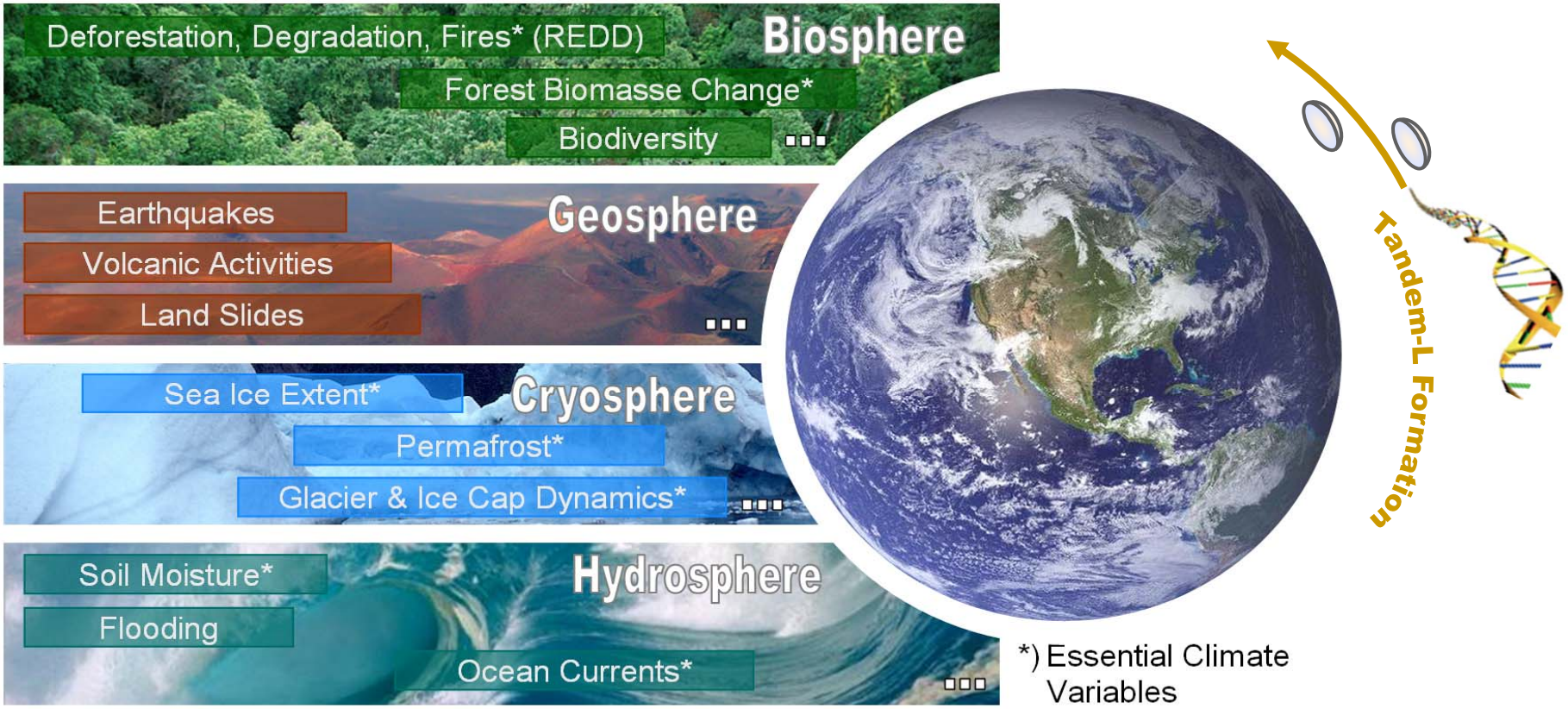
[(1)] German Aerospace Center (DLR), Microwaves and Radar Institute, Germany
[(2)] ETH Zurich, Institute of Environmental Engineering, Switzerland
[(3)] German Aerospace Center (DLR), Remote Sensing Technology Institute, Germany
[(4)] Japan Aerospace Exploration Agency (JAXA), Japan

Tandem-L:
Proposal for an innovative radar mission for monitoring Earth dynamic processes



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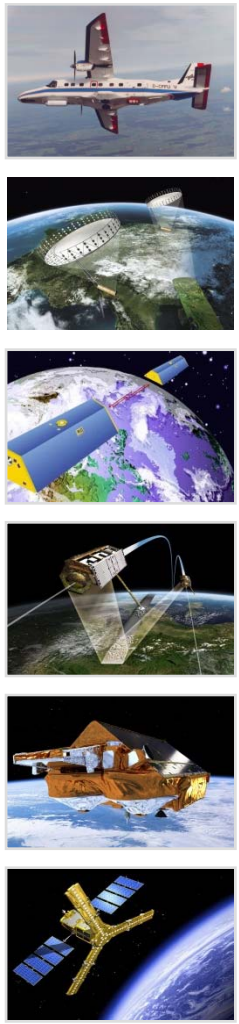
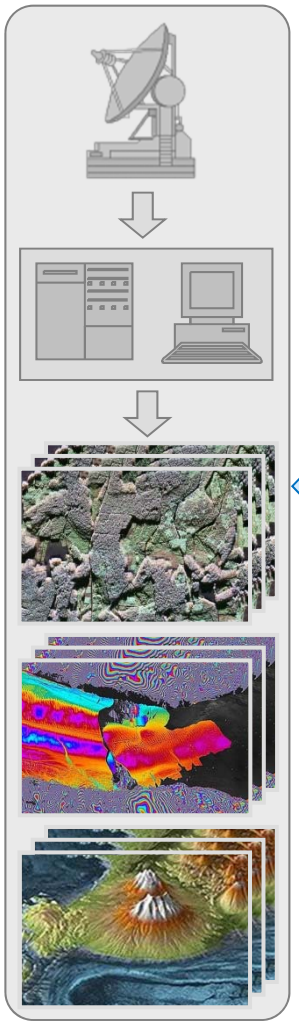
Next Generation of Remote Sensing Satellites

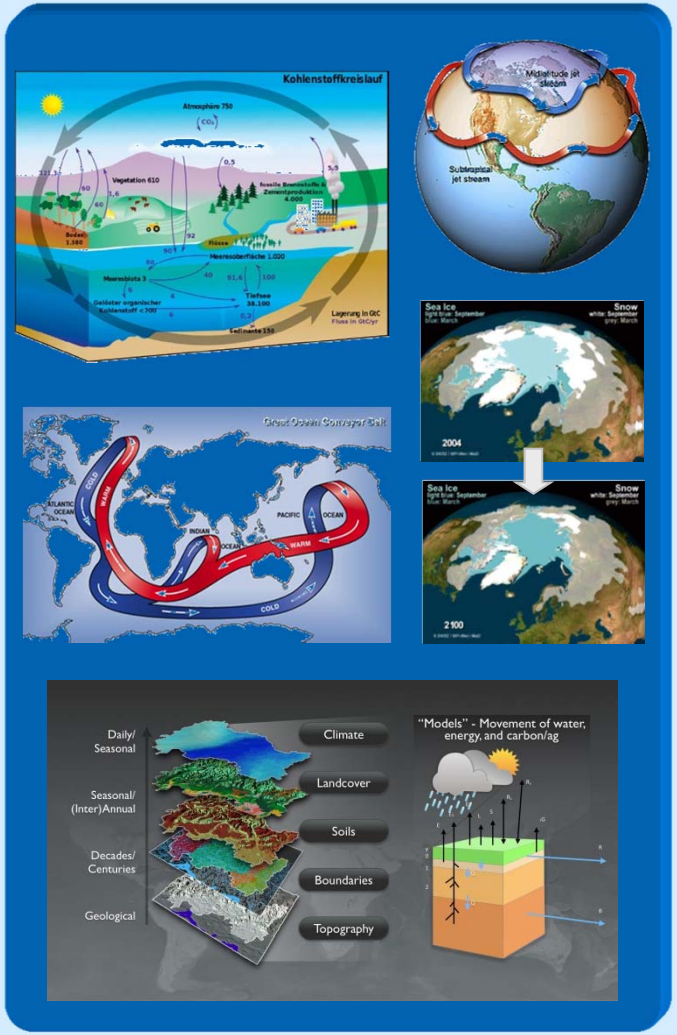


Satellites



Ground Segment

Remote Sensing and Earth System Dynamics



Helmholtz Alliance

Societal Challenges

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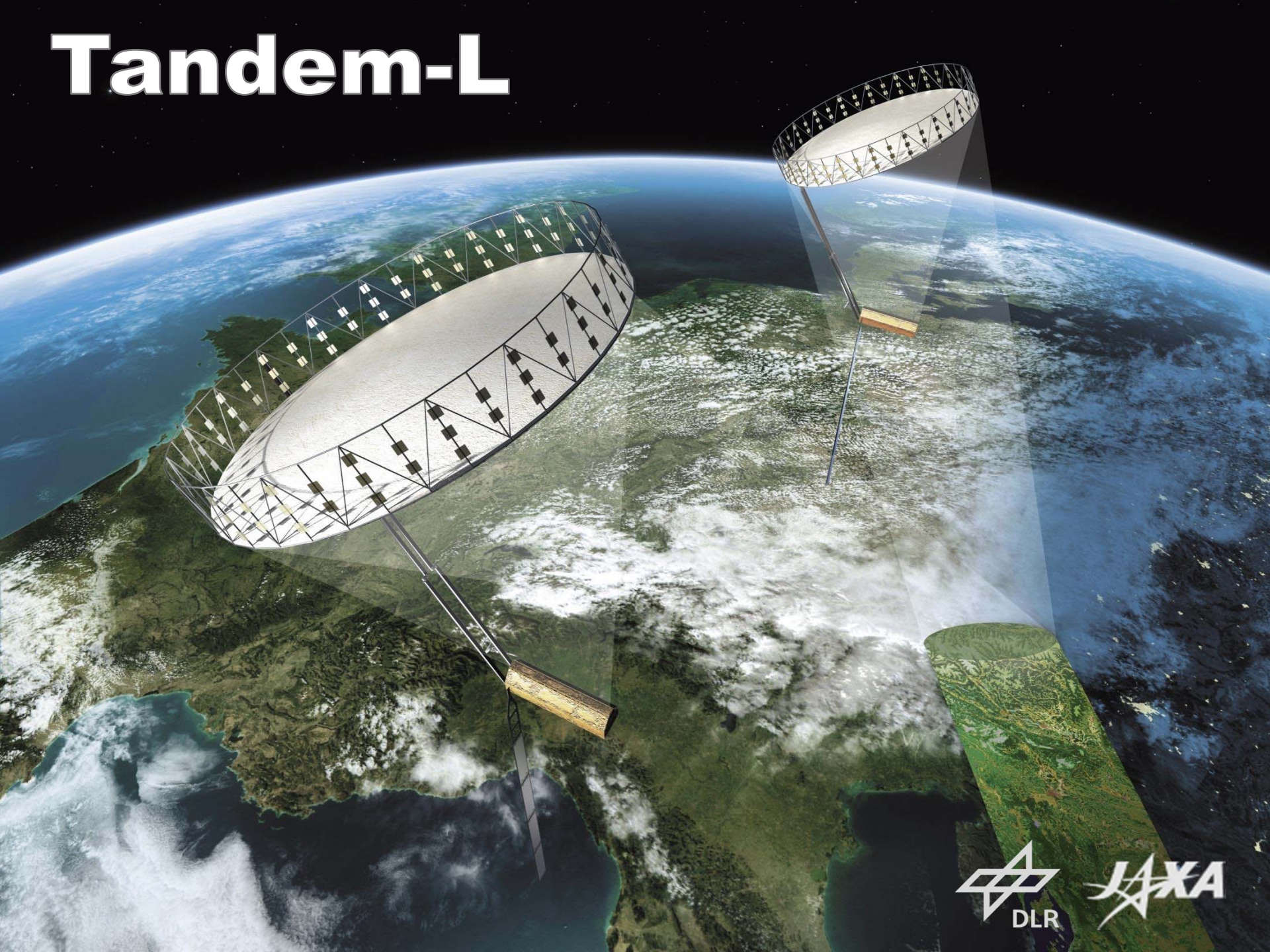
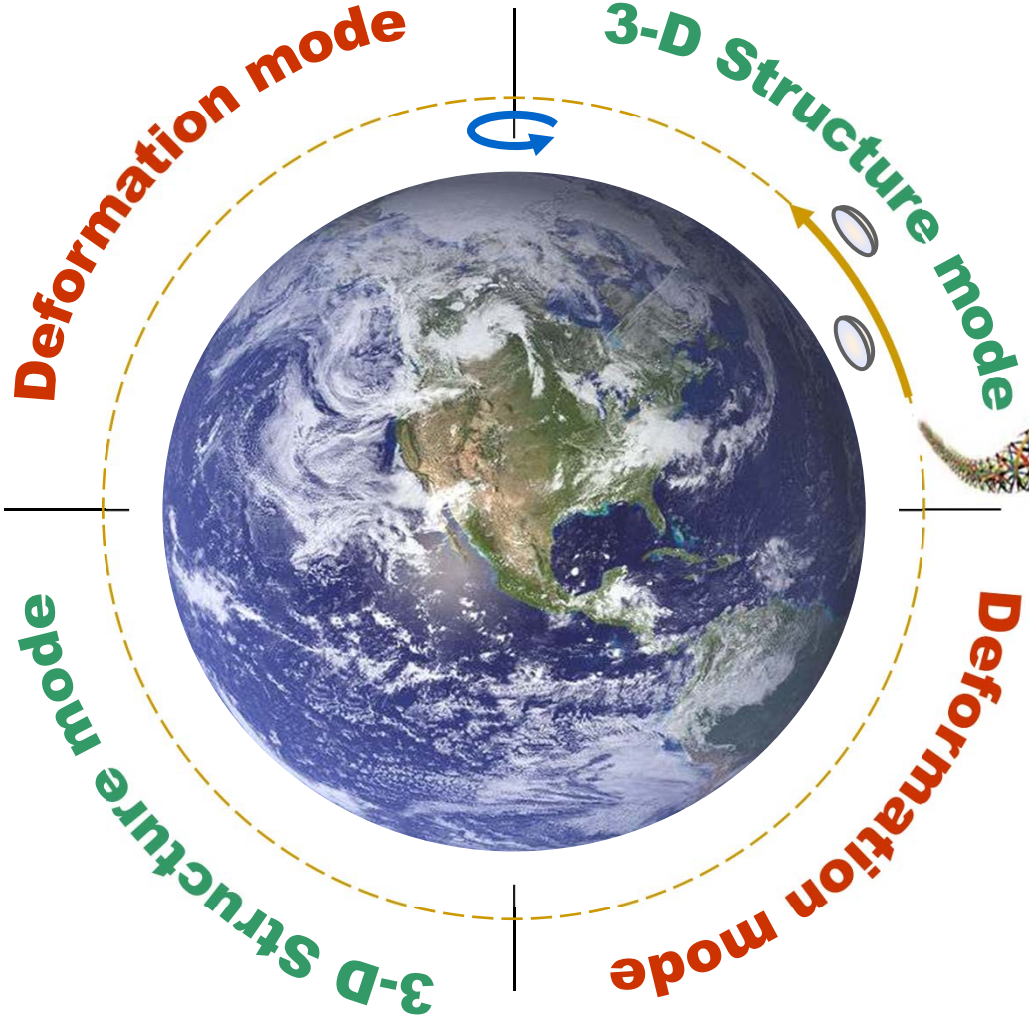
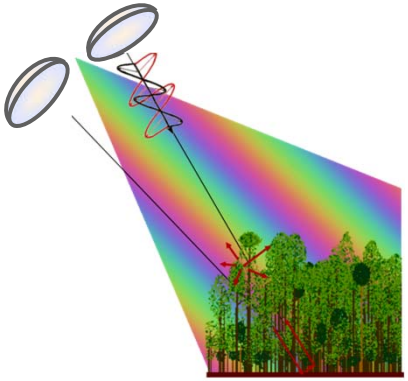
Helmholtz Alliance:
Remote Sensing and Earth System Dynamics


Tandem-L
DLR
JAXA

Mission Concept





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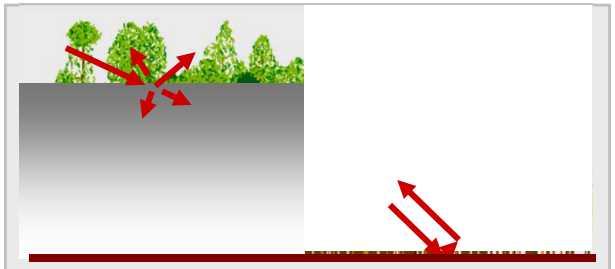
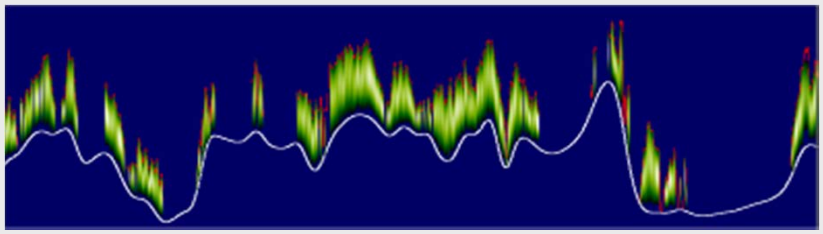
Biosphere

3-D Structure Mode

Polarimetric Backscattering



3-D Forest Structure



Forest height and Biomass

Tomography

Polarimetric SAR Interferometry (Pol-InSAR)

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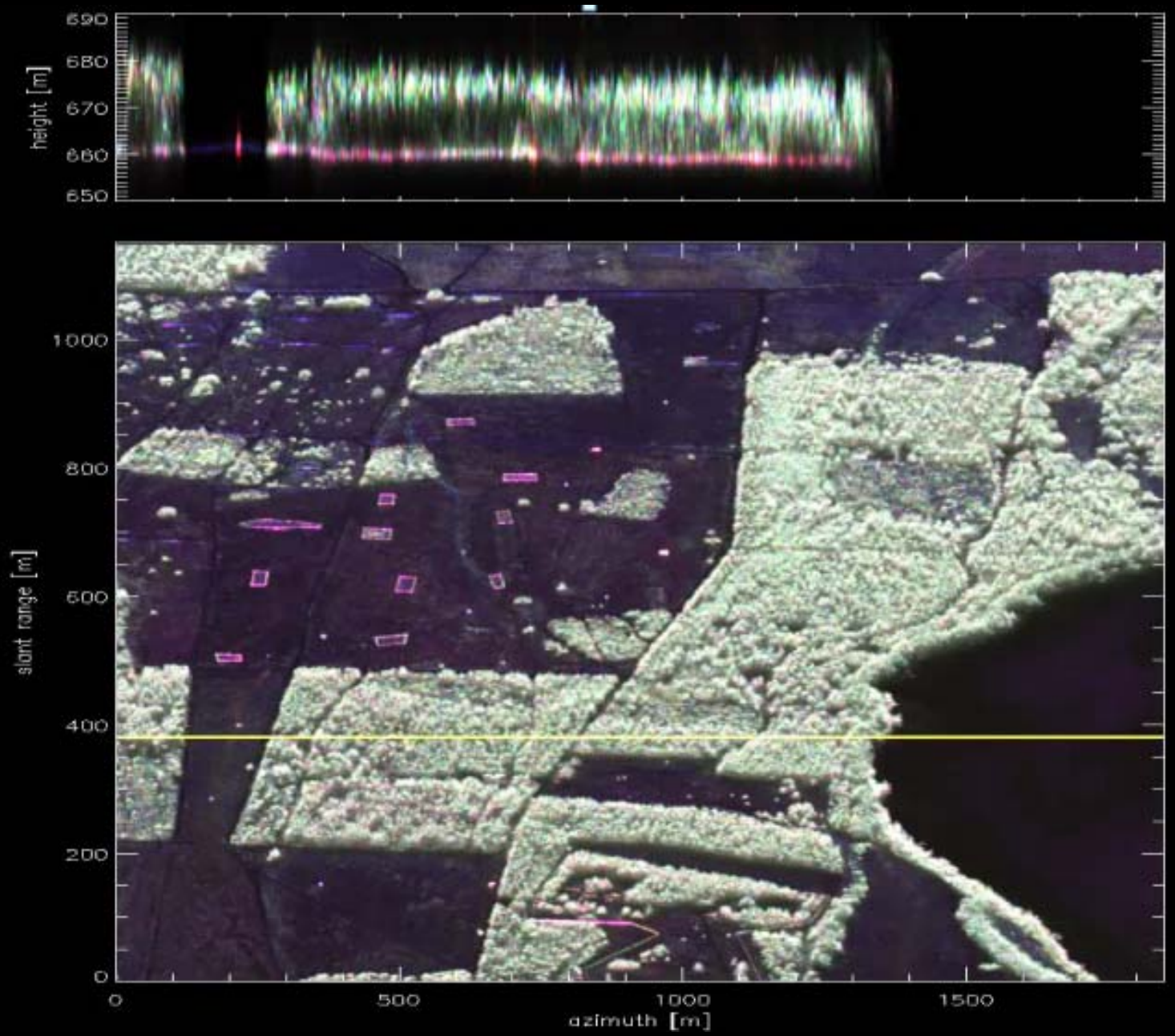
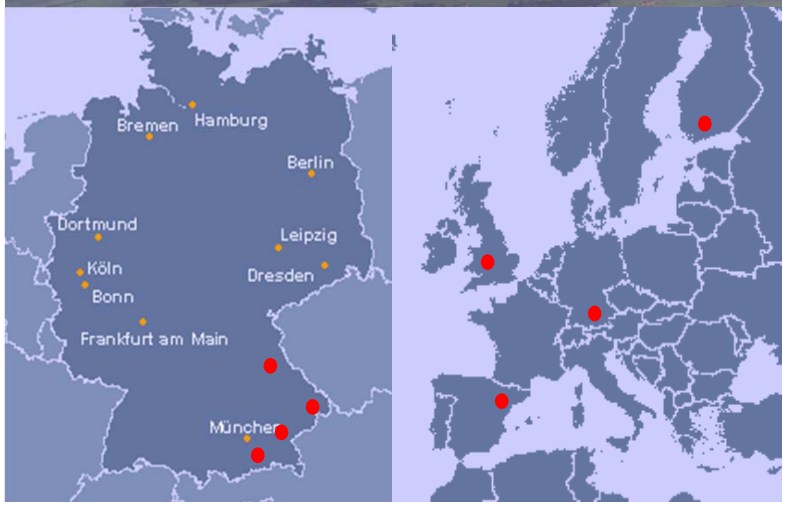
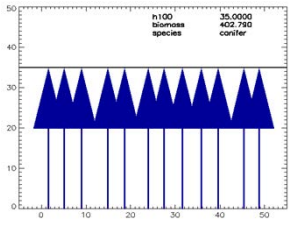
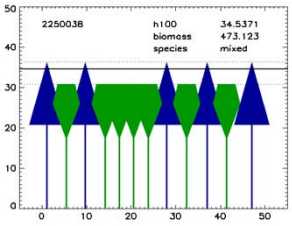


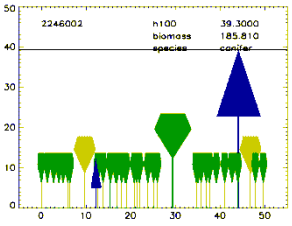
Radar Tomography – Forest Profile in L-band

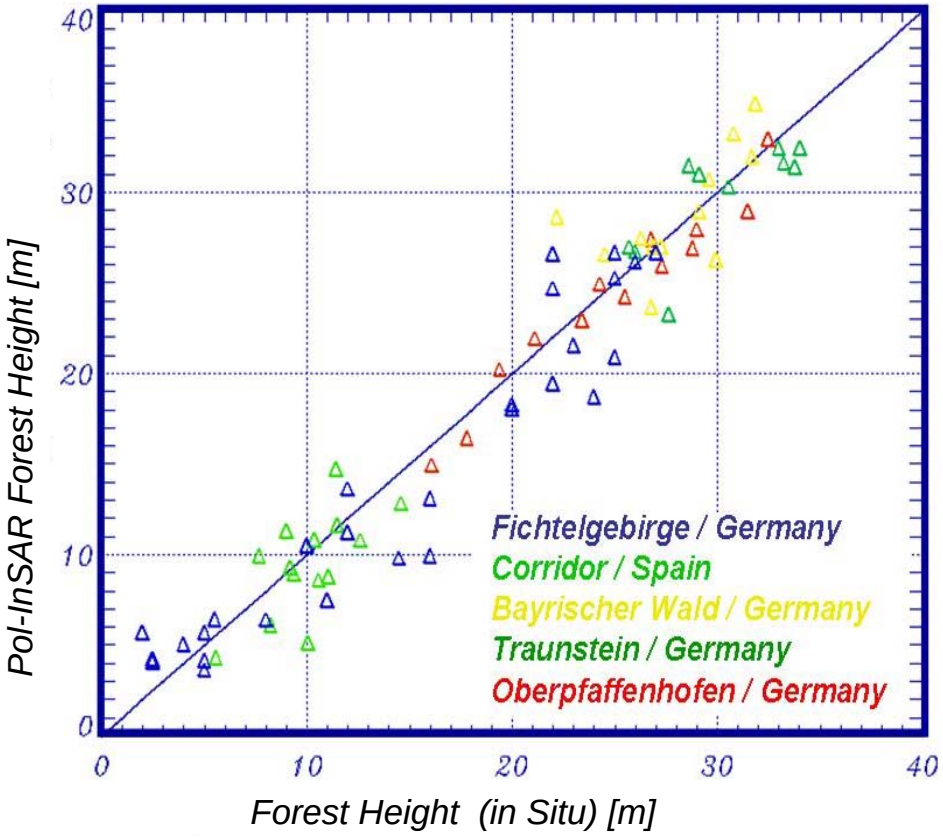
Forest Height Estimation











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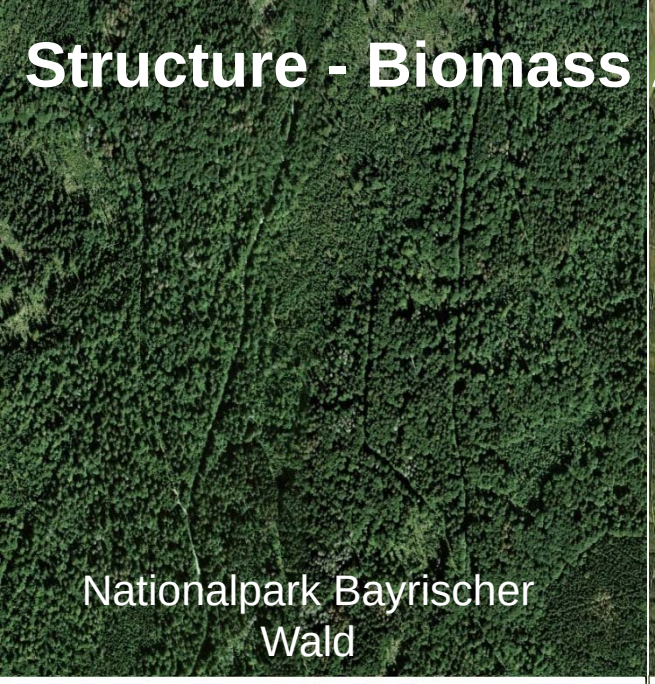
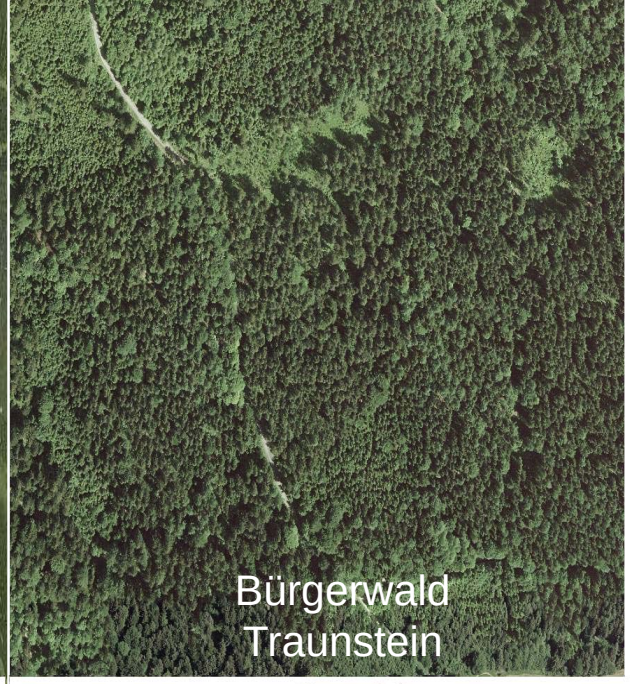
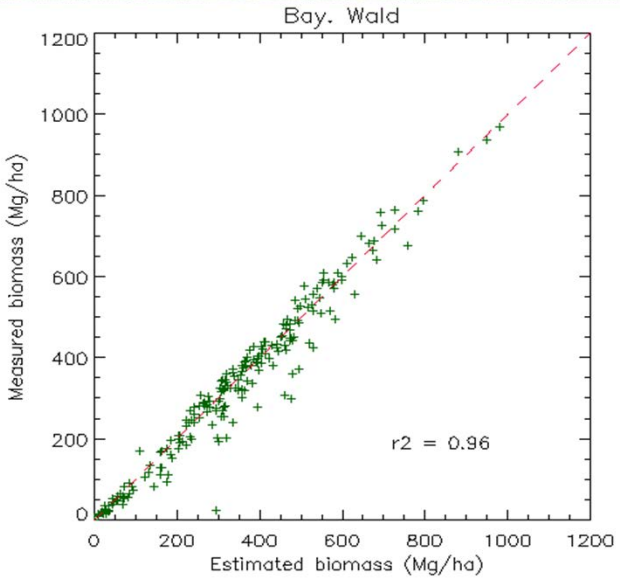
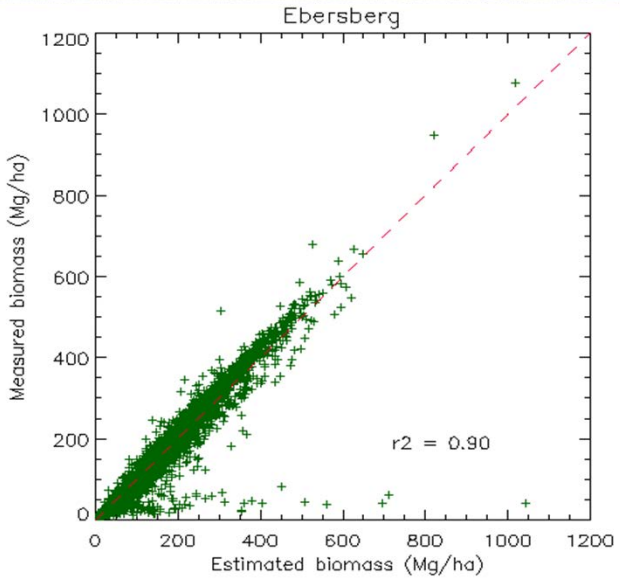
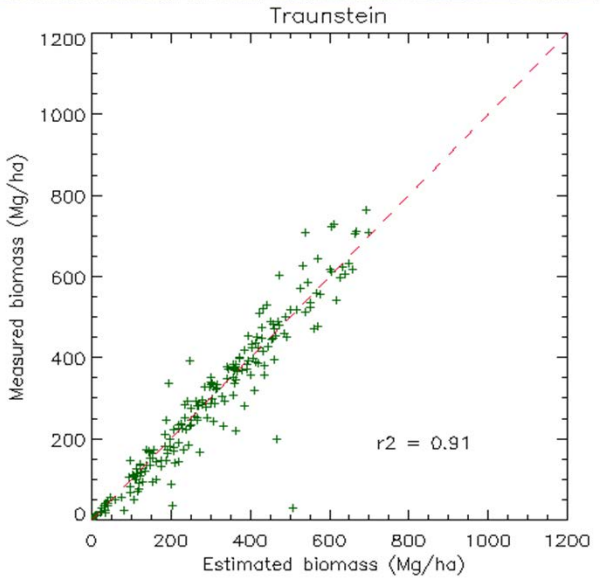
Structure - Biomass Allometry



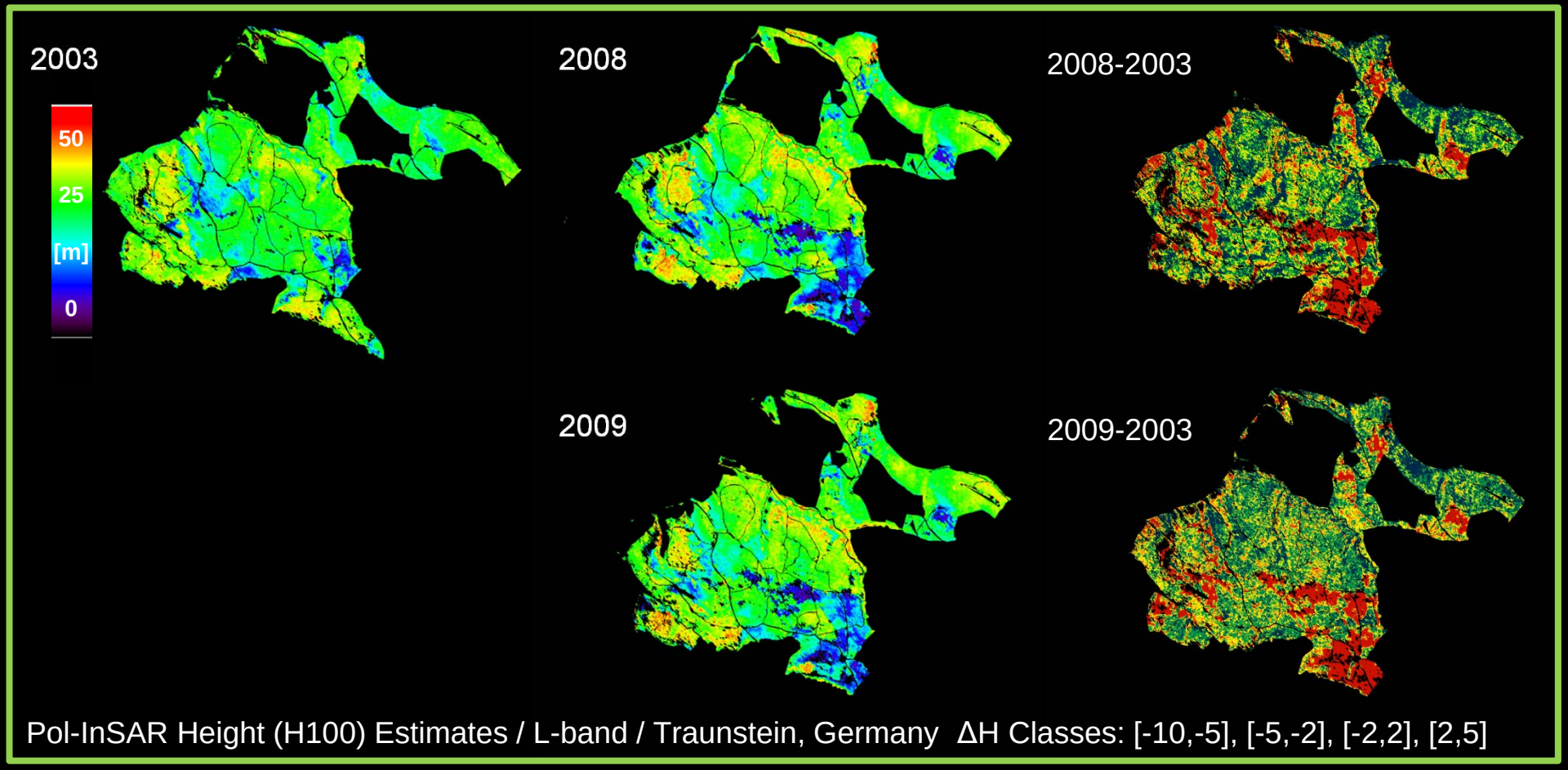




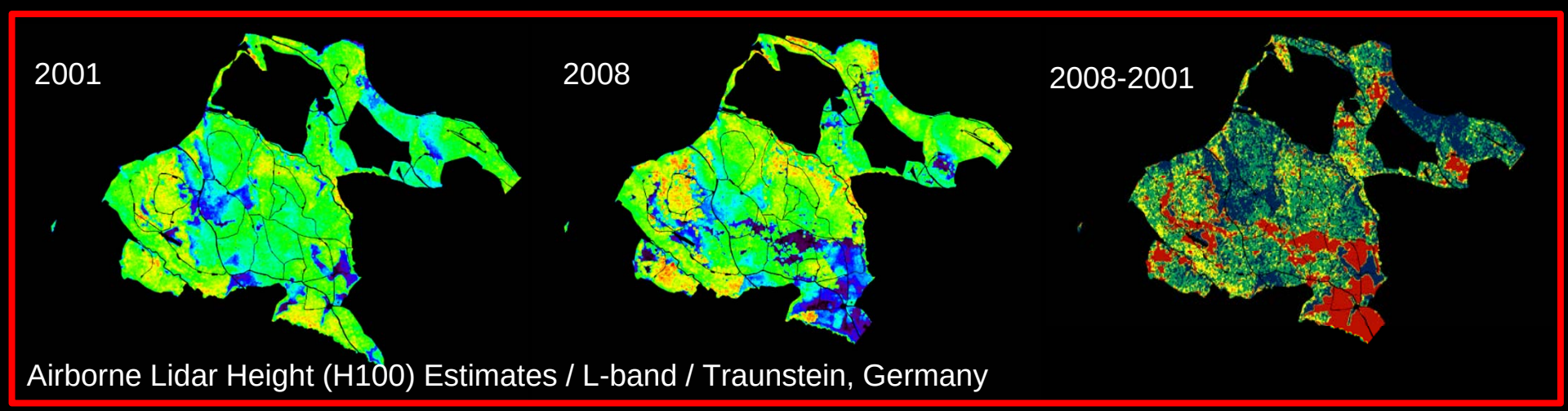




DLR

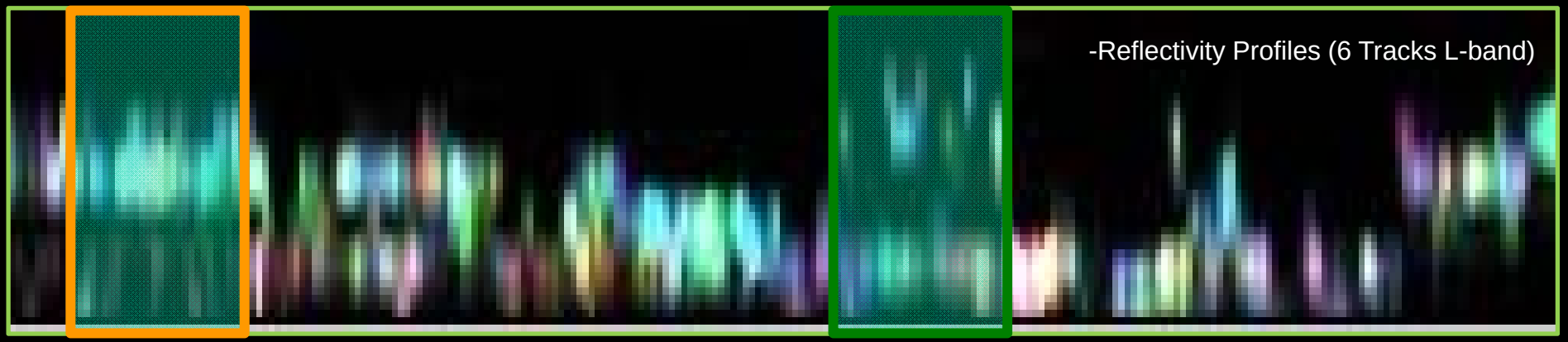


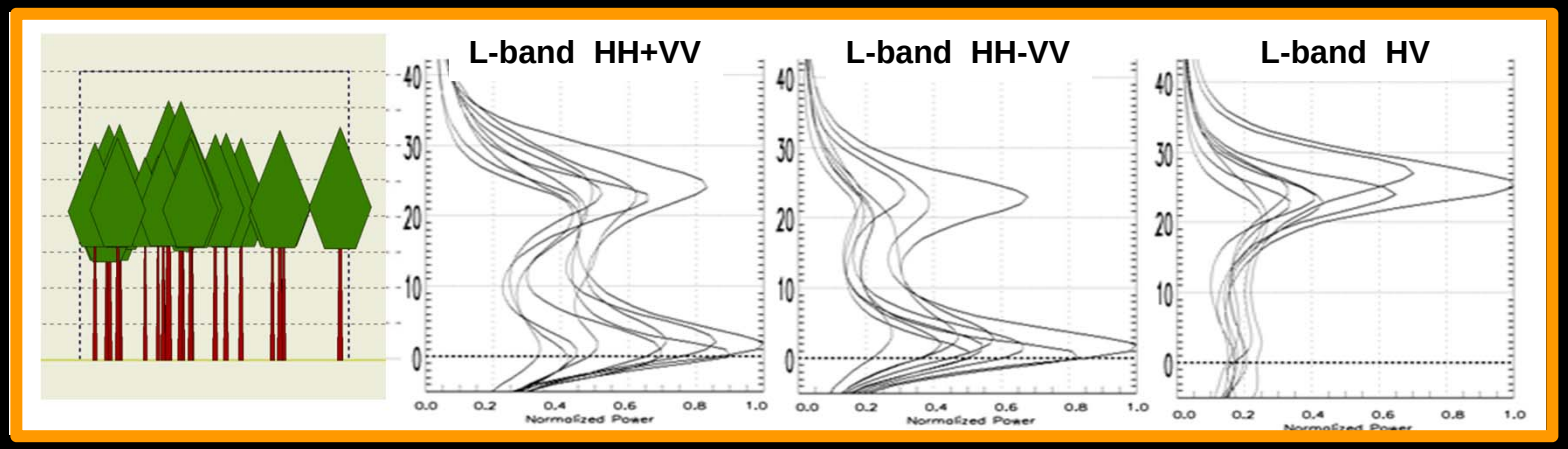
Pol-InSAR Height (H100) Estimates / L-band / Traunstein, Germany ΔH Classes: [-10,-5], [-5,-2], [-2,2], [2,5]

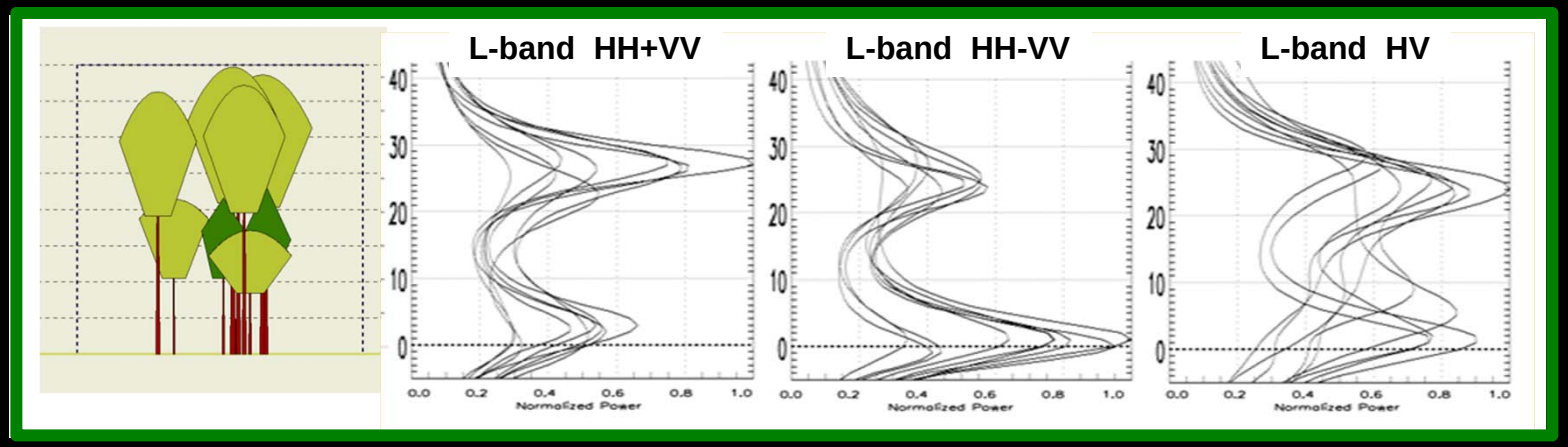


Airborne Lidar Height (H100) Estimates / L-band / Traunstein, Germany

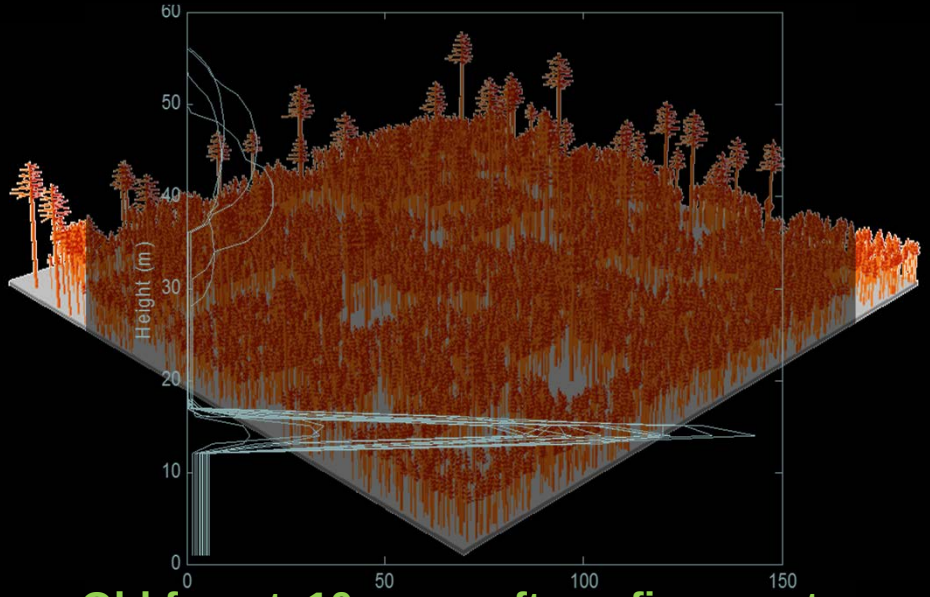
Vertical Forest Reflectivity Profiles: L-band



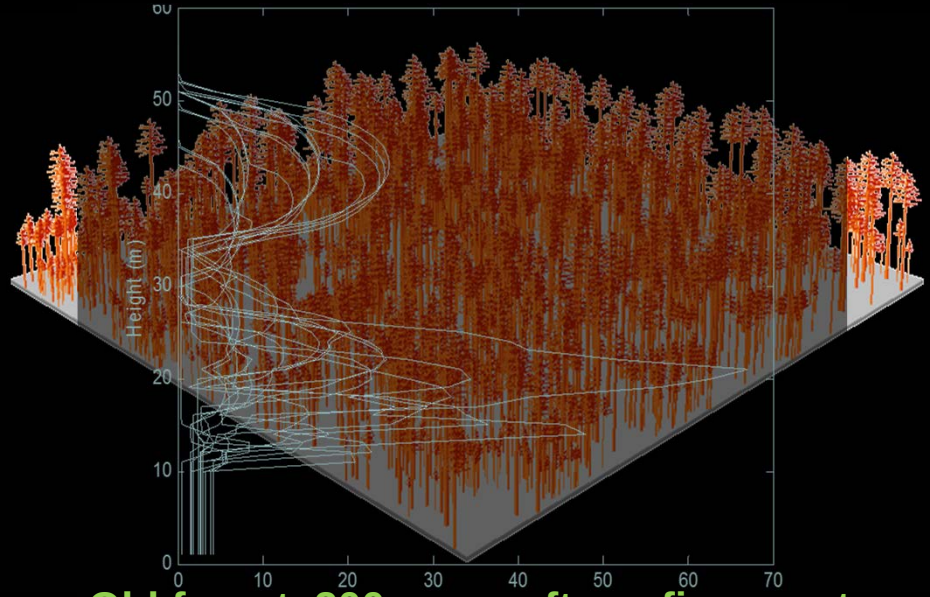




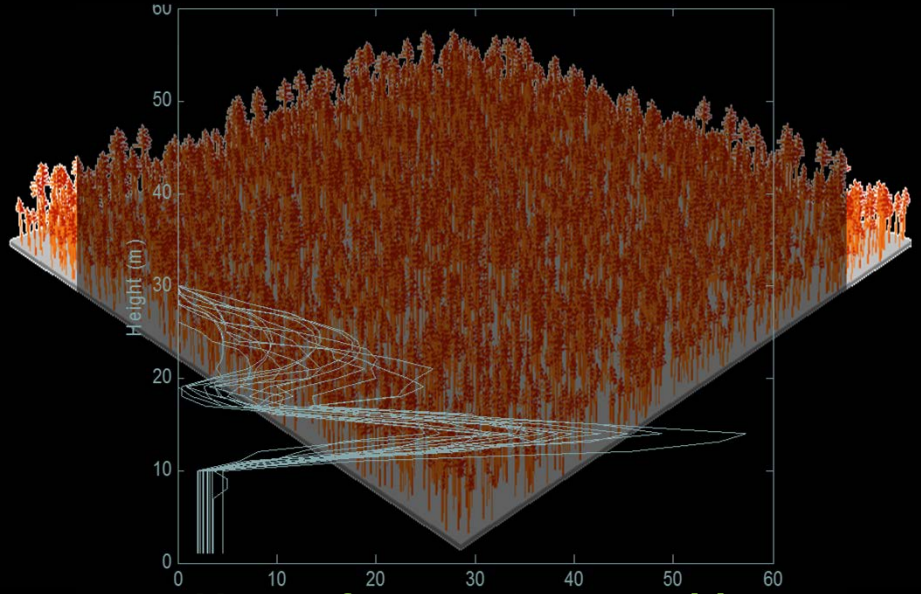
Forest Structure Characterisation



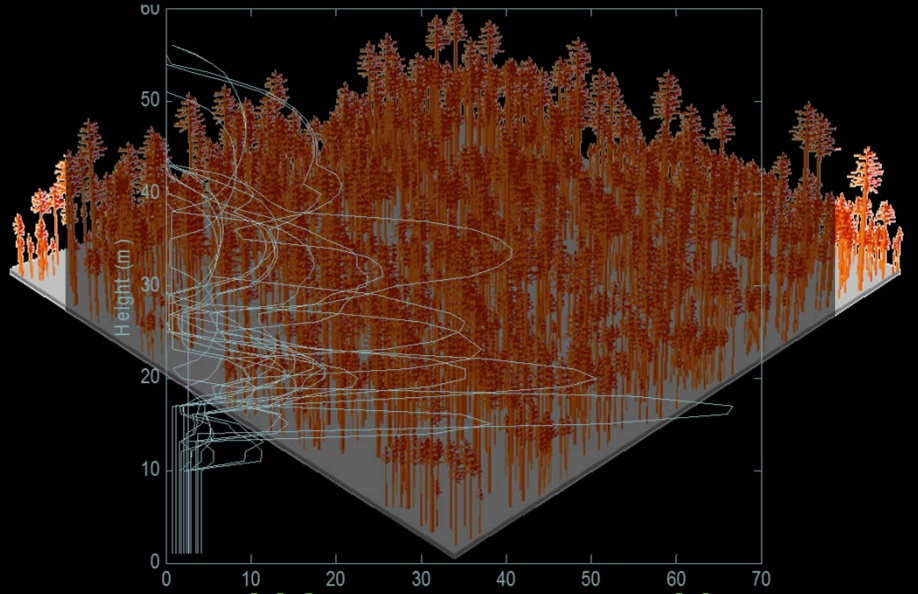
Old forest, 10 years after a fire event



Old forest, 200 years after a fire event

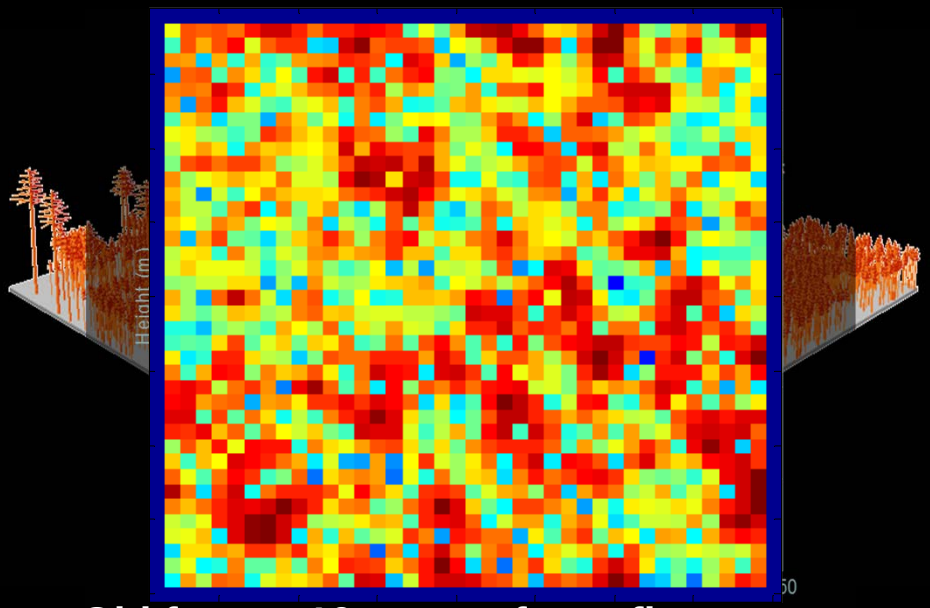


Young forest, 50 years old

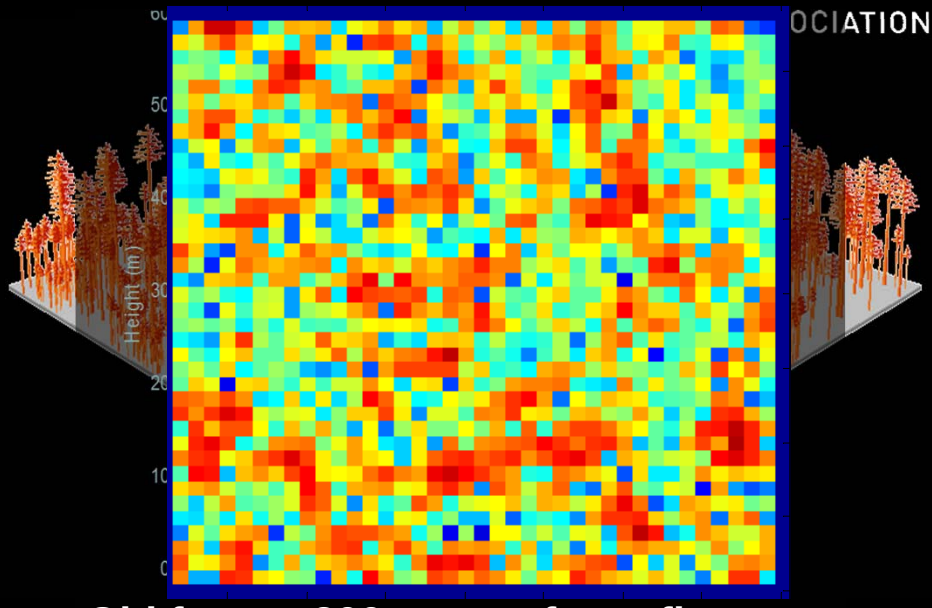


Old forest, 500 years old

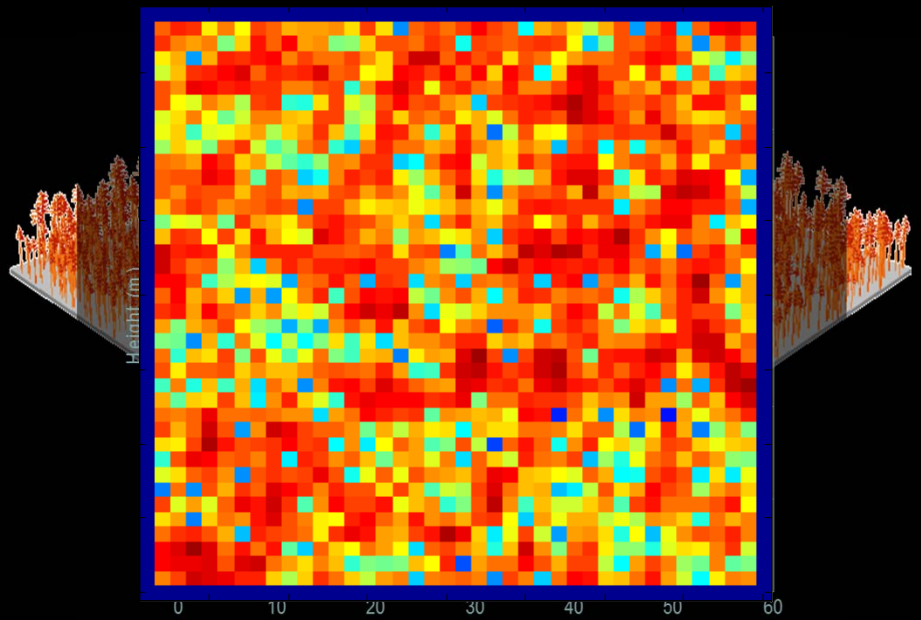
Forest Structure Classification



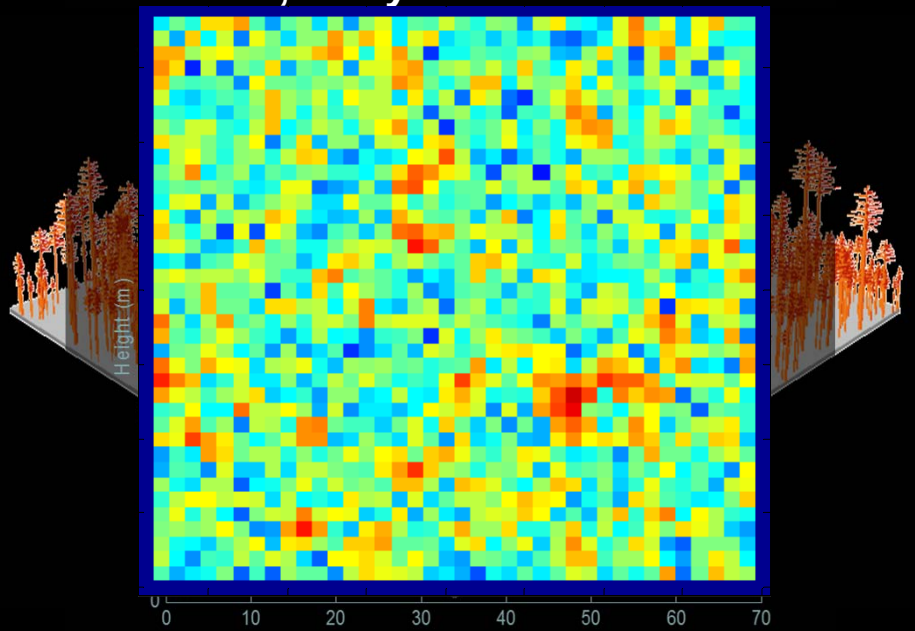
Old forest, 10 years after a fire event



Old forest, 200 years after a fire event



Young forest, 50 years old

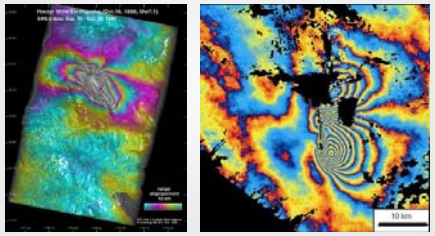


Old forest, 500 years old

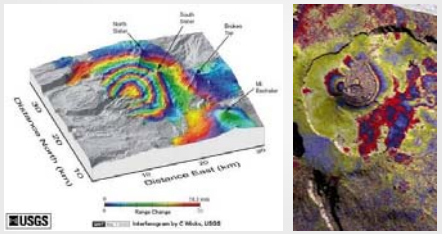
Geosphere

Deformation Mode

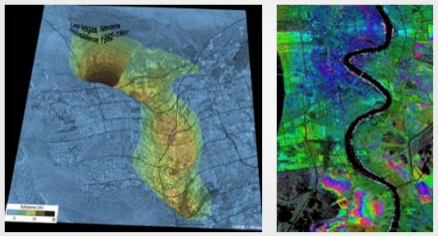
Earthquakes



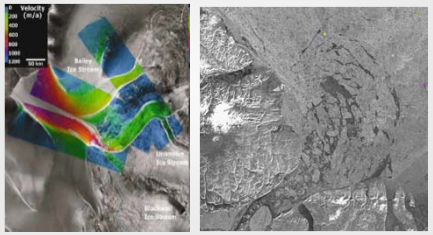
Volcanoes



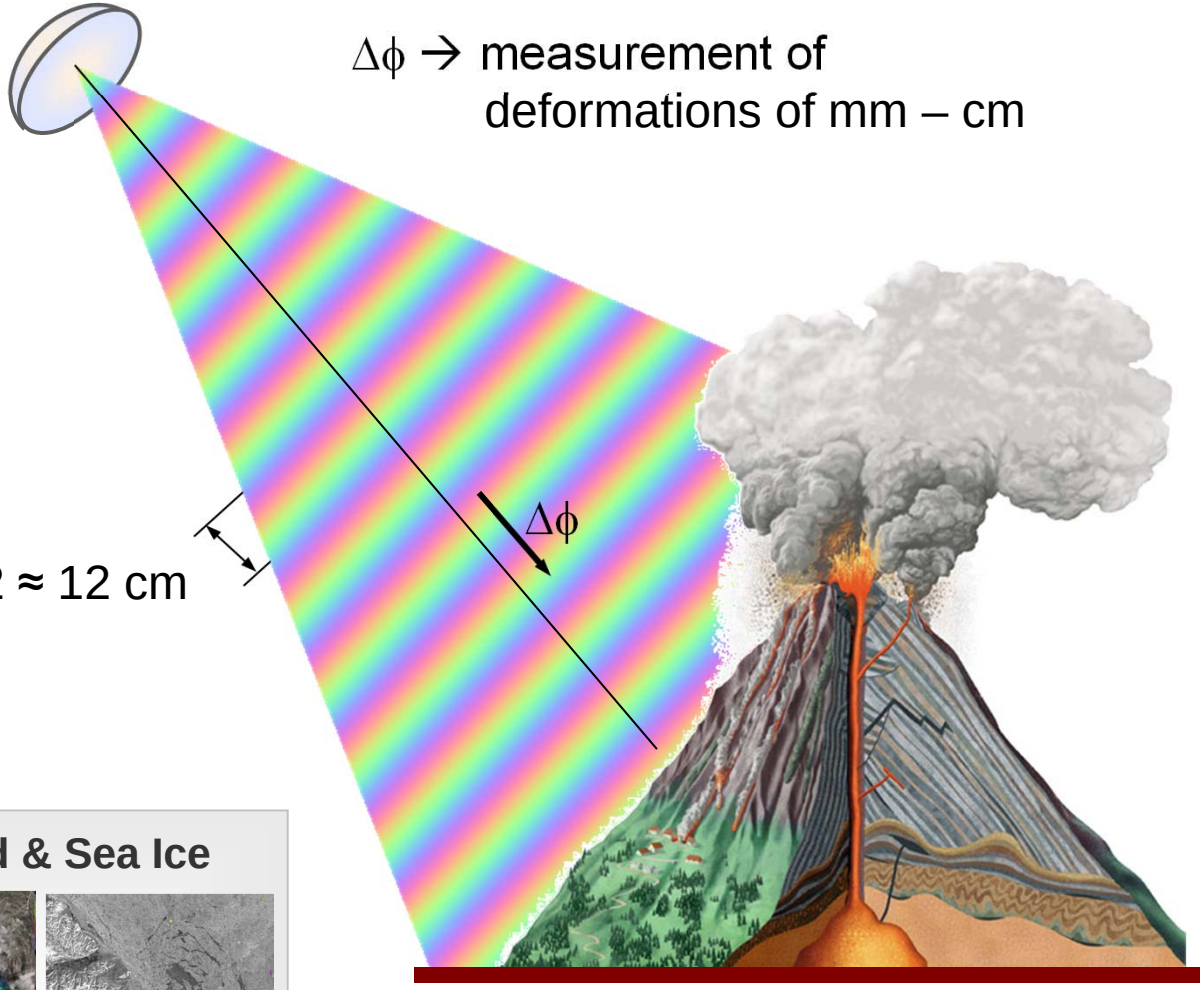
Subsidence



Land & Sea Ice



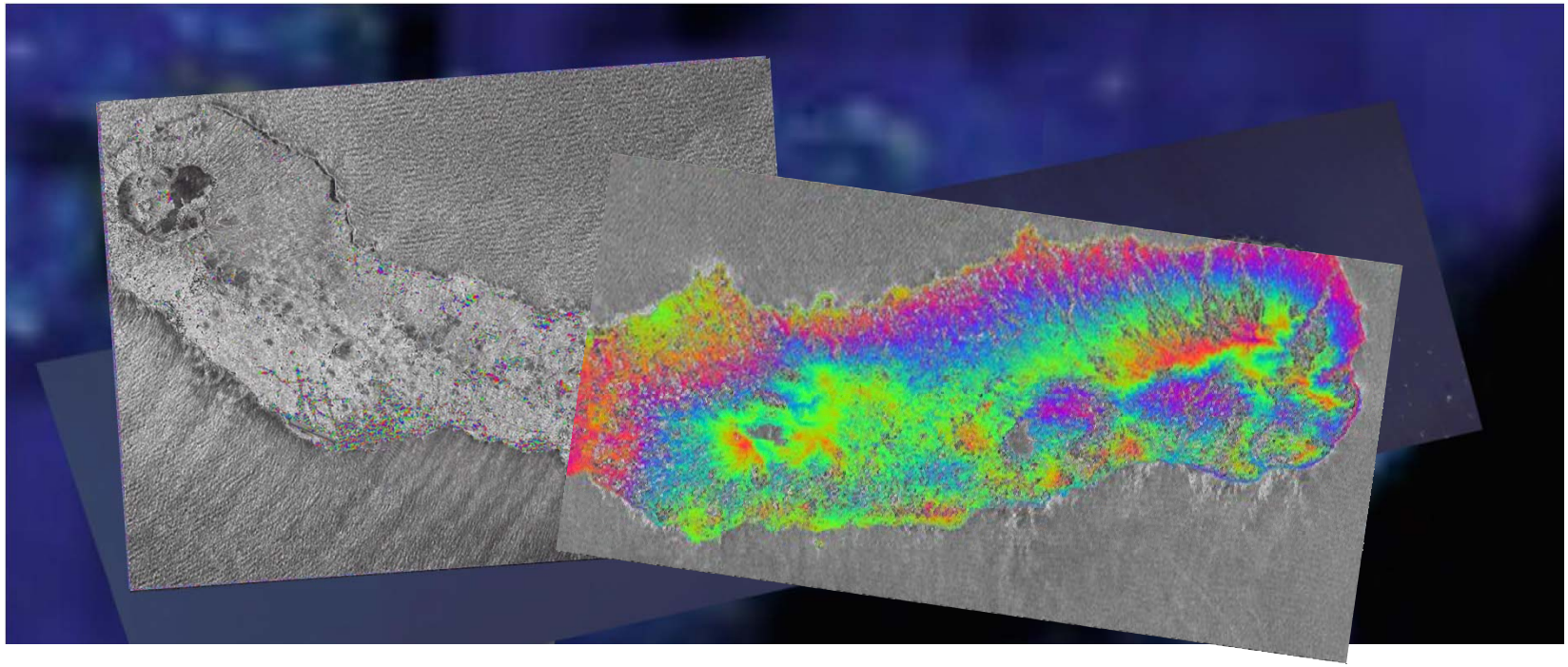
$\Delta\phi$ → measurement of deformations of mm – cm



systematic multi-temporal acquisitions (image stacks)

DLR JAXA

Fogo on Sao Miguel, Azores



TerraSAR-X interferogram
Time between acquisitions = 22 days (2 cycles)

ALOS L-Band interferogram
Time between acquisitions = 46 days (1 cycle)

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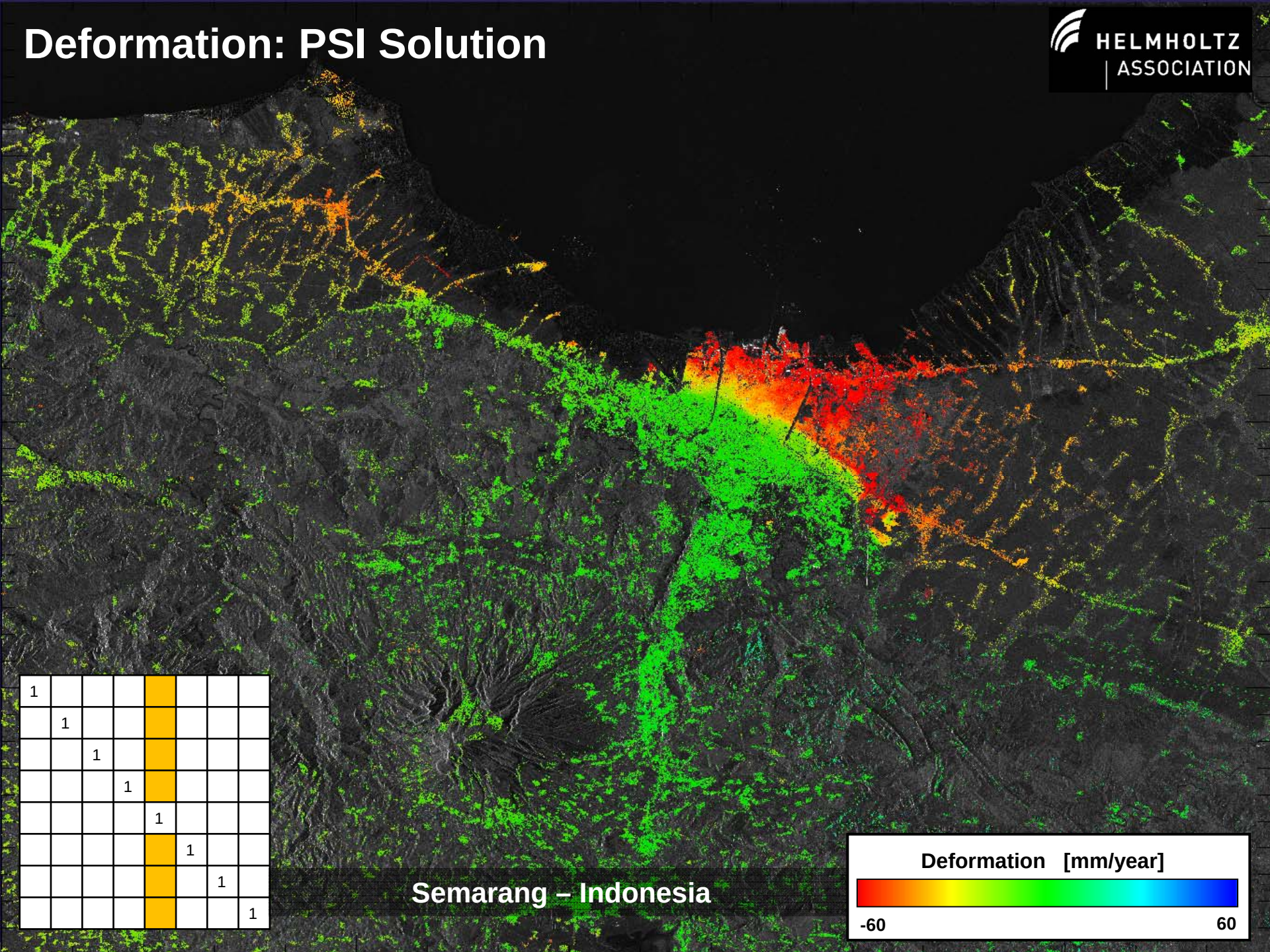
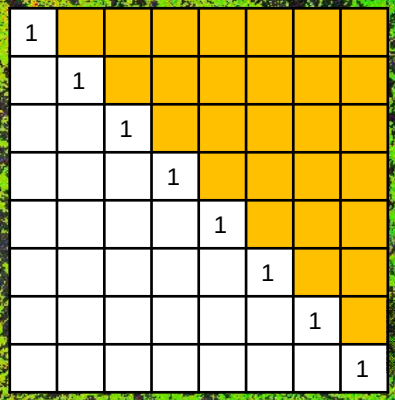
Deformation: PSI Solution



Deformation: Full Covariance Matrix Solution

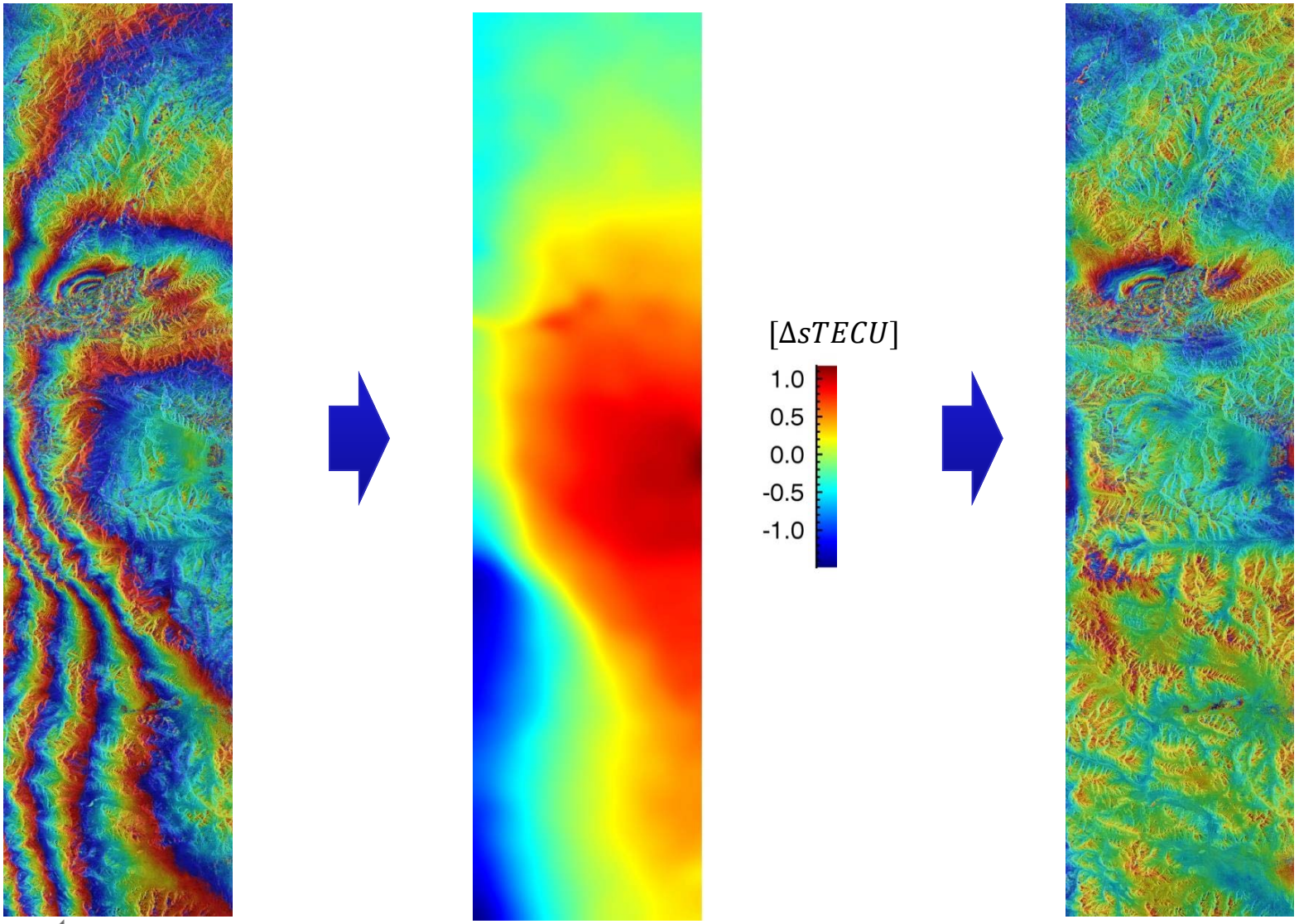


Semarang – Indonesia

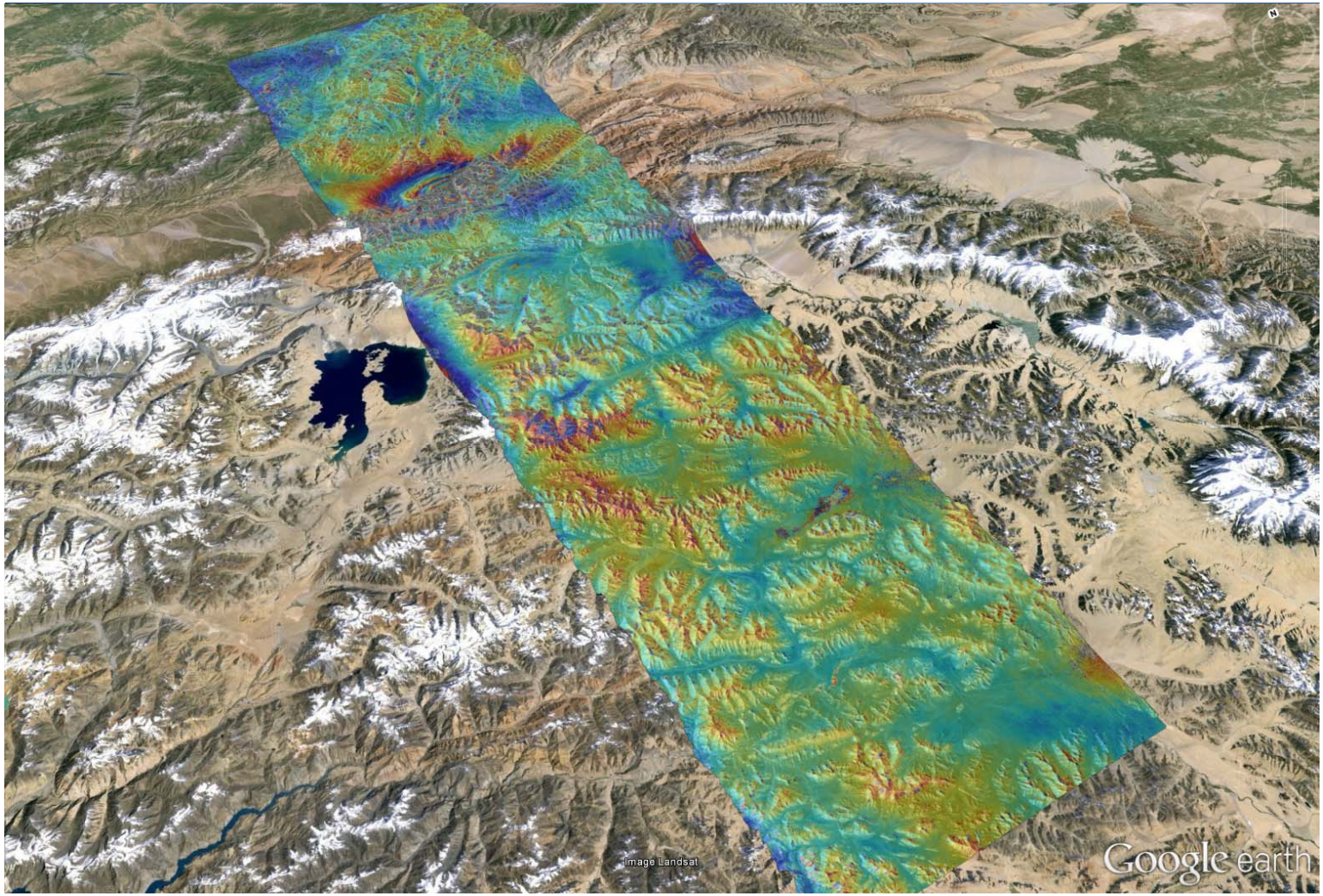
Deformation [mm/year]

-60 60

Tajikistan Earthquake



Geocoded compensated interferogram



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Helmholtz Alliance:
Remote Sensing and Earth System Dynamics

Hydrosphere

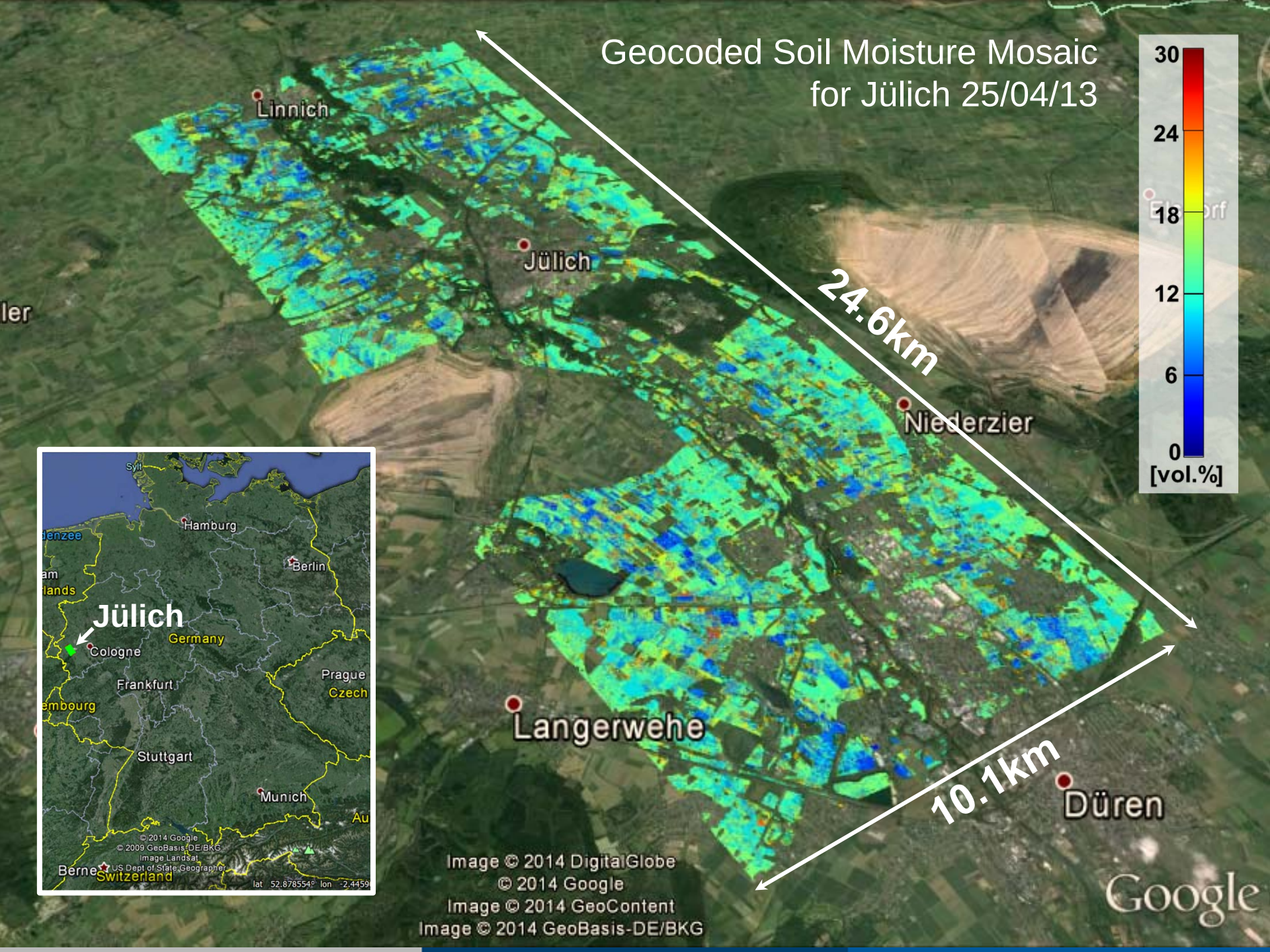
Geocoded Soil Moisture Mosaic
for Jülich 25/04/13
30
24
18
12
6
0
[vol.%]
Linnich
Jülich
Niederzier
Langerwehe
Düren
24.6km
10.1km
Sylt
Hamburg
Berlin
Jülich
Germany
Cologne
Frankfurt
Prague
Czech
Stuttgart
Munich
Switzerland
Image © 2014 DigitalGlobe
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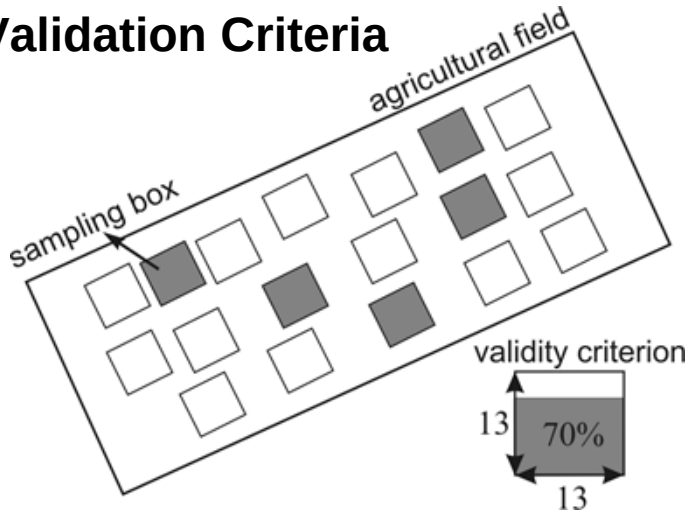
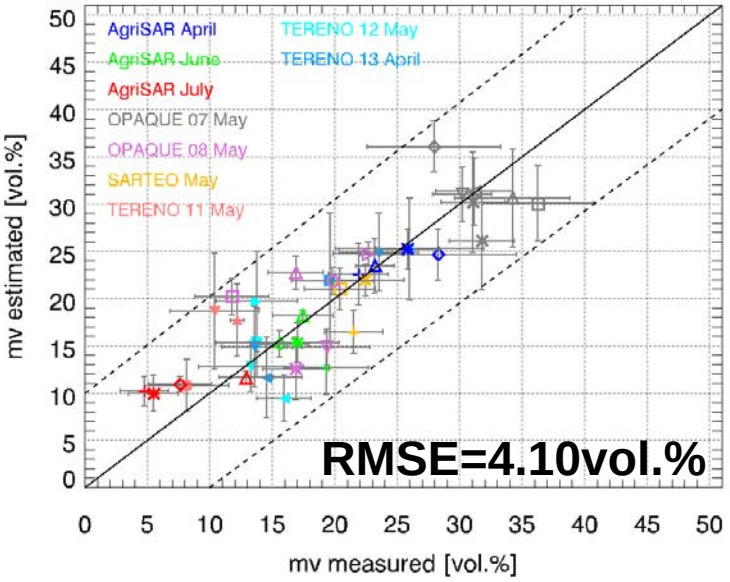
Image © 2014 GeoContent
Image © 2014 GeoBasis-DE/BKG
Google

Validation of Soil Moisture Inversion @ L-Band

Validation Criteria



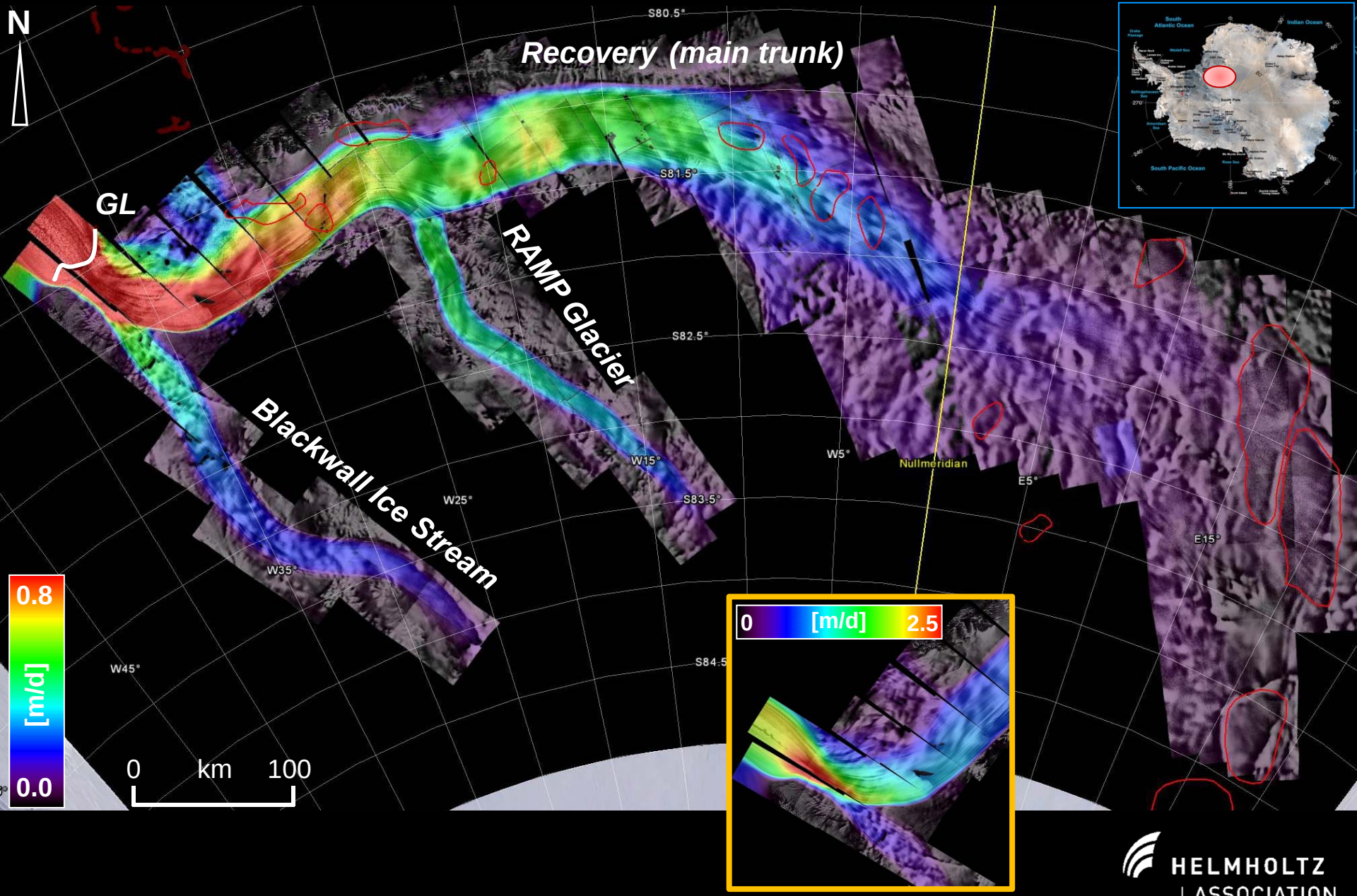
9 Campaigns (E-SAR+F-SAR)



Variety in Vegetation Cover

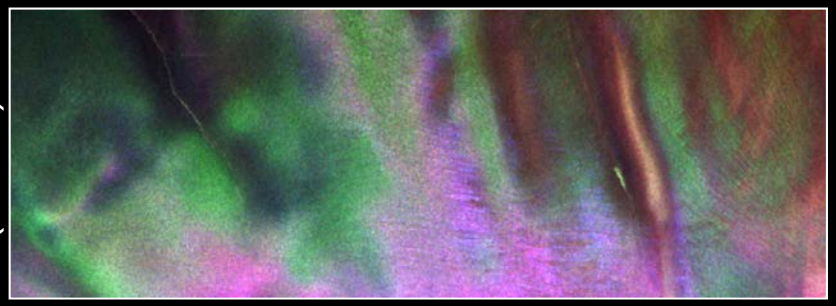
Cryosphere

TerraSAR-X Velocity Mosaic of Recovery Ice Stream

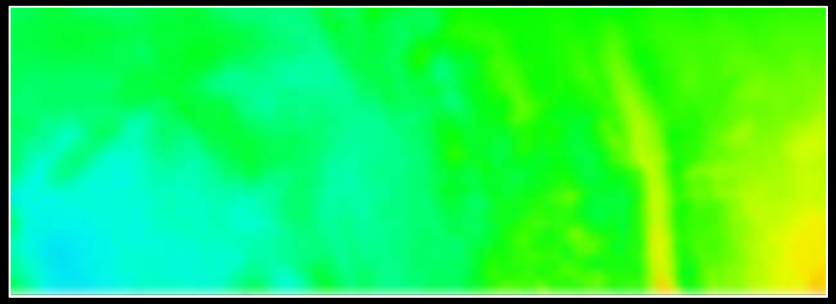


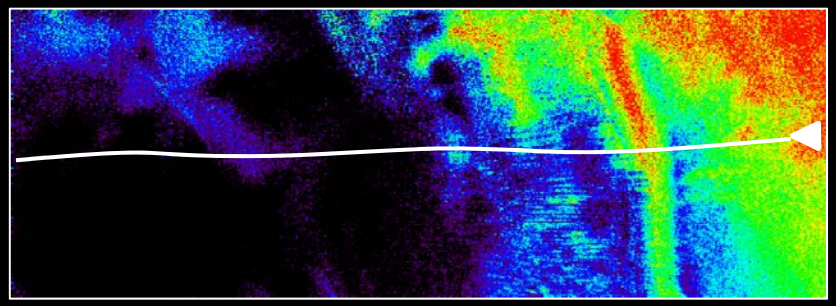
HELMHOLTZ ASSOCIATION

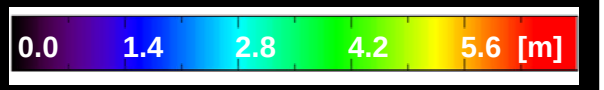
Glaciers & Ice Sheets: Characterization of Subsurface Layers



IceSAR2007, Svalbard

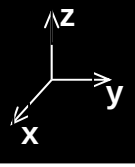


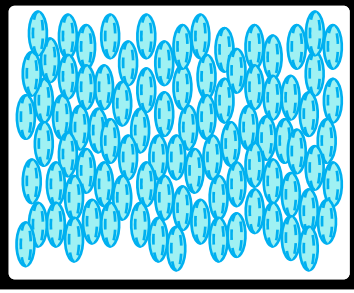


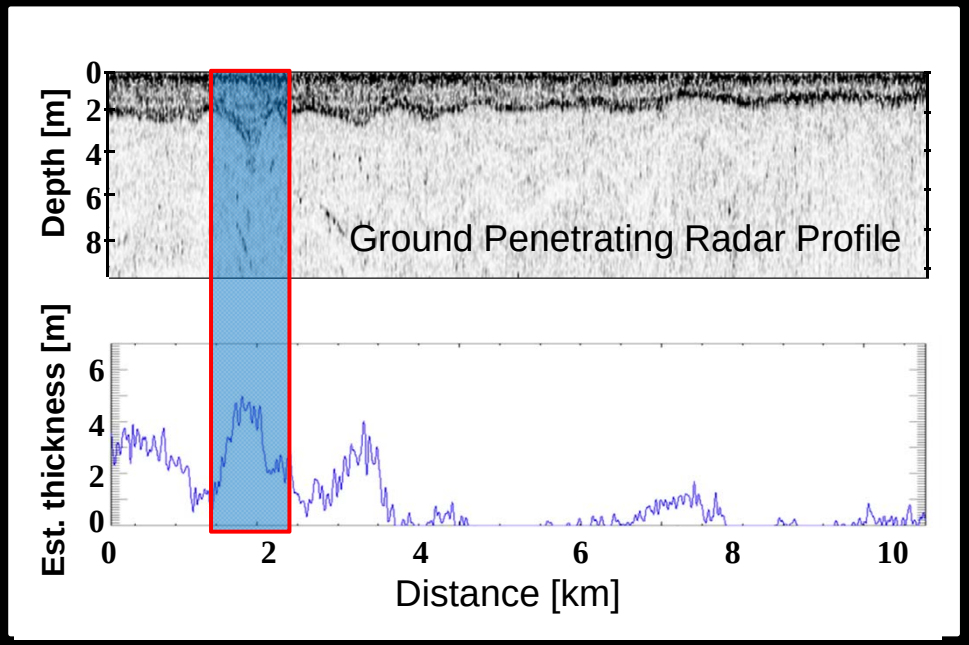


- Structural anisotropy of snow and firn introduces dielectric anisotropy;
- H and V polarizations propagate with different propagation constants → HH-VV phase difference
- Polarimetric model relate HH-VV phase to firn anisotropy and thickness;

$\varepsilon_{eff,x} = \varepsilon_{eff,y} \neq \varepsilon_{eff,z}$







Main Applications: Summary

Vegetation and Hydrology

Application	Min spatial resolution	Covered area	Formation	Acquisition Frequency	Commonalities/ Overlaps
Forest	80 MHz, 10 m, quad-pol	all forests	bistatic XTI HoA: 120 m, 80 m, 50 m, 30 m, <30 m	2 x 3-5/ year	forest DEM, deforestation, degradation, land cover ch. biomass, inundation, soil moisture
Agriculture Maps (pasture)	3 m Japan 40 MHz 10 m all other regions quad-pol	FAO defined agriculture areas (see map)	1 satellite	3 m every 16 days 10 m every 16 days	soil moisture, land use ch., crop cal., classification, rice paddy maps, biomass
Wetland Extent and Change	20 MHz (or 40 MHz) 50 m quad-pol	deforestation hot spot (pan-tropical belt +/-20°)	1+1 satellite	12 per year monthly	wetland inundation, soil moisture
Soil Moisture	80 MHz 10 m quad-pol	forest + agriculture + all land surfaces	1+1 satellite	< 8 days	crop phenology

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Geosphere

Application	Min spatial resolution	Covered area	Formation	Acquisition Frequency	Commonalities/ Overlaps
Large Scale Deformation	80 MHz (ascending) (local time 6:00) 20+5 MHz (descending) (local time 18:00) 10 m, single-pol (desired dual-pol)	strain + volcanos + city areas + major oil fields; mt.+outlet glaciers (global)	1+1 satellite, (2nd satellite left-looking)	20+40/year ascending & descending	glacier movement, permafrost
Global Basemap	80 MHz, 10 m quad-pol	all land surfaces	bistatic XTI pursuit monostatic	2/year	land cover, deformation, disaster, DEM, ice sheets, glaciers, Greenland, permafrost, soil moisture

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Cryosphere and Ocean

Application	Min. spatial resolution	Covered area	Formation	Acquisition Frequency	Commonalities/ Overlaps
Ice sheet monitoring	80 MHz 10 m quad-pol	icesheet+outlet glaciers (Arctic/Antarctic)	1+1 satellite (after global base map)	8 times (3 consecutive acquisitions – summer SH)	coastal area change, grounding line position, ice sheet changes
Sea Ice extent	80 MHz 10 m quad-pol	Arctic region; Antarctic sea	1+1 satellite	once per season (Arctic/Antartic)	max and min sea ice extent
Ocean Monitoring (Wind speed estimation)	350 km swath 20 MHz 50 m dual-pol (HH, HV)	global costal region (water area: 200 km)	1+1 satellite	every opportunity	coastal area chan. ship detection, ocean waves, wind, currents, oil slick
Ship routing	350 km swath 20 MHz 10 m Dual pol HH+HV	Arctic region (> N60); Antarctic sea Okhotsk sea	1+1 satellite	once every cycle (8 days) Nov-March Dec-April	ship routing and detection

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Disaster and Risk Areas

Application	Min spatial resolution	Covered area	Formation	Acquisition Frequency	Commonalities/ Overlaps
Emergency Mode	80 MHz 1 m 50 km, quad-pol (<36h latency req.)	Selected areas (mainly Japanese region)	bistatic XTI (small) ATI (bigger than 0.1 sec)	5-10 /year	DEM, landslide, flooded regions, surface decorrelation, damage assessment
Japan Basemap	80 MHz 3 m 175 km quad-pol	Japan (coastal region 200 km)	1+1 satellite	every year (asc/desc)	

SAR System Concept

Tandem-L: Overview

Parameter	Value	Comments
Orbit height	745 km	231 cycles / 16 days
Orbital tube	500 m (3σ)	refers to master satellite
Horizontal baselines	1… 18 km	variable horizontal baselines for bistatic mode in close formation
Radial baselines	0 m … 400 m	radial baselines are mainly for passive safety in close formation
Local time	6 h / 18 h	dawn/dusk
Inclination	98.4°	sun synchronous orbit
Revisit time	16 days	the 350 km wide swath mode enables up to 4 global data acquisitions from different viewing directions every 16 days
Frequency	L-band	available frequency band: 1215 … 1300 MHz
Range bandwidth	up to 85 MHz	split frequency modes for ionospheric corrections (only for reduced bandwidth modes)
Azimuth resolution	7 … 10 m	for swath widths up to 350/[175] km (single/dual pol/[quad pol])
	3 m	for swath widths up to 350/[175] km (single/dual pol/[quad pol])
	1 m	for 50 km swath (all polarizations)
Downlink capacity	~8 Terabyte /day	based on Ka-band (and X-band) downlink to a ground station network (extension with a LCT to be investigated in phase A)
Look direction	right & left	right looking (left-looking by horizontal satellite rotation)
Reflector diameter	15 m	deployable reflector with 10/15 m boom
Mission lifetime	>7 years	goal > 10 years
Polarization	single/dual /quad	optional use of hybrid and compact polarimetric modes shall be investigated in the phase-A study

DLR JAXA

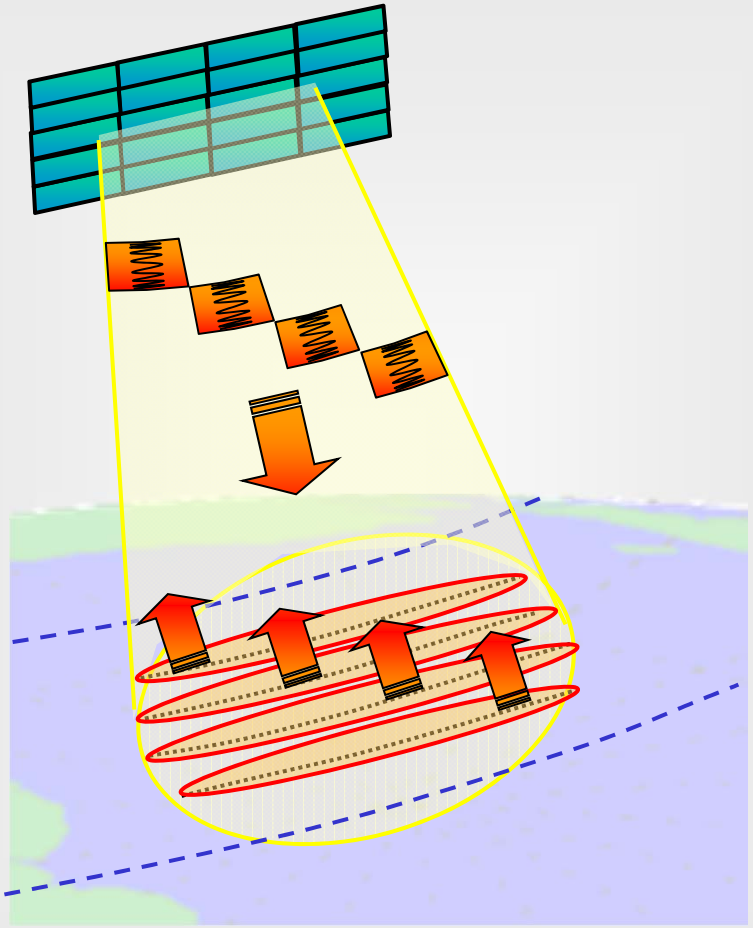
The SAR System Design Dilemma

Azimuth Resolution	Swath Width ($30° < \theta_i < 45°$)
20 m	200 .. 300 km
10 m	100 .. 150 km
3 m	30 .. 45 km
1 m	10 .. 15 km

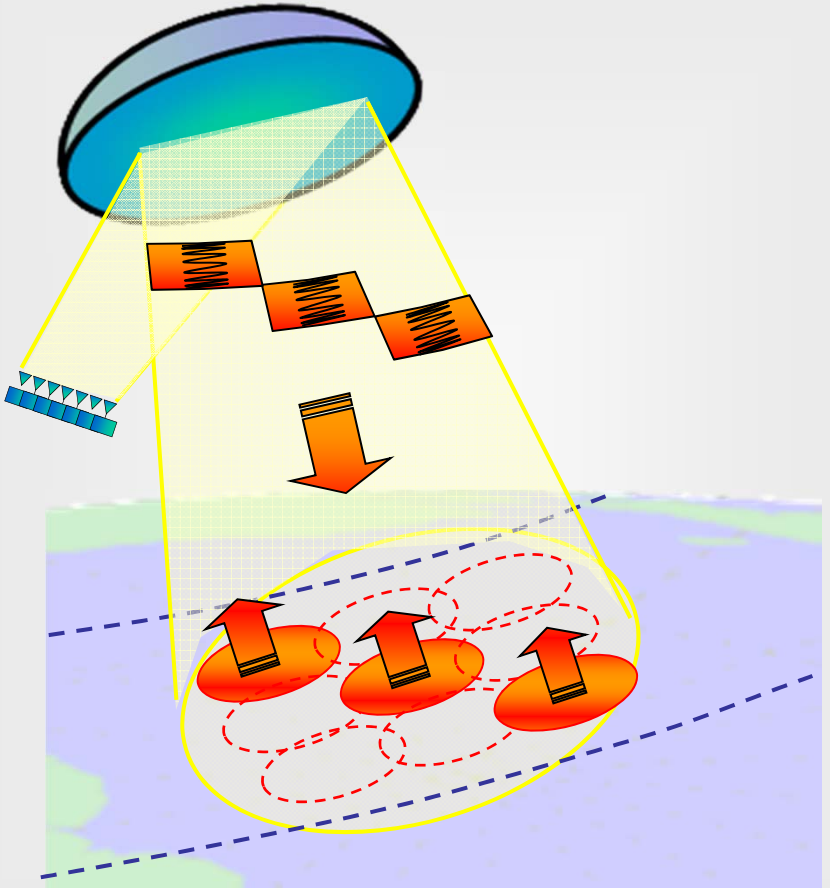
DLR JAXA

Digital Beamforming

Direct Radiating Arrays



Reflectors with Digital Feed Array



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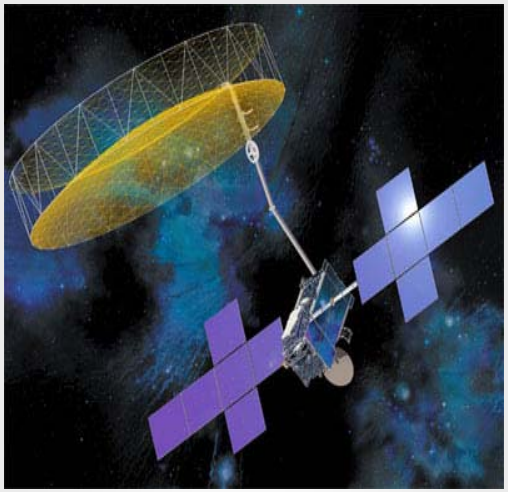
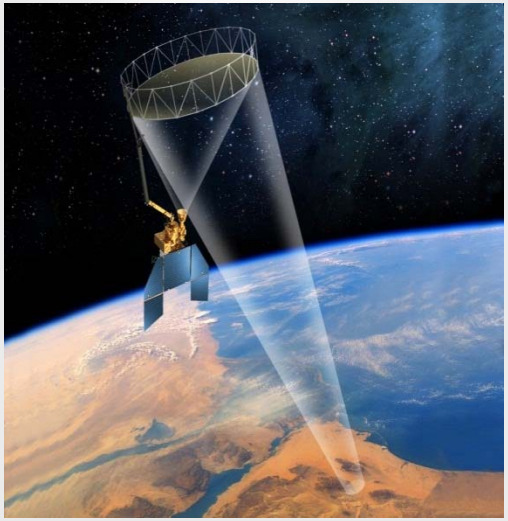
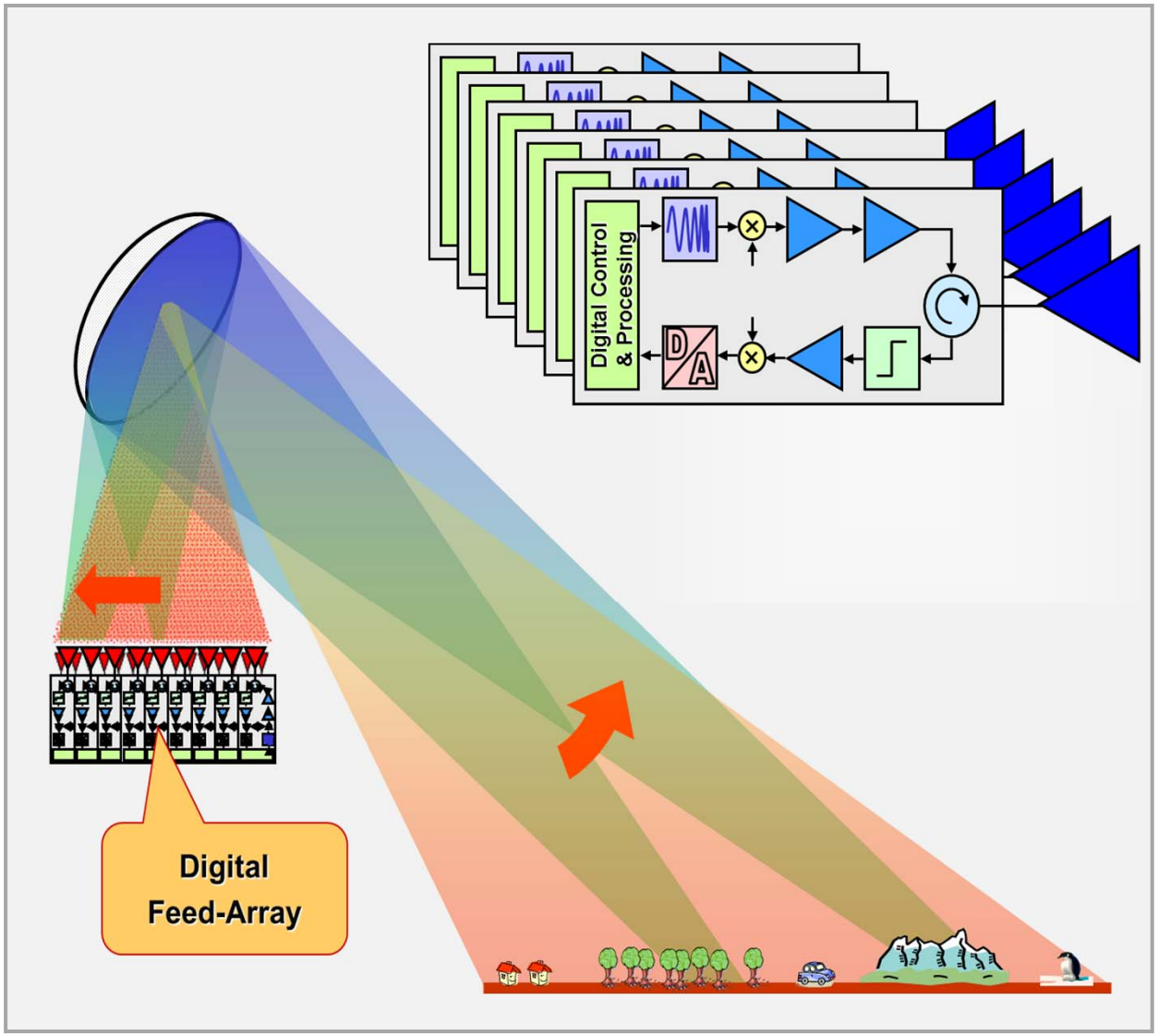
Digital Beamforming with Reflector Antennas

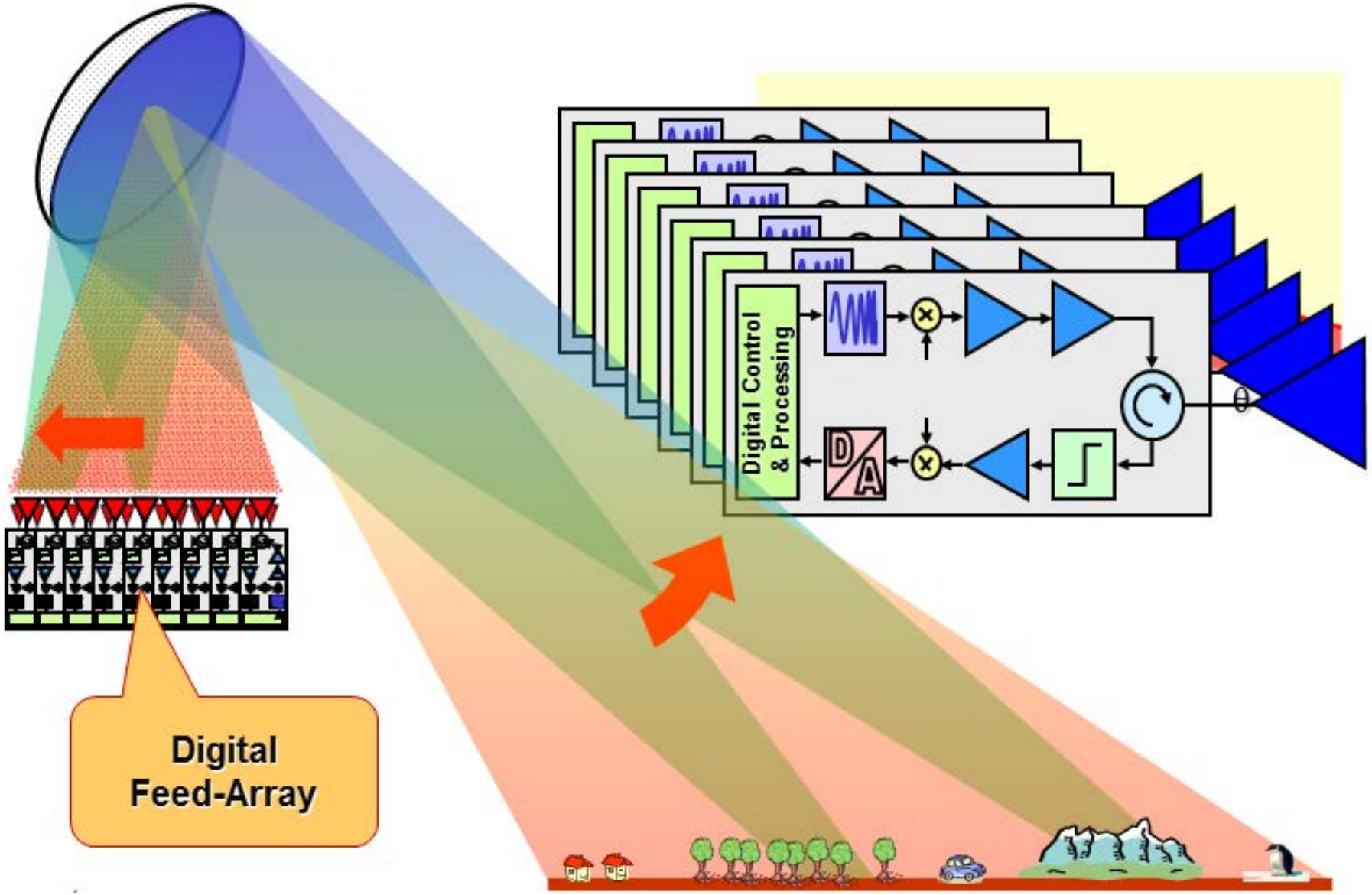






DLR JAXA

DBF-SAR with Reflector Antennas



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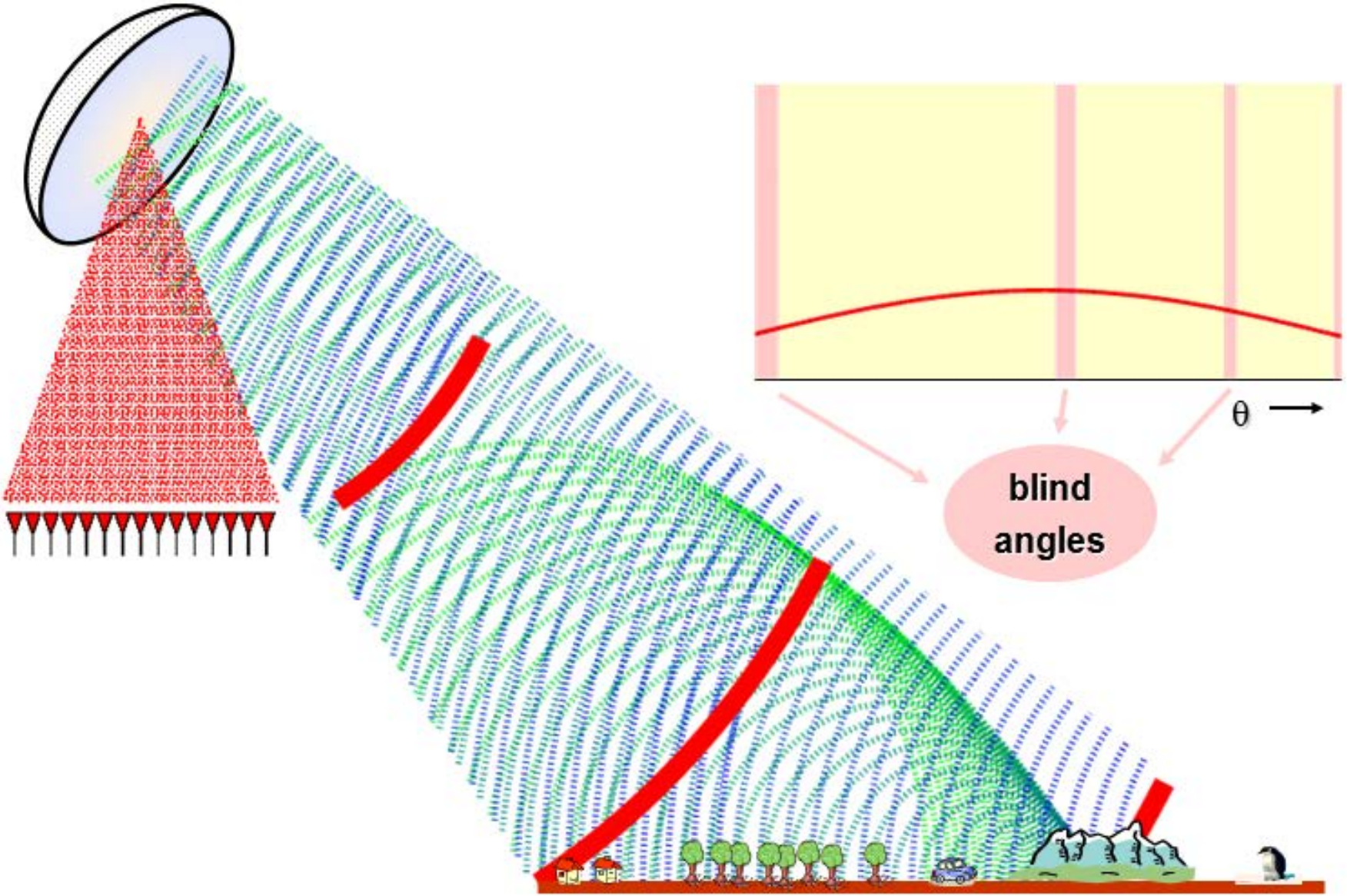
Innovative SAR Instrument with Multiple Swath Mapping



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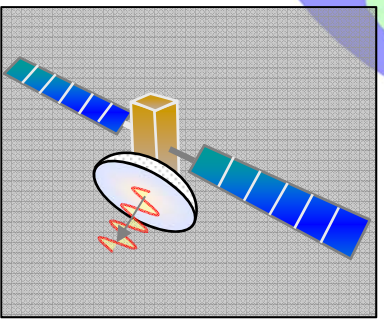
Comparison of Imaging Capacity

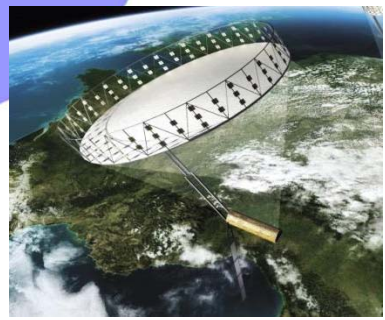
State of the Art

1 global coverage / year



Digital Beamforming

2 global coverages / week



1

Days

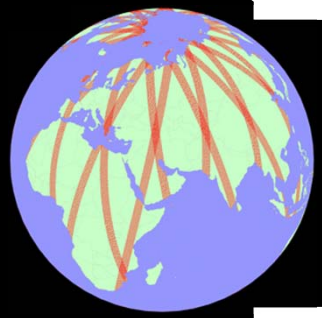
DLR

JAXA

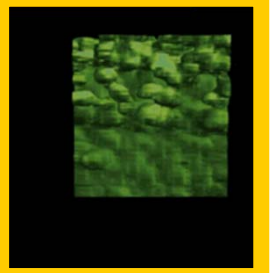
Tandem-L:

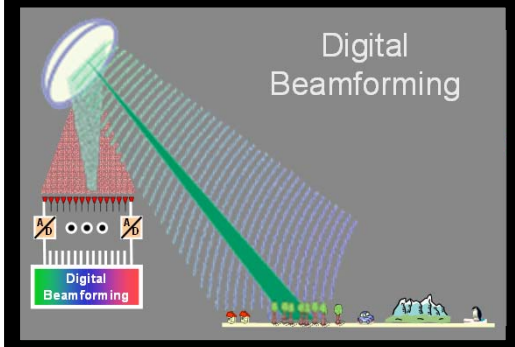
Proposal for an innovative radar mission for monitoring Earth dynamic processes

Global weekly coverage

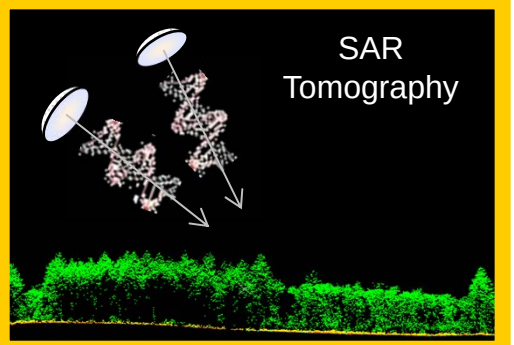


Monitoring of Earth Dynamics





new sensor technologies

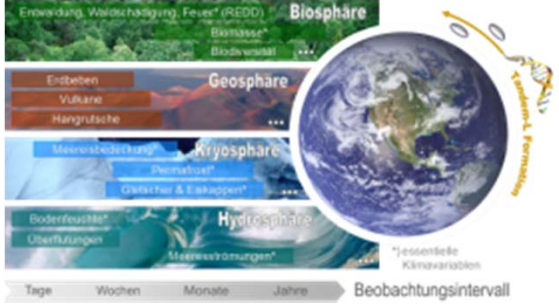


new Imaging techniques

DLR

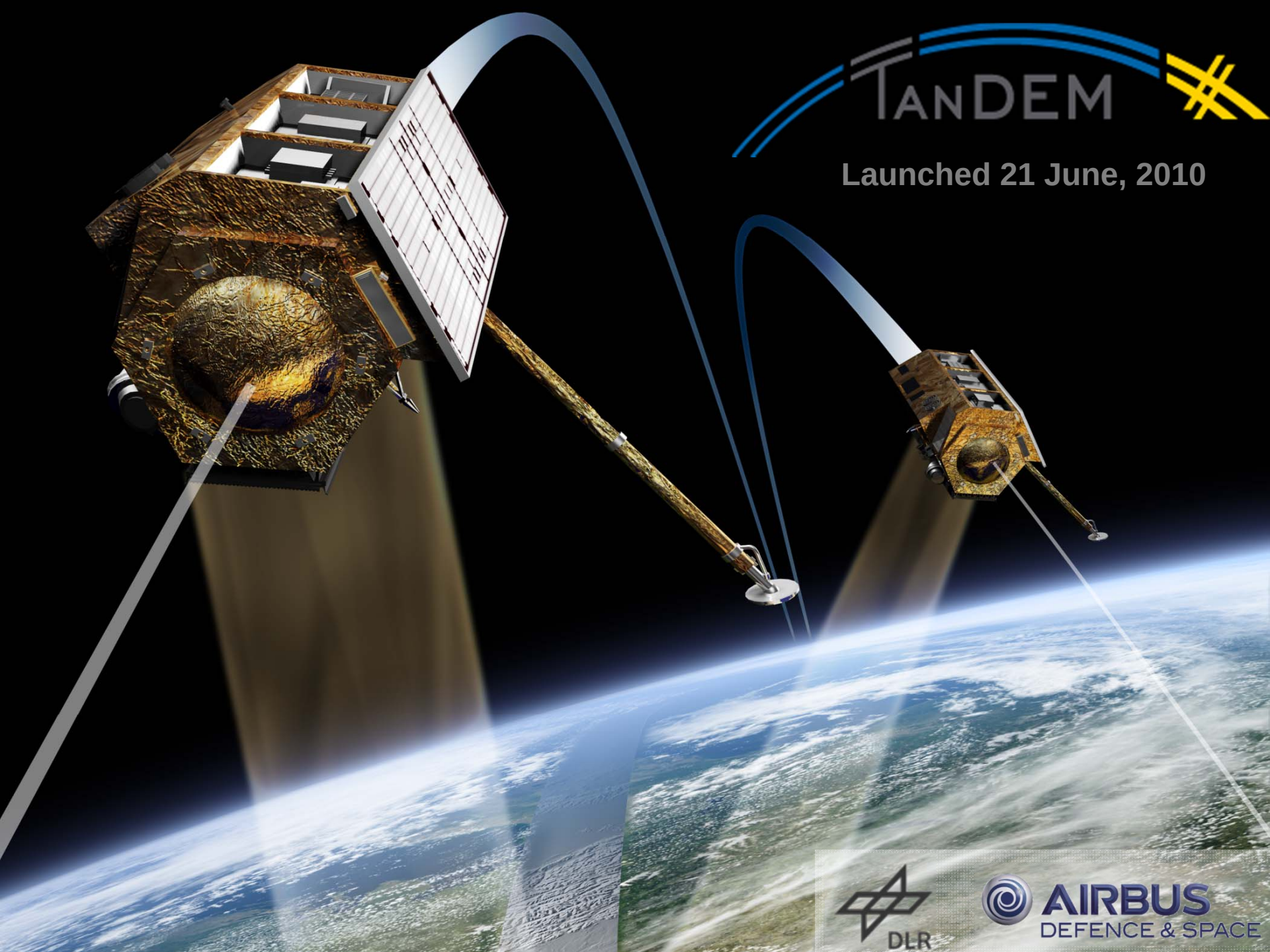
JAXA

Tandem-L: Time Schedule

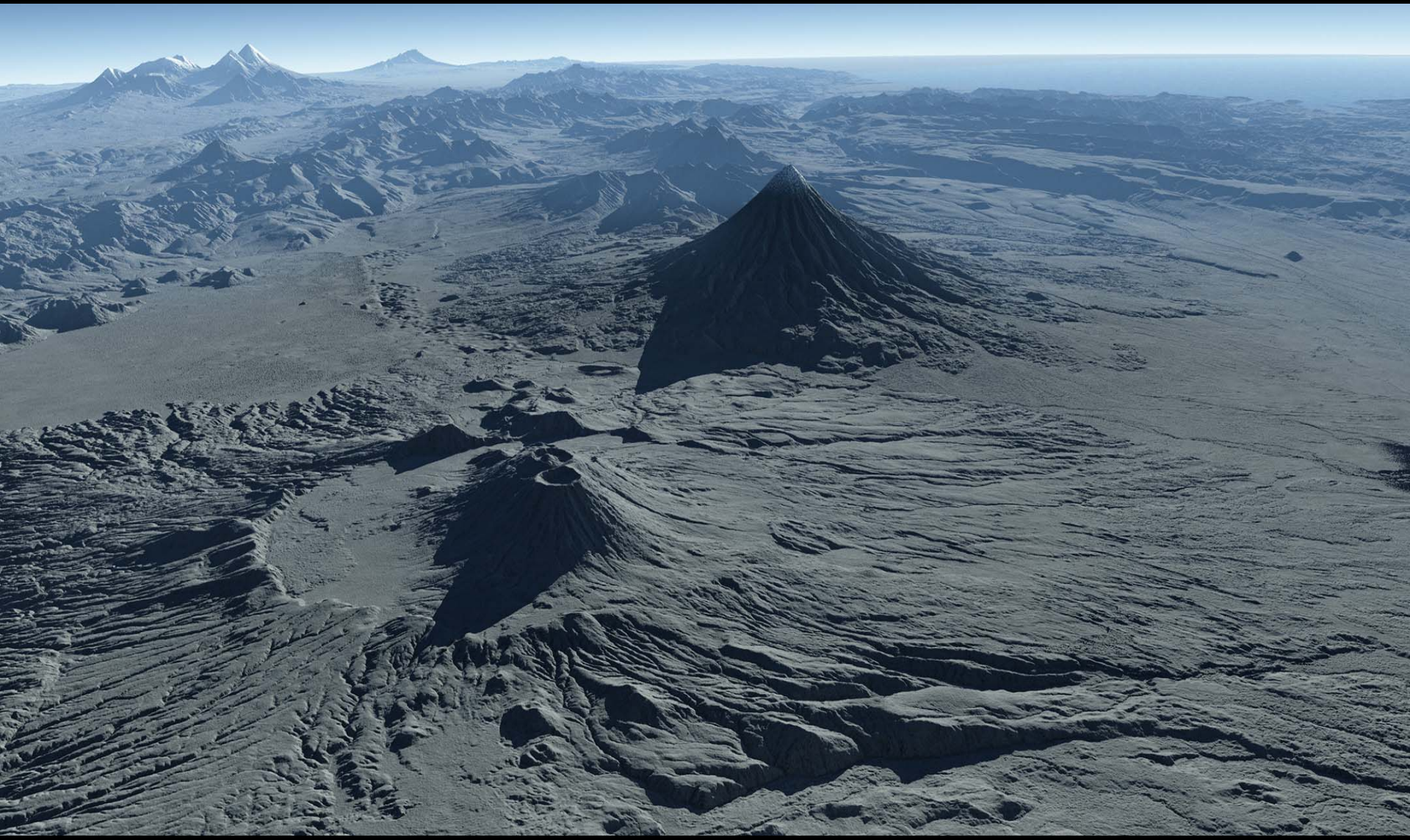


Year	Mission Phase
2013 - 2014	Pre-Phase A (DLR/JAXA)
2014 – 2015	Phase A (DLR/JAXA)
2016	Phase B
2017 - 2021	Phase C/D
2021	Launch of both satellites
2021 – 2027	7 years of operations (extension of at least 5 years possible)

DLR JAXA

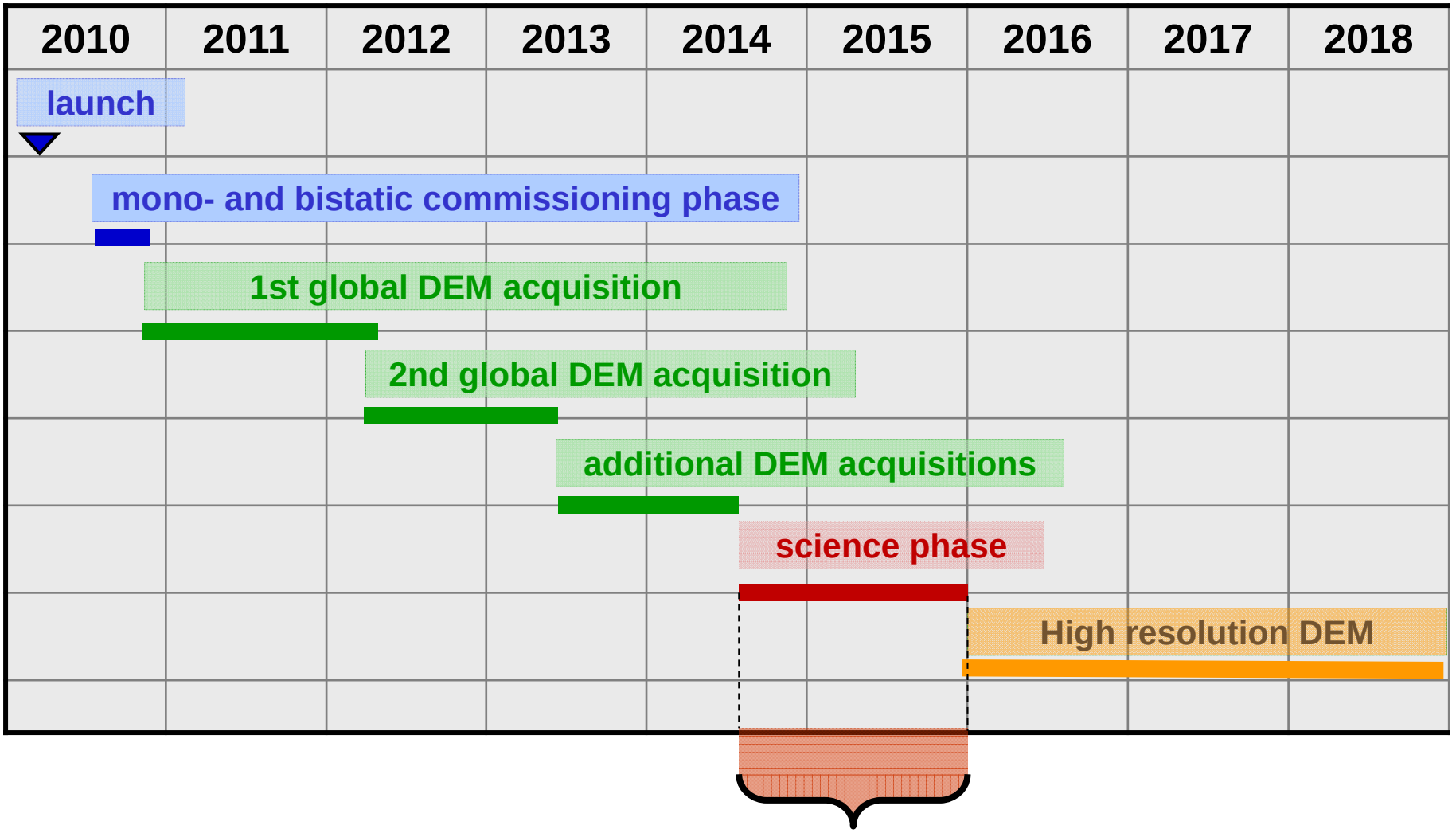

TanDEM
Launched 21 June, 2010
DLR
AIRBUS
DEFENCE & SPACE

Australia, Finke Gorge National park



Kamchatka, Russia

TanDEM-X Timeline



offers unique opportunities for science

TanDEM-X sees the Spring !

Pol-InSAR Phase Difference detects the appearing of the leaves…

0 [m] 5

12.04.2011

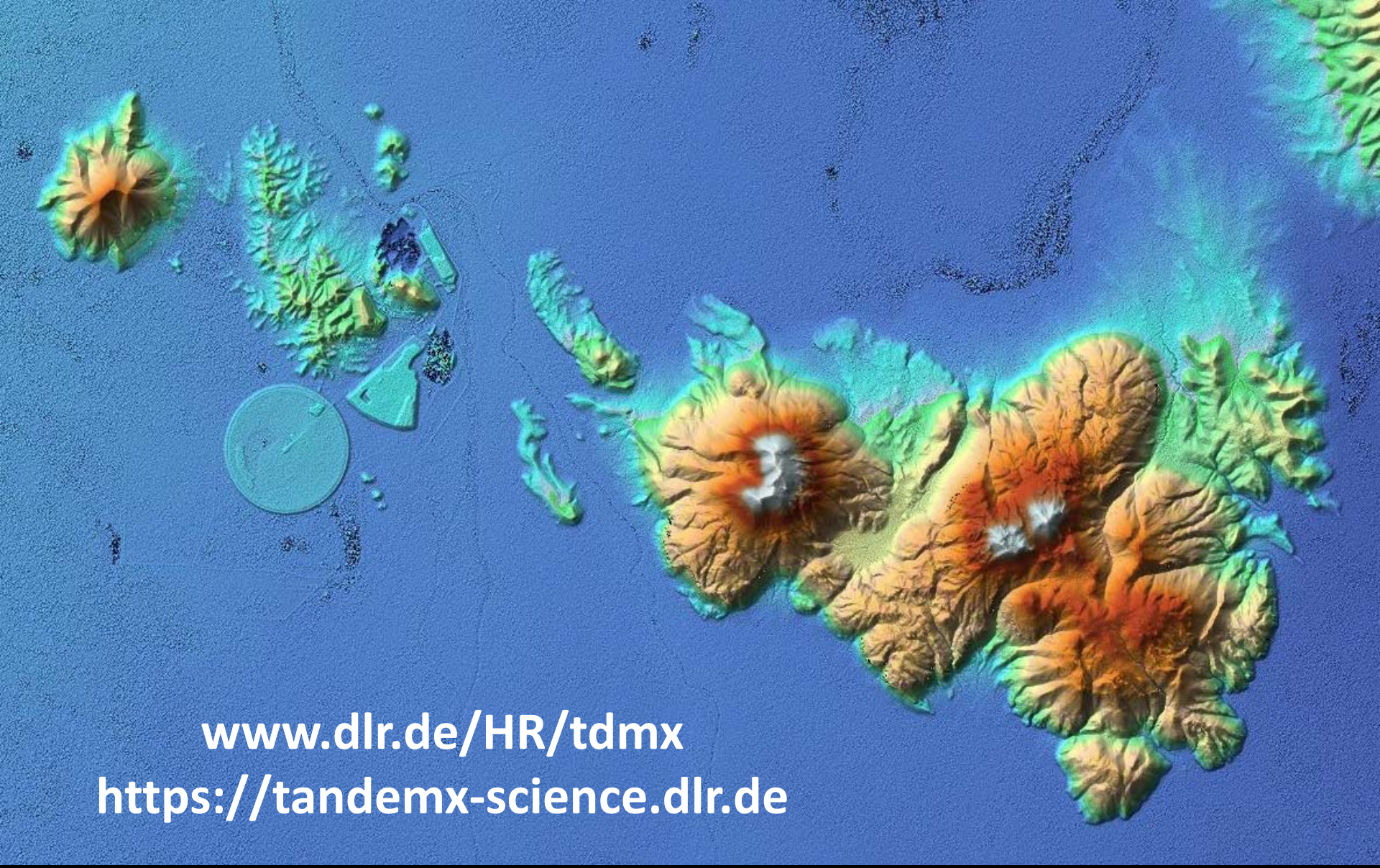
04.05.2011

15.05.2011

Almost No Leaves on the Trees

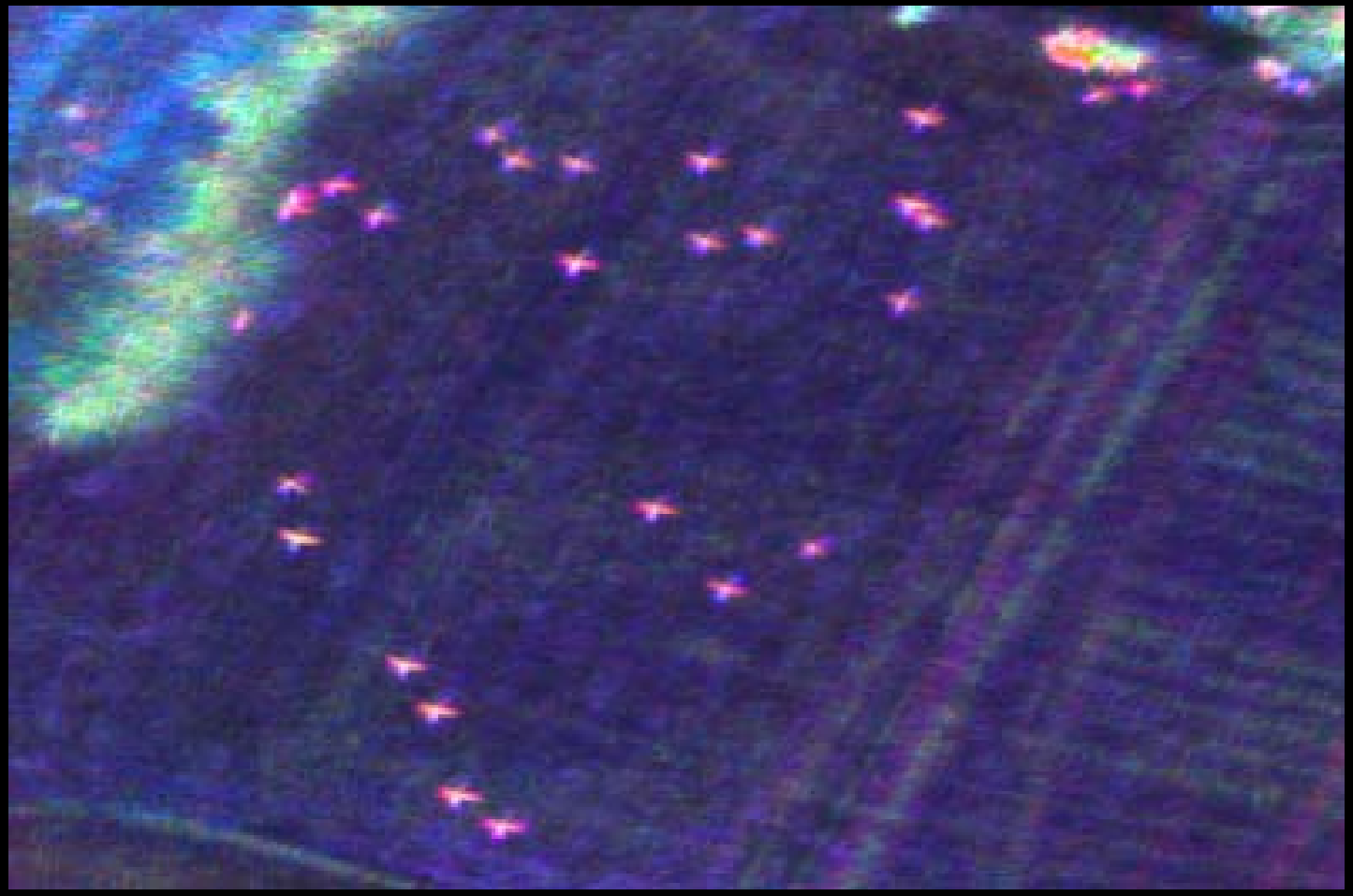
The First Leaves

The Leaves are Here !



Gold Mine, Kori Kollo, Bolivia

L-Band image with 6 cm sampling



What are you seeing here?