German Spaceborne Radar Program:

TerraSAR-X, TanDEM-X and Beyond

Alberto Moreira

1st German/Japanese Science and Application Workshop
for Next Generation SAR
Sola City, Tokyo
June 27, 2013

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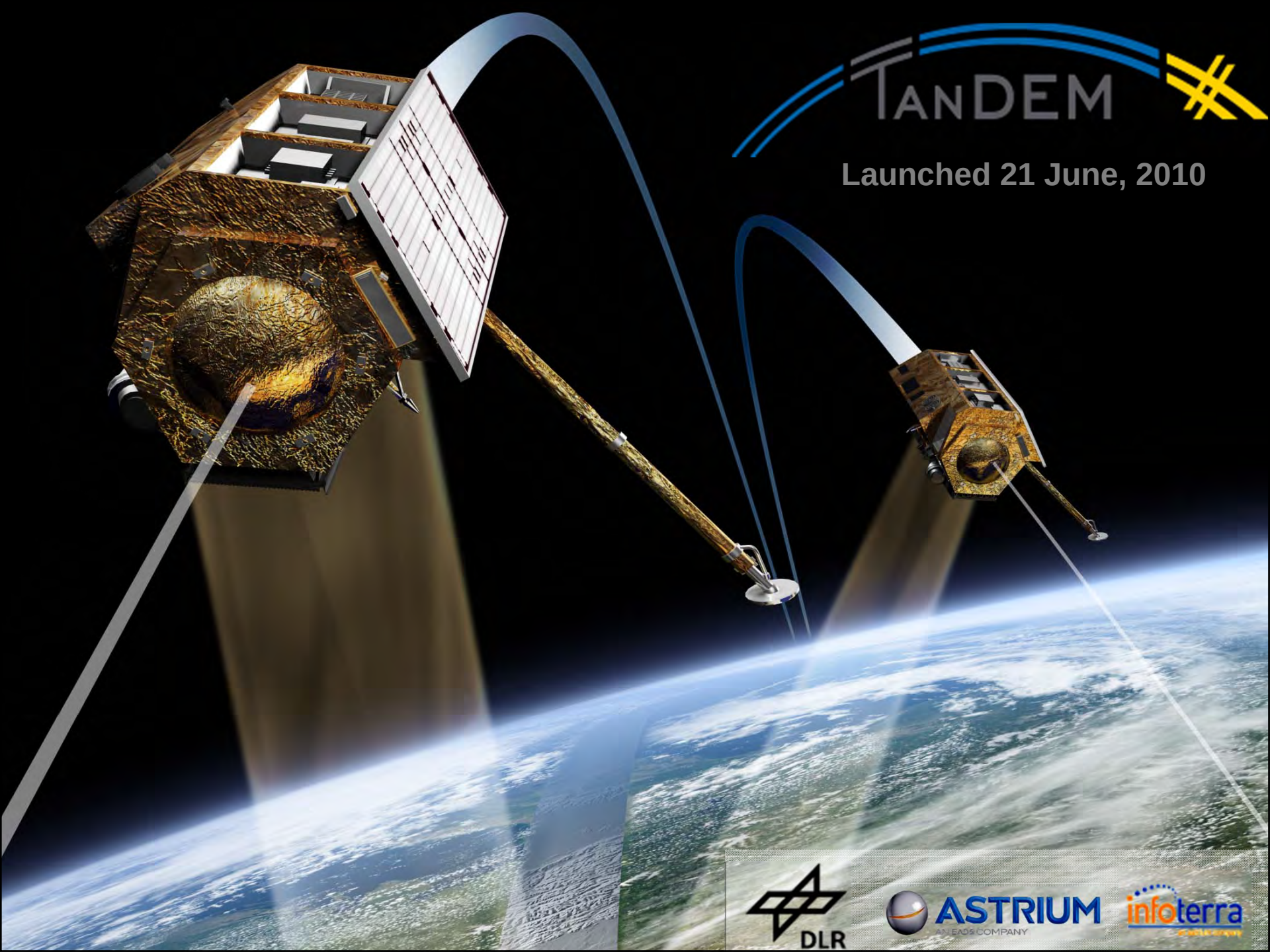
TanDEM
Launched 21 June, 2010
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Atacama Desert, Chile

TanDEM

Societal Challenges of Global Dimension

Climate Change

Environment

Resources

Sustainable Development

Megacities

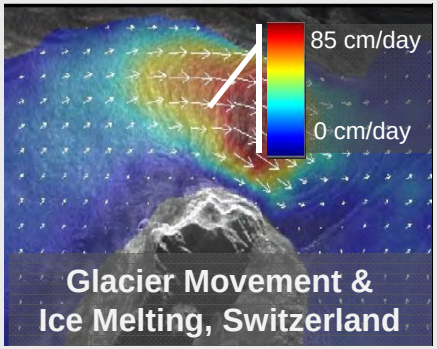
Mobility

Hazards

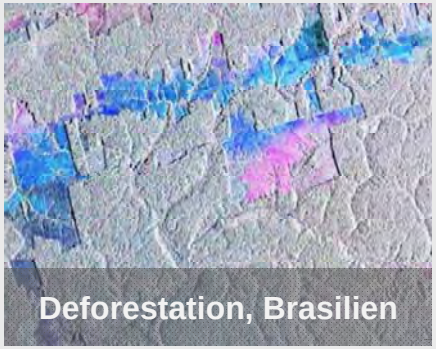
Disaster

DLR

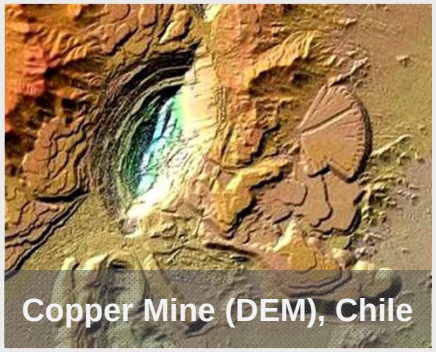
SAR Remote Sensing and Global Societal Challenges



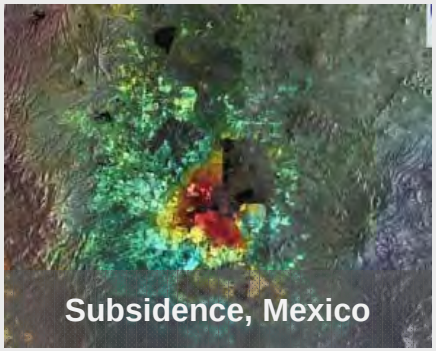
Climate Change



Environment

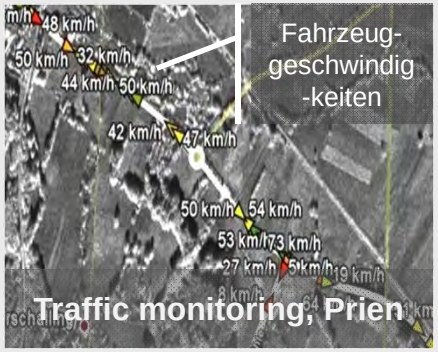


Resources

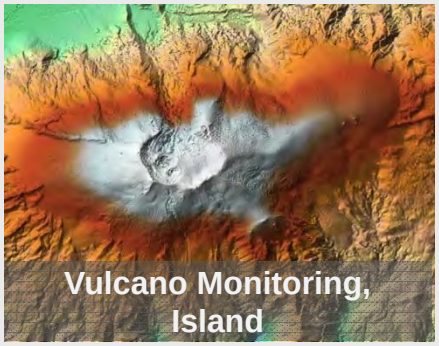


Sustainable Development

Megacities



Mobility



Hazards

Disaster

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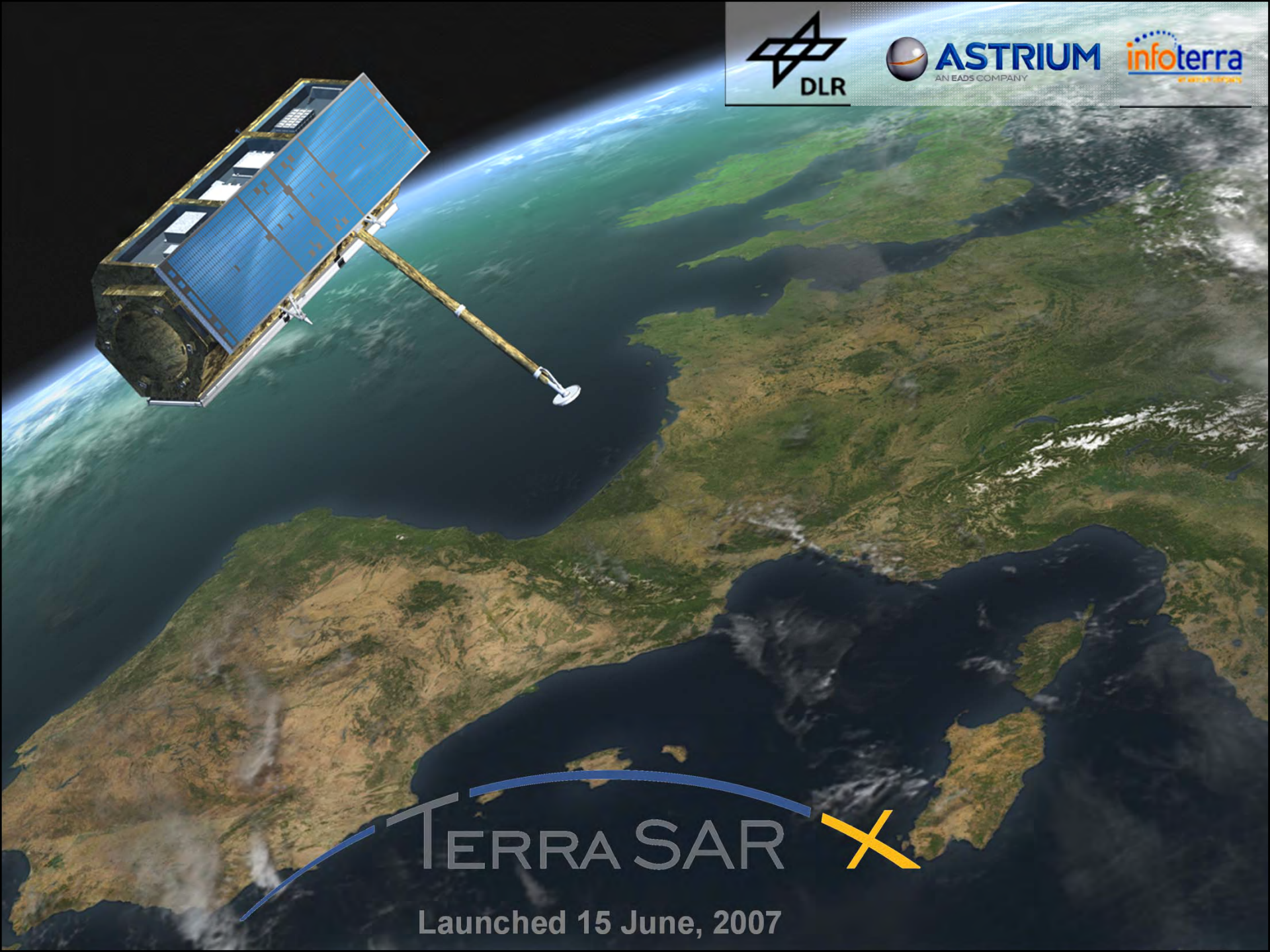
The German Spaceborne Radar Program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TERRA SAR X
Launched 15 June, 2007

TerraSAR-X …during the environmental tests

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TerraSAR-X Mission Profile

Launch in April 2007
from Baikonour
utilizing a
DNEPR-1 Launcher

Downlink of
stored
radar data
@ 300
Mbit/sec

Image processing & archiving
DLR Oberpfaffenhofen &
DLR Neustrelitz

S-Band
Telemetry &
Telecommand

Mission Operations
DLR Oberpfaffenhofen

Acquisition of
radar data

DLR

TerraSAR-X Development and Operations

Satellite Development

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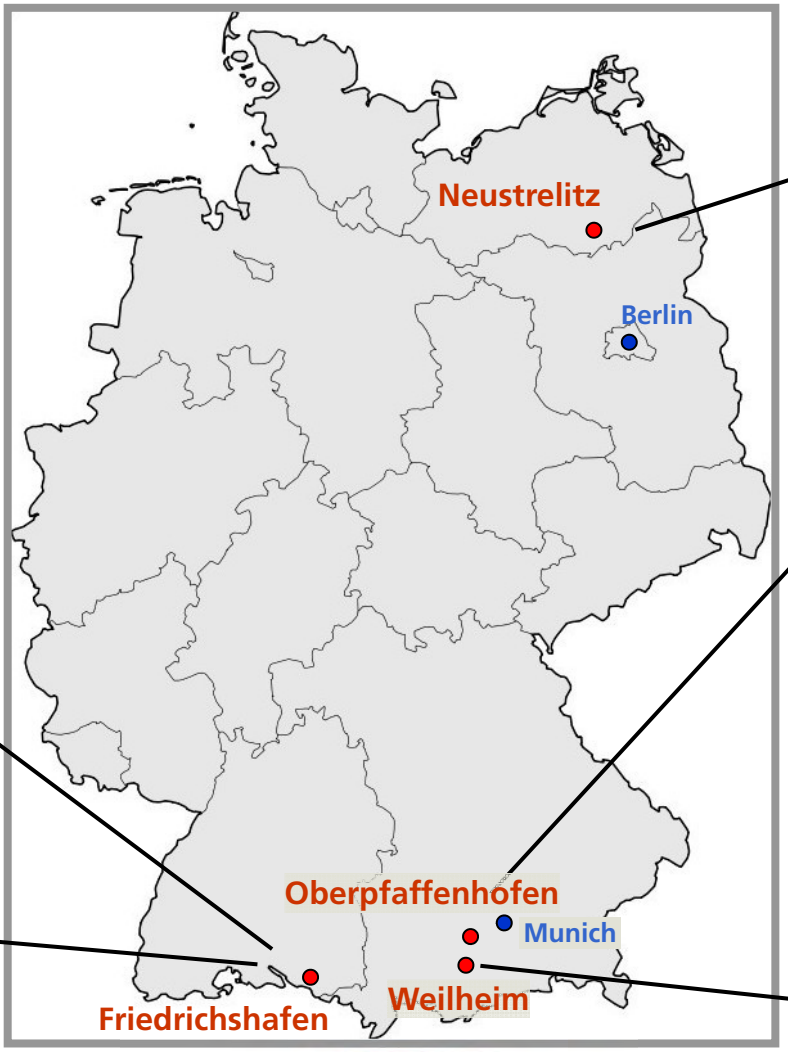


Data Reception

Mission control, data processing and scientific coordination

Telemetry & Telecommand

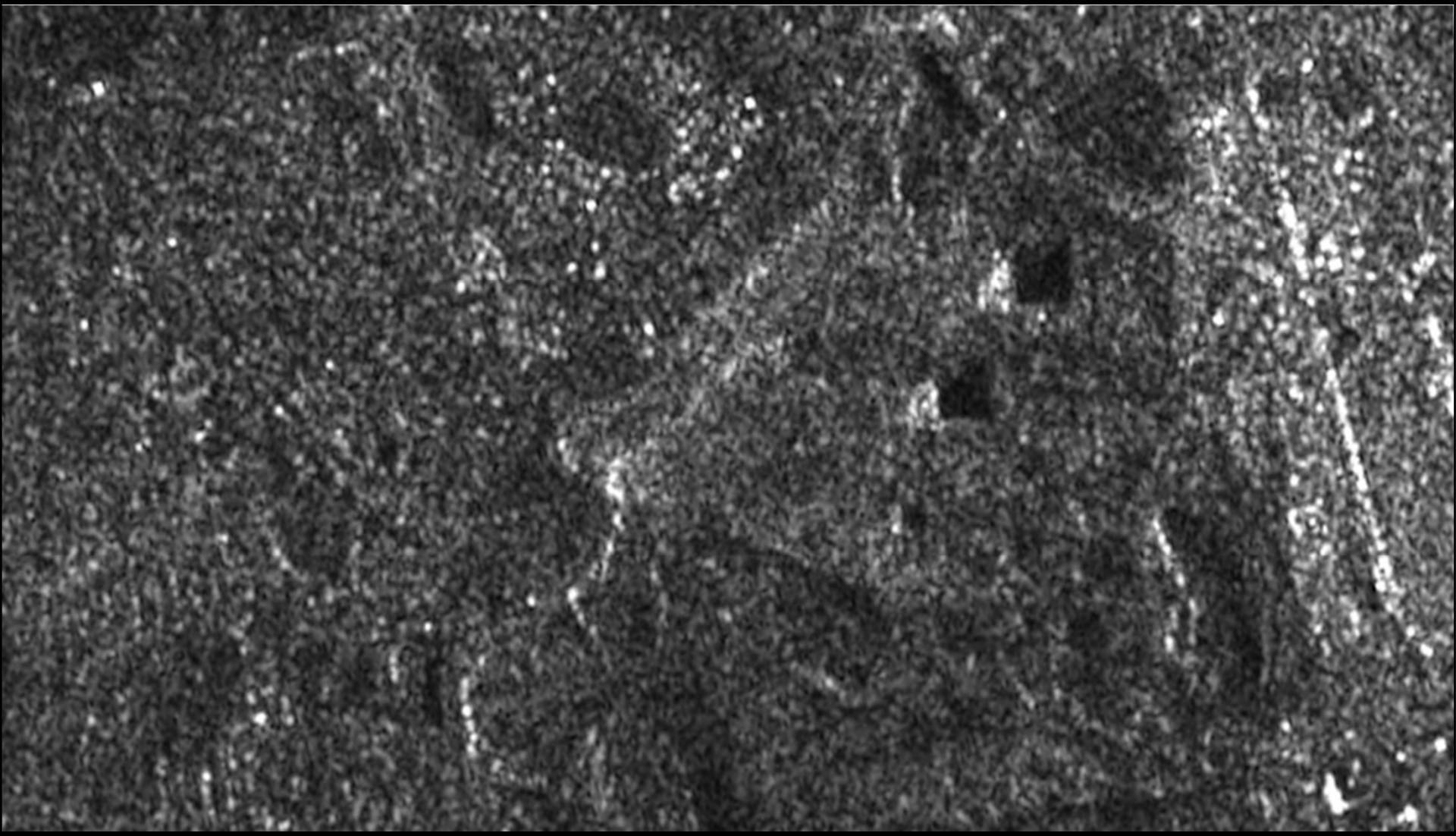
infoterra
an astrium company

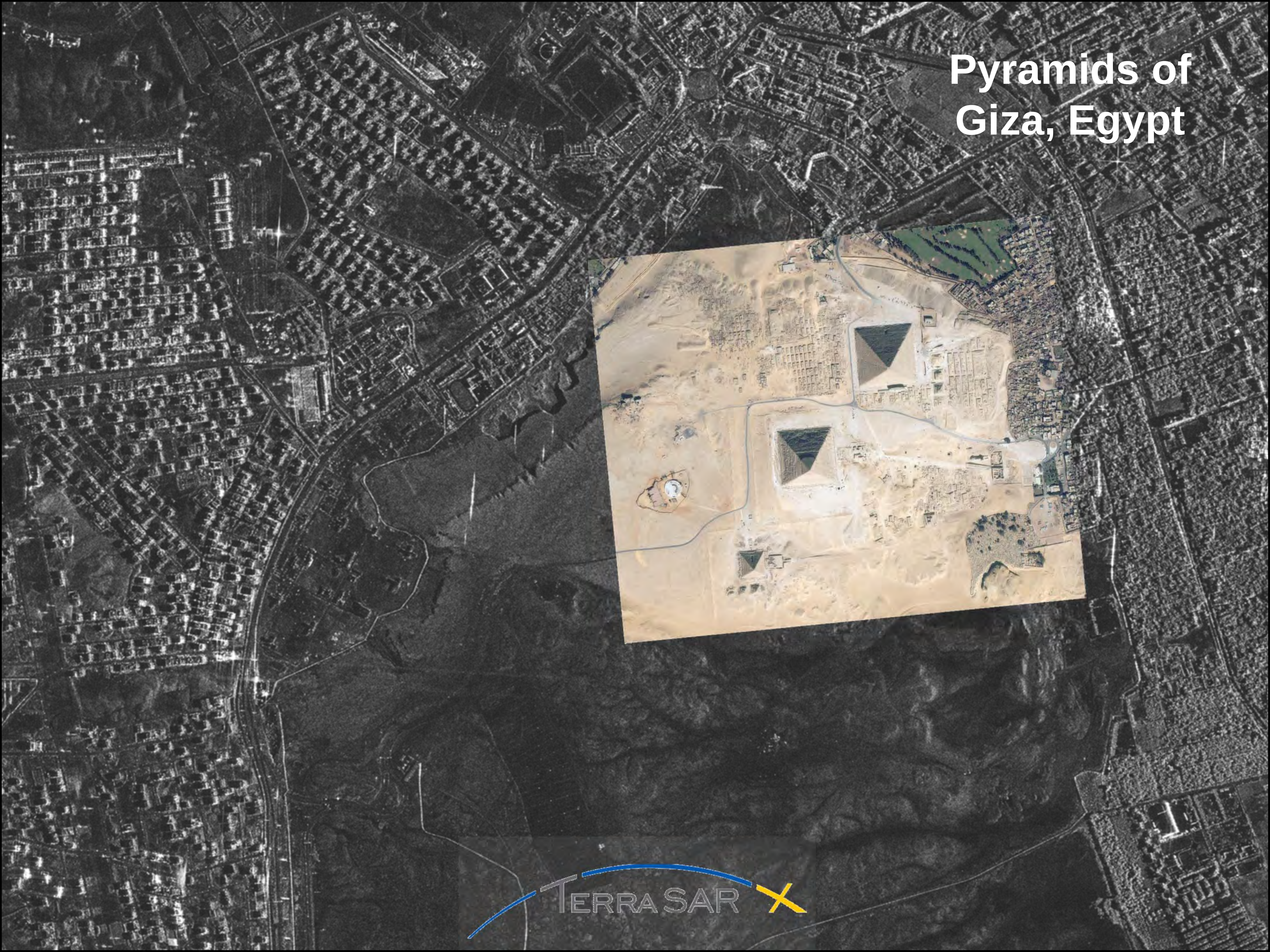
Commercial Data Exploitation

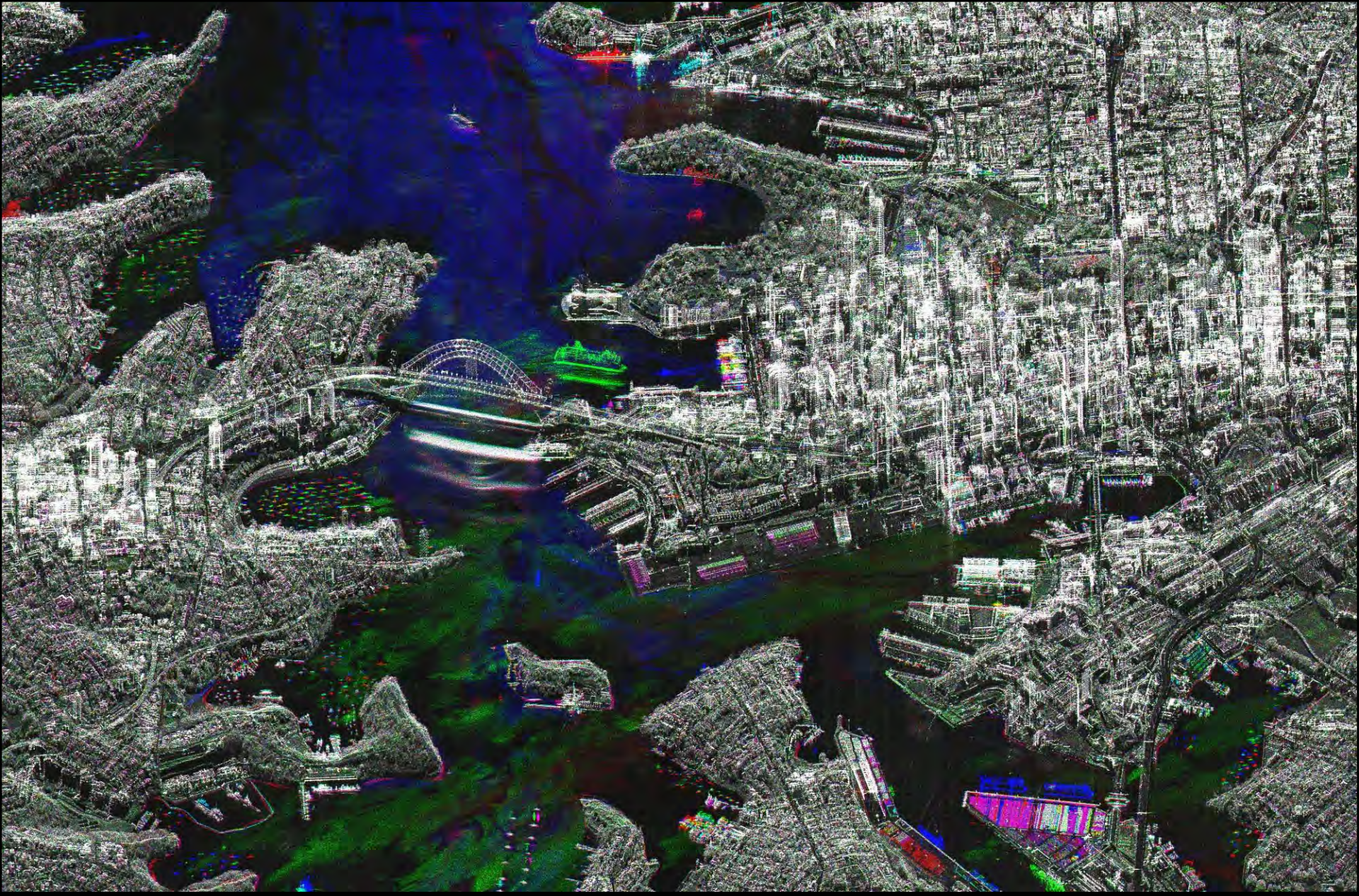
TERRASAR X

Image Quality of European SAR Satellites (Year 2000)

ca. 10 m × 20 m resolution

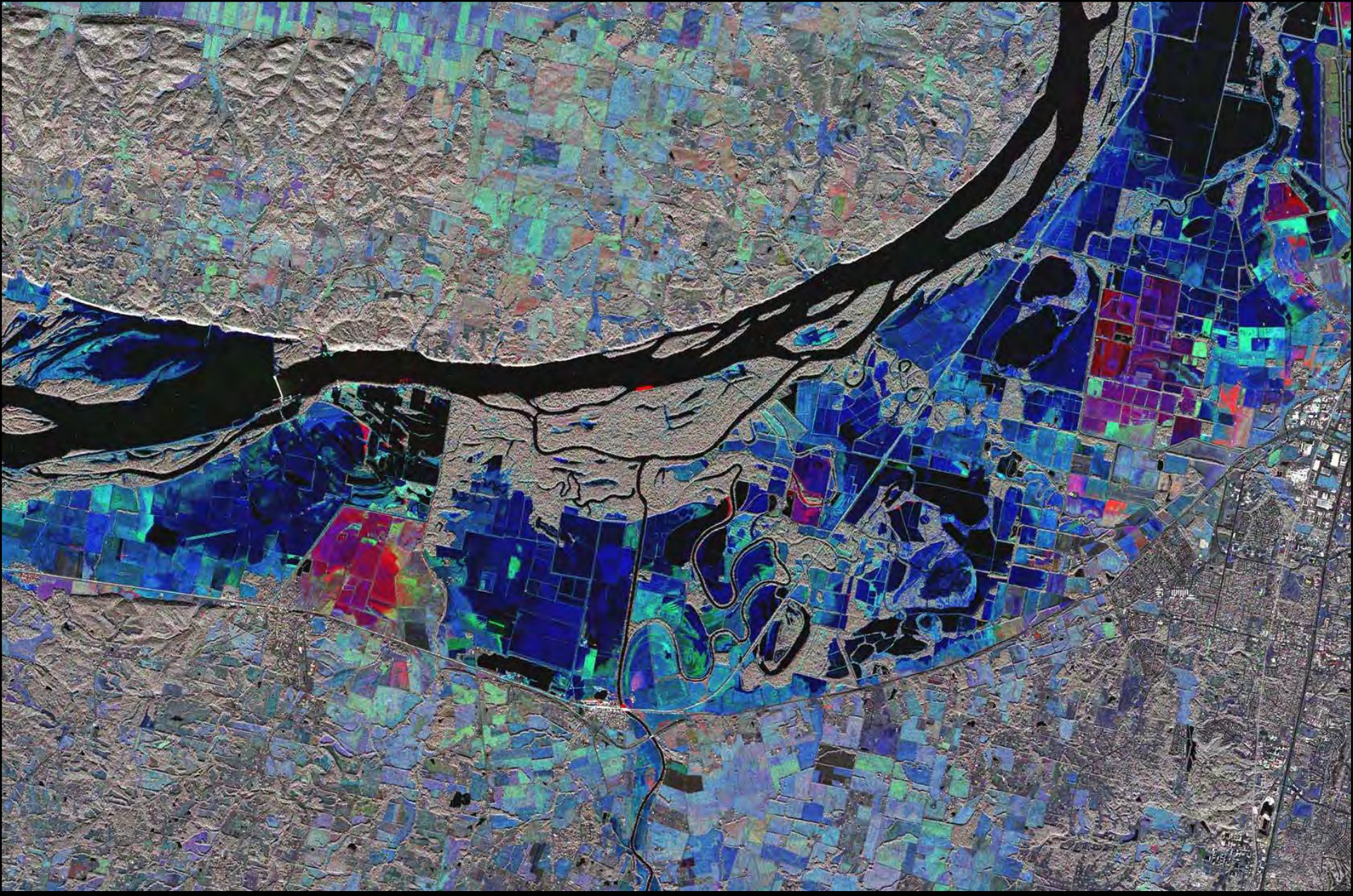



Pyramids of
Giza, Egypt
TERRASAR X



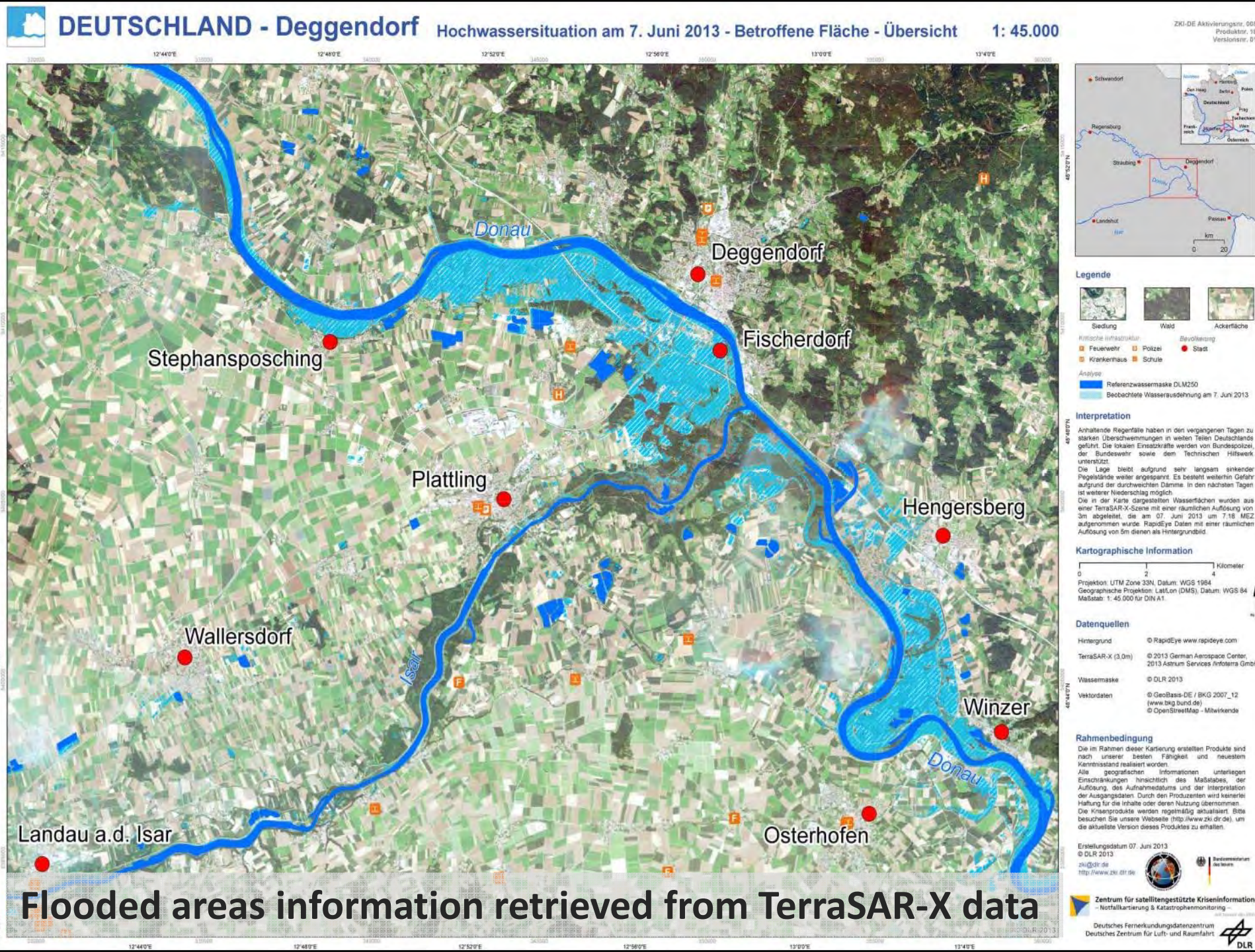
Sydney, Australia, multi-temporal

TERRA SAR X



Mississippi, USA - Flooding

TERRA SAR X



Flooded areas information retrieved from TerraSAR-X data

Disaster Monitoring

Deepwater Horizon
Gulf of Mexico
30 April 2010

Oil Platform

100 km (54 nmi)

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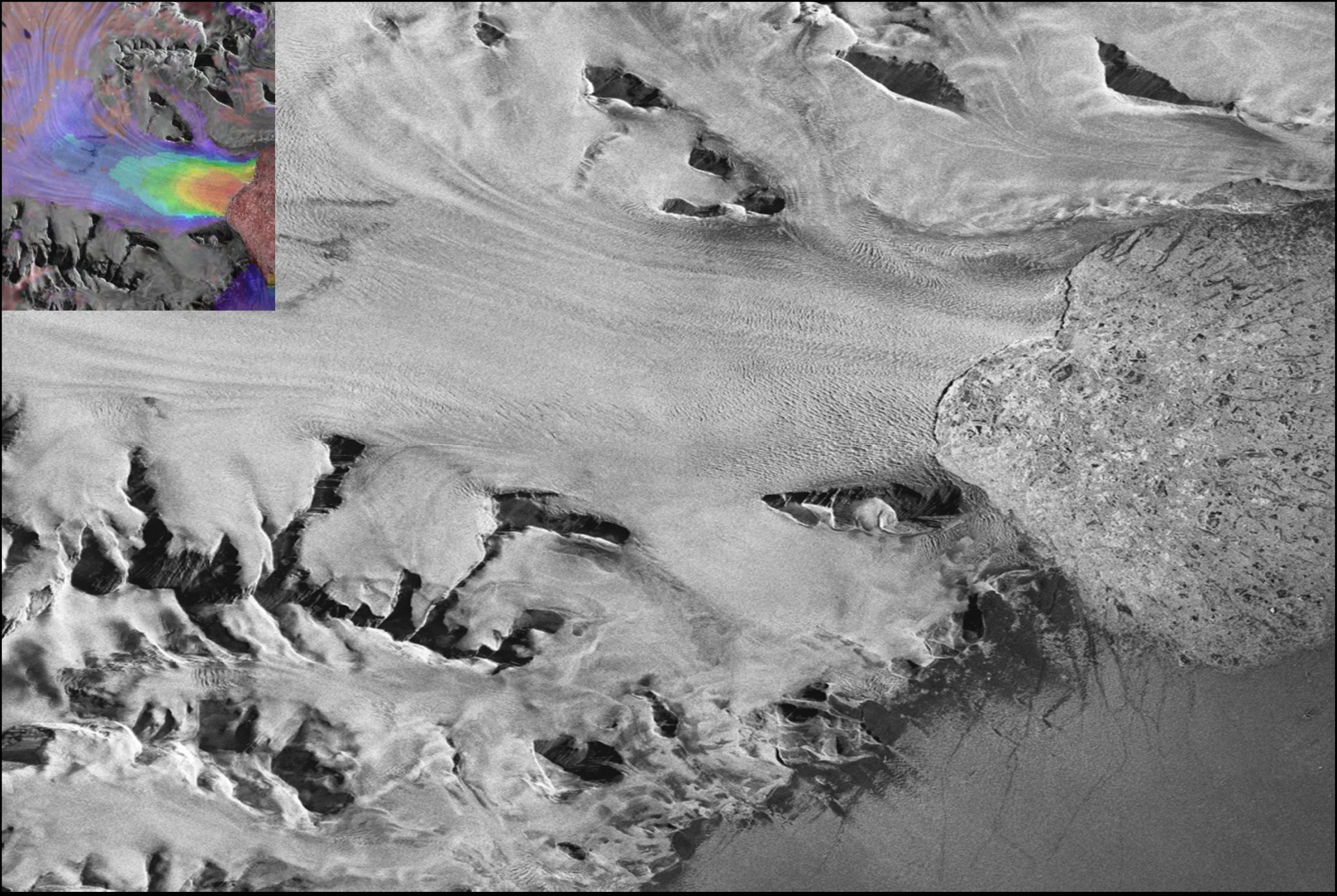
TERRA SAR X



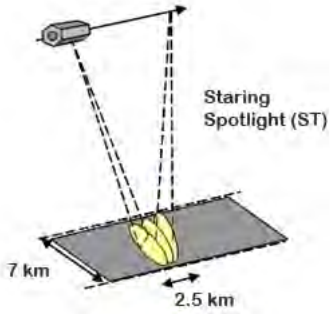
Drygalski Glacier, Oct 2007 – July 2008

TERRA SAR X

Las Vegas, USA (time series of 20 images)

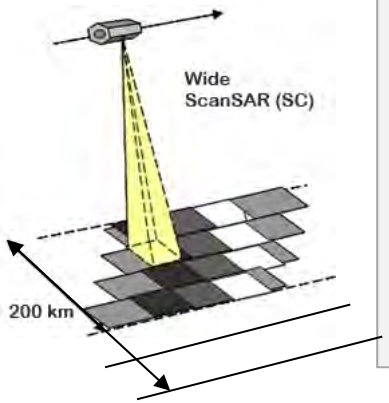
TERRA SAR X

TerraSAR-X: New SAR-Modes



Staring Spotlight Mode – Available October 2013

	Azimuth:	*Range:*
Resolution:	**0.24 m**	0.85…1.77 m
Scene Size:	2.1…2.7 km	7.5…4.6 km
Single Polarization (HH, VV)		



Wide ScanSAR Mode – Available August 2013

	Azimuth:	*Range:*
- Resolution:	40 m	6…10 m
- Scene Size:	200 km	**194…266 km**
- Single Polarization (HH, VV, HV/VH)		

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Staring Spotlight Mode

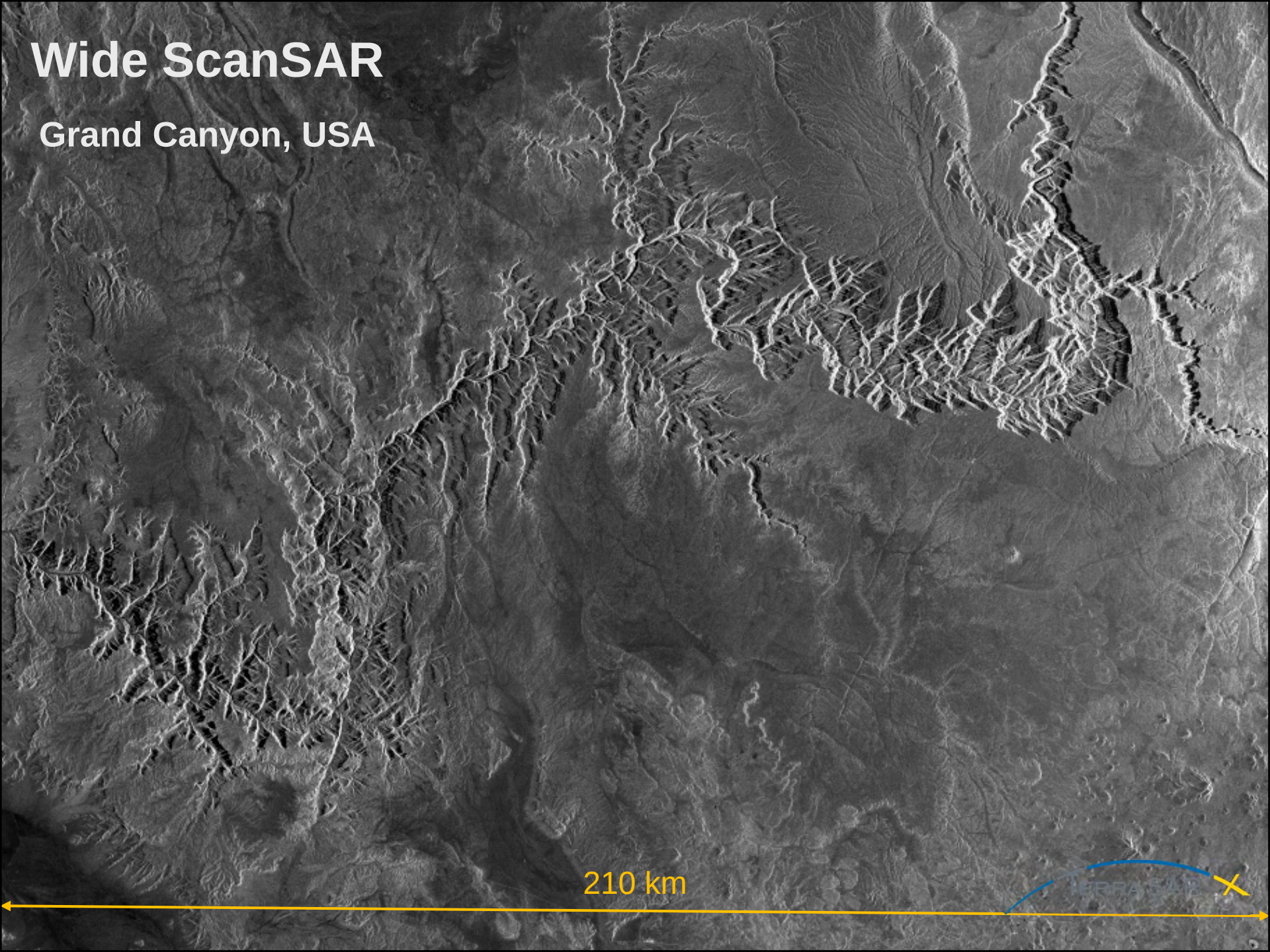
Spotlight Basic Product

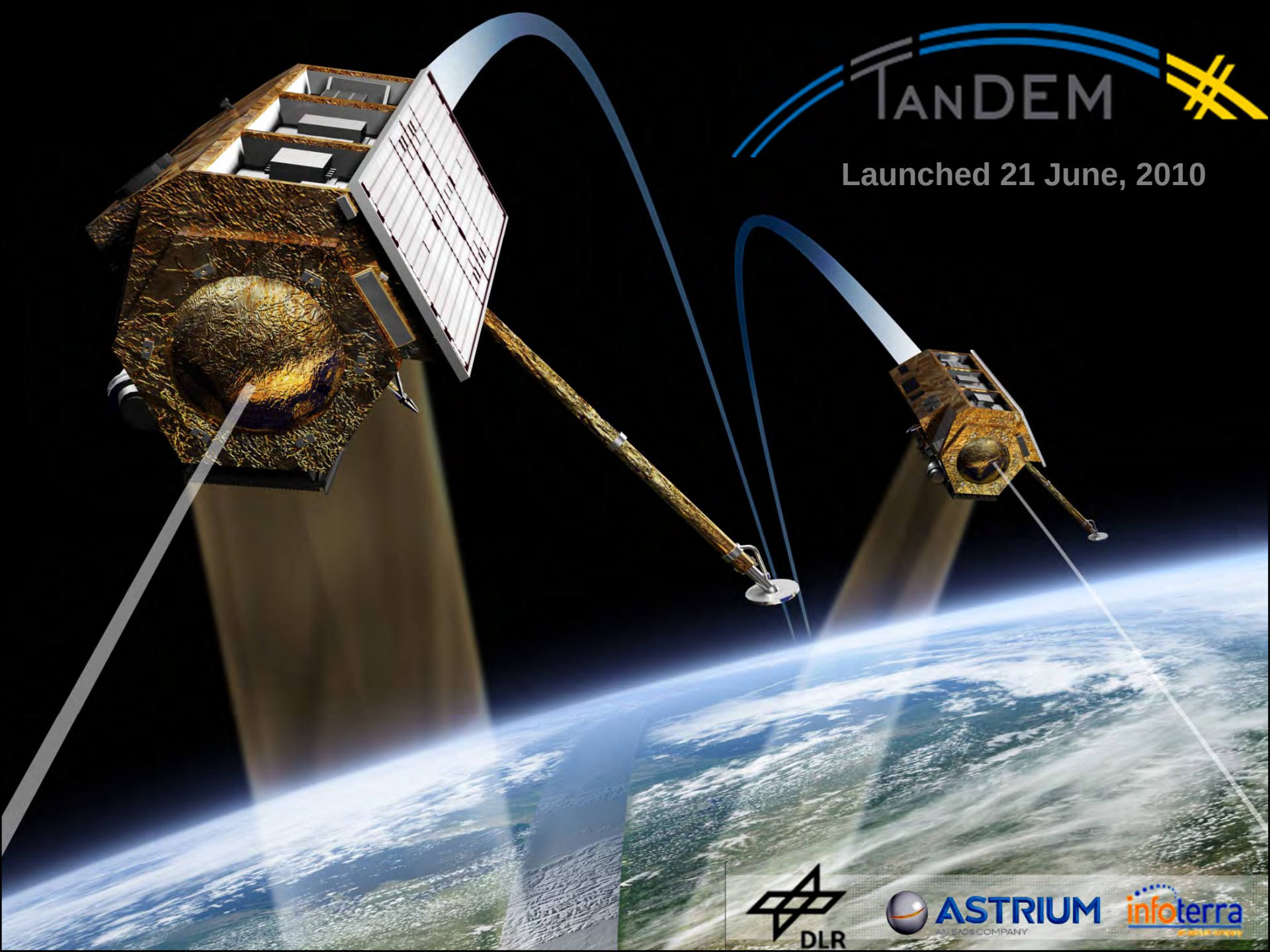
Staring Spotlight Product

improved radiometric resolution

Geometric Resolution: ~ 1 m × 1 m

TERRA SAR X


Wide ScanSAR
Grand Canyon, USA
210 km


TanDEM
Launched 21 June, 2010
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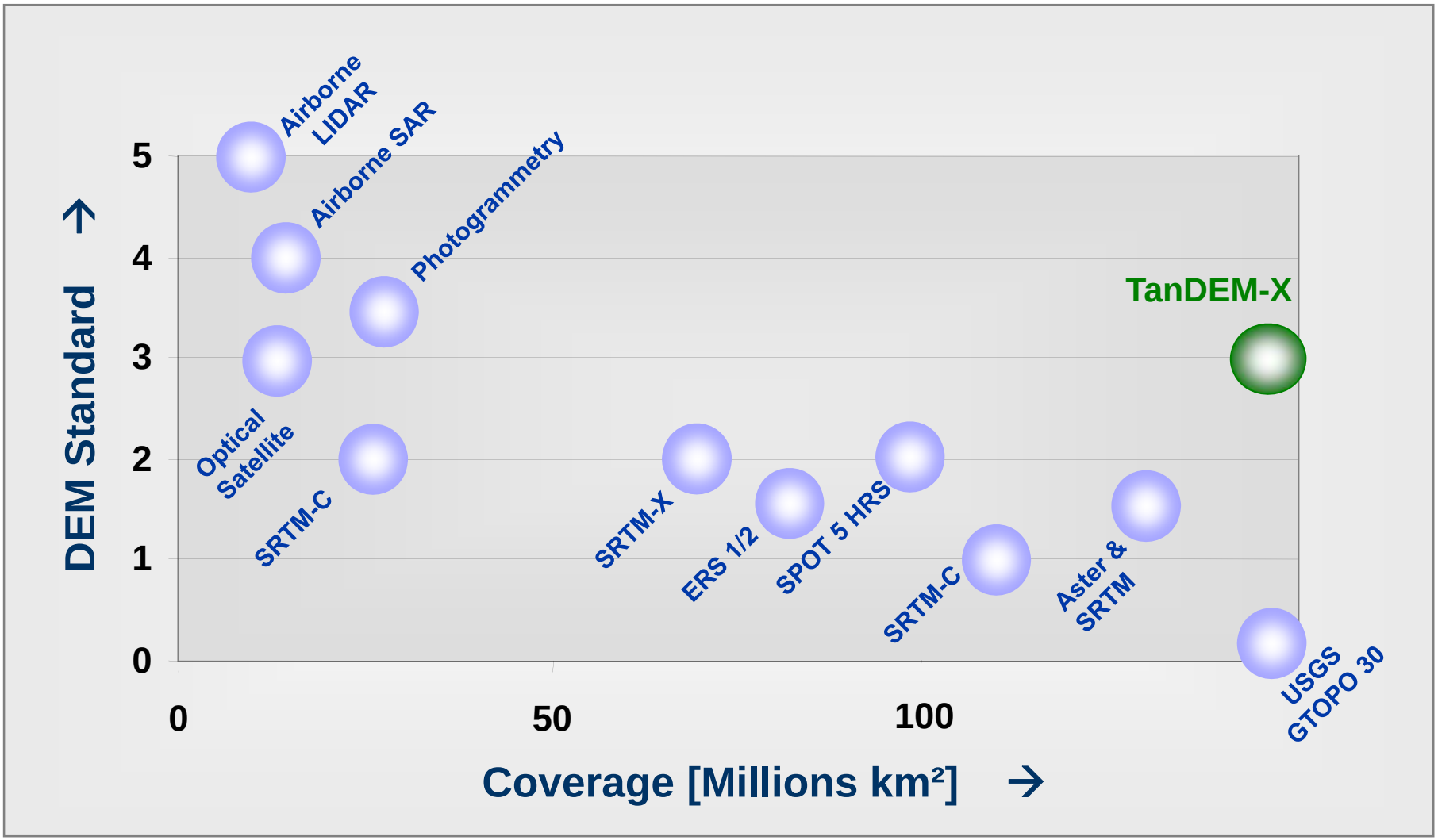
Standards for Digital Elevation Models (DEM)



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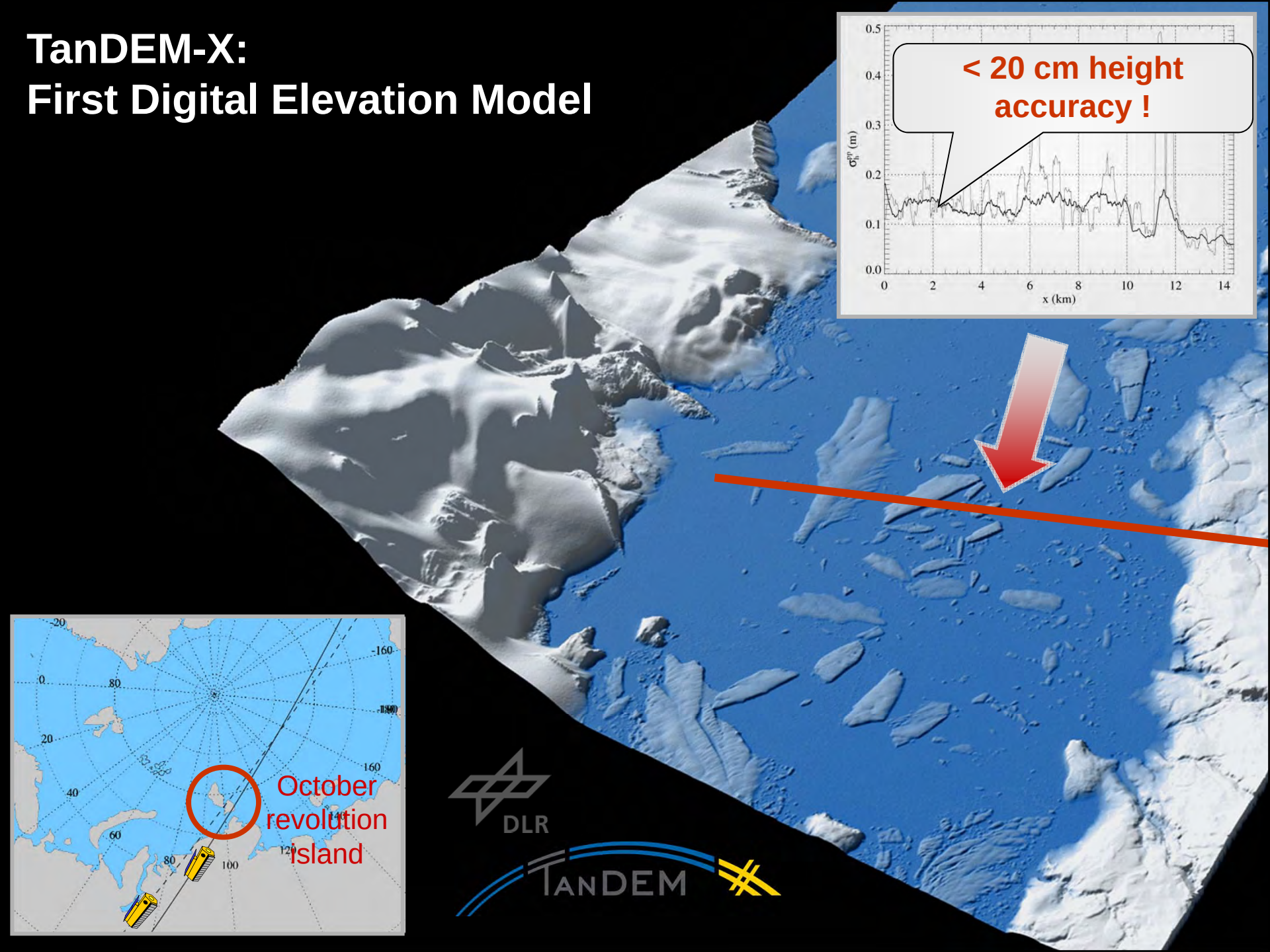
Madagascar
24.06. 2010 14:55:44

TanDEM-X:
First Digital Elevation Model



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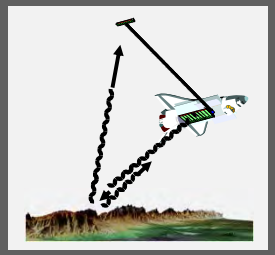
TanDEM

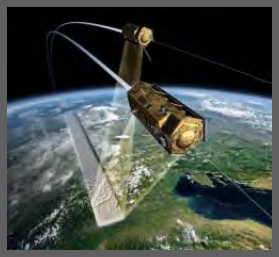

TanDEM

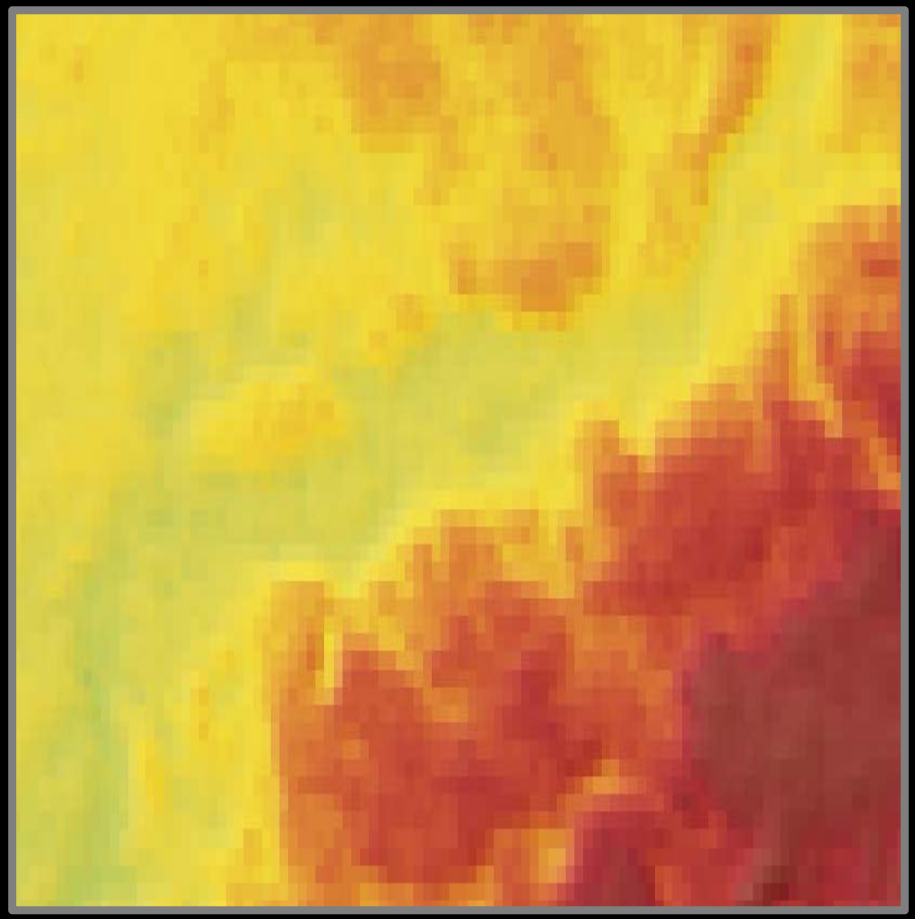
DEM Performance Comparison

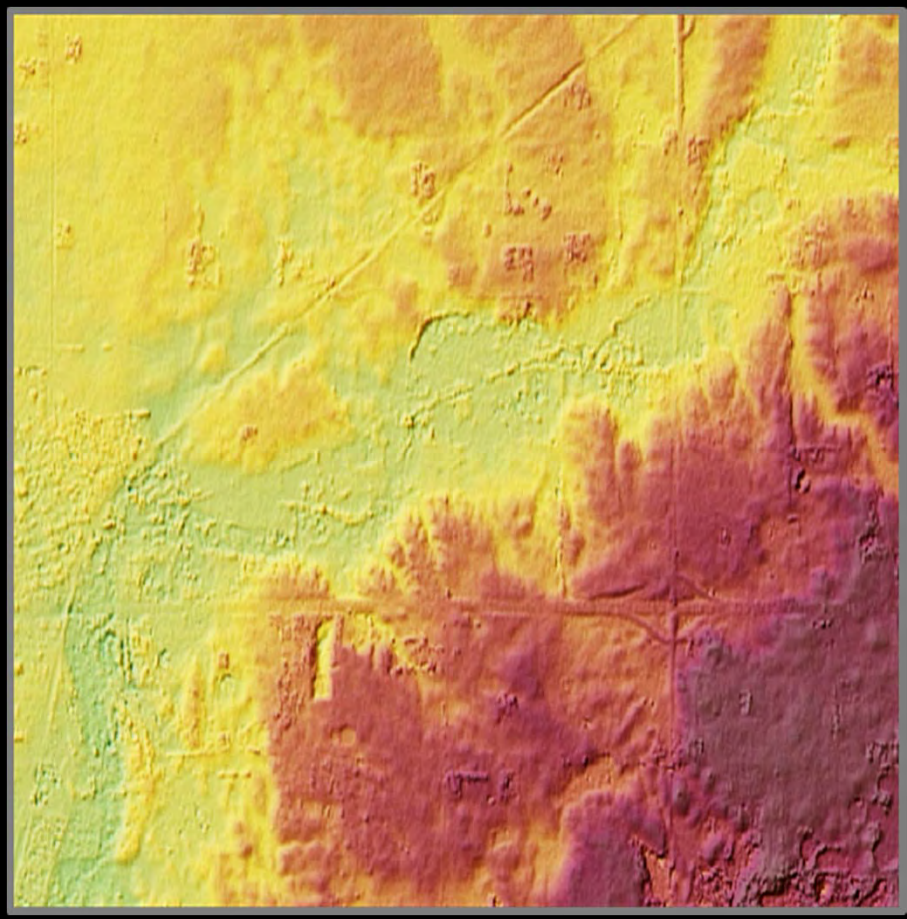


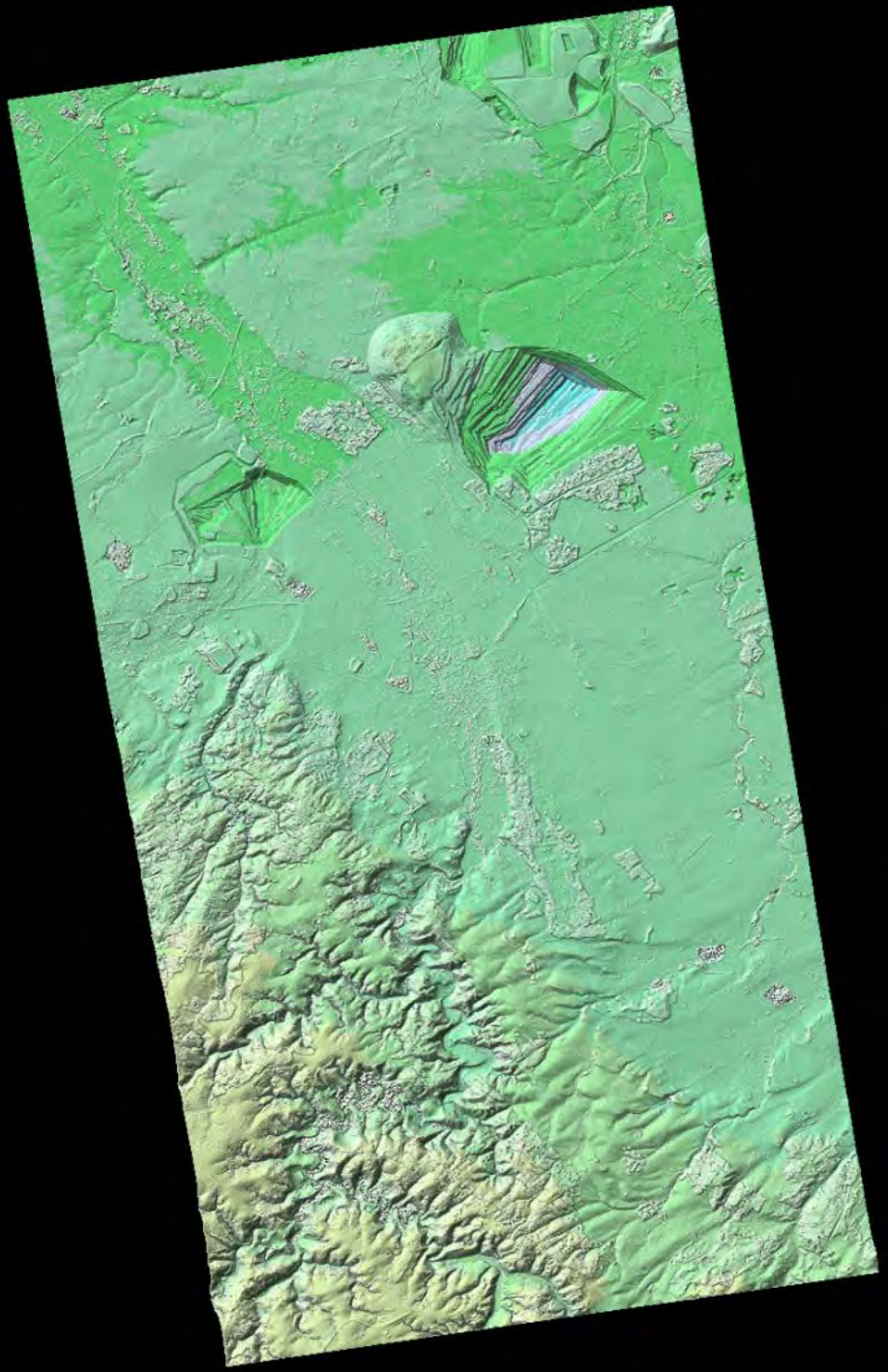
SRTM (2000)

TanDEM-X (2013)

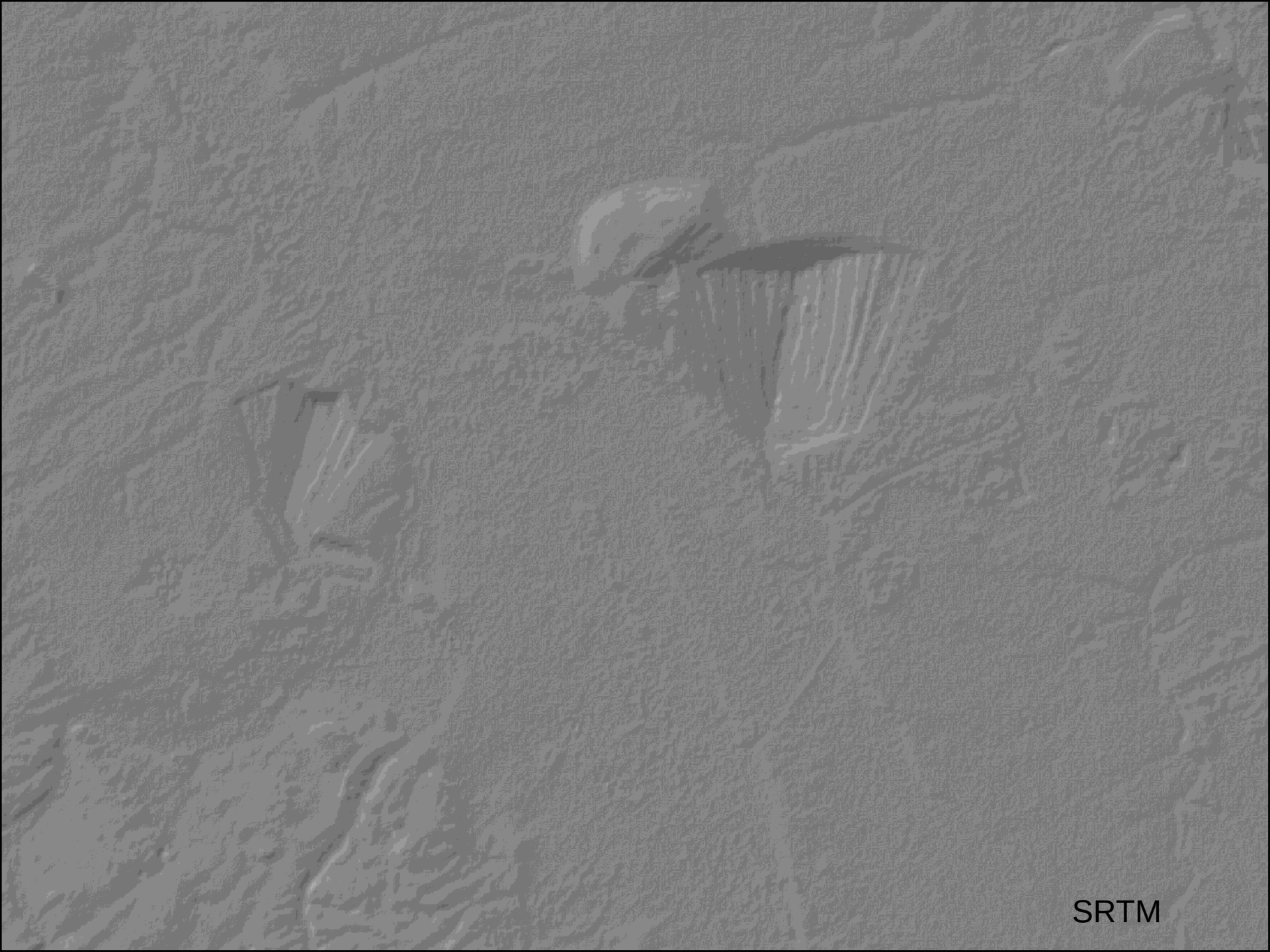


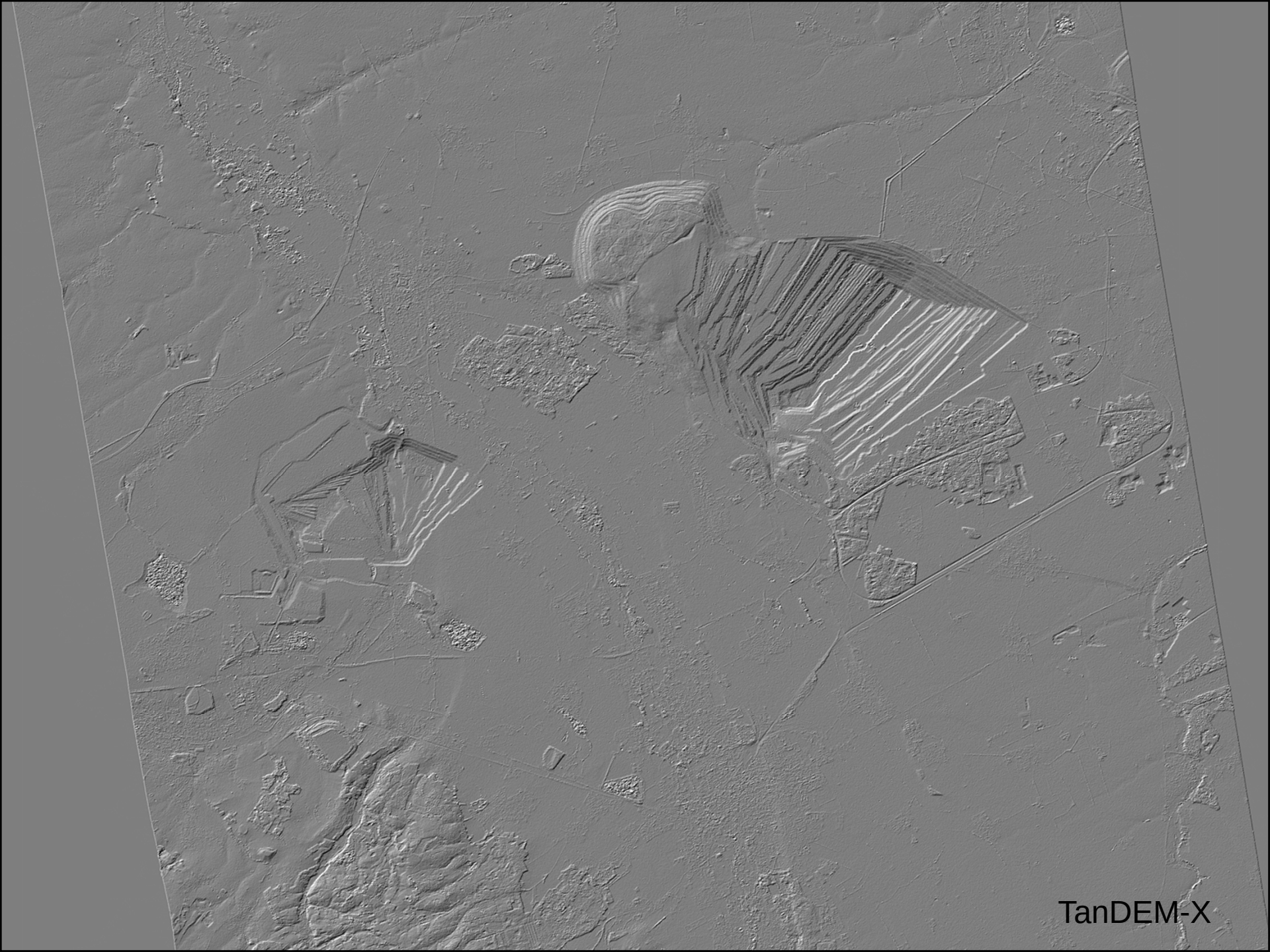


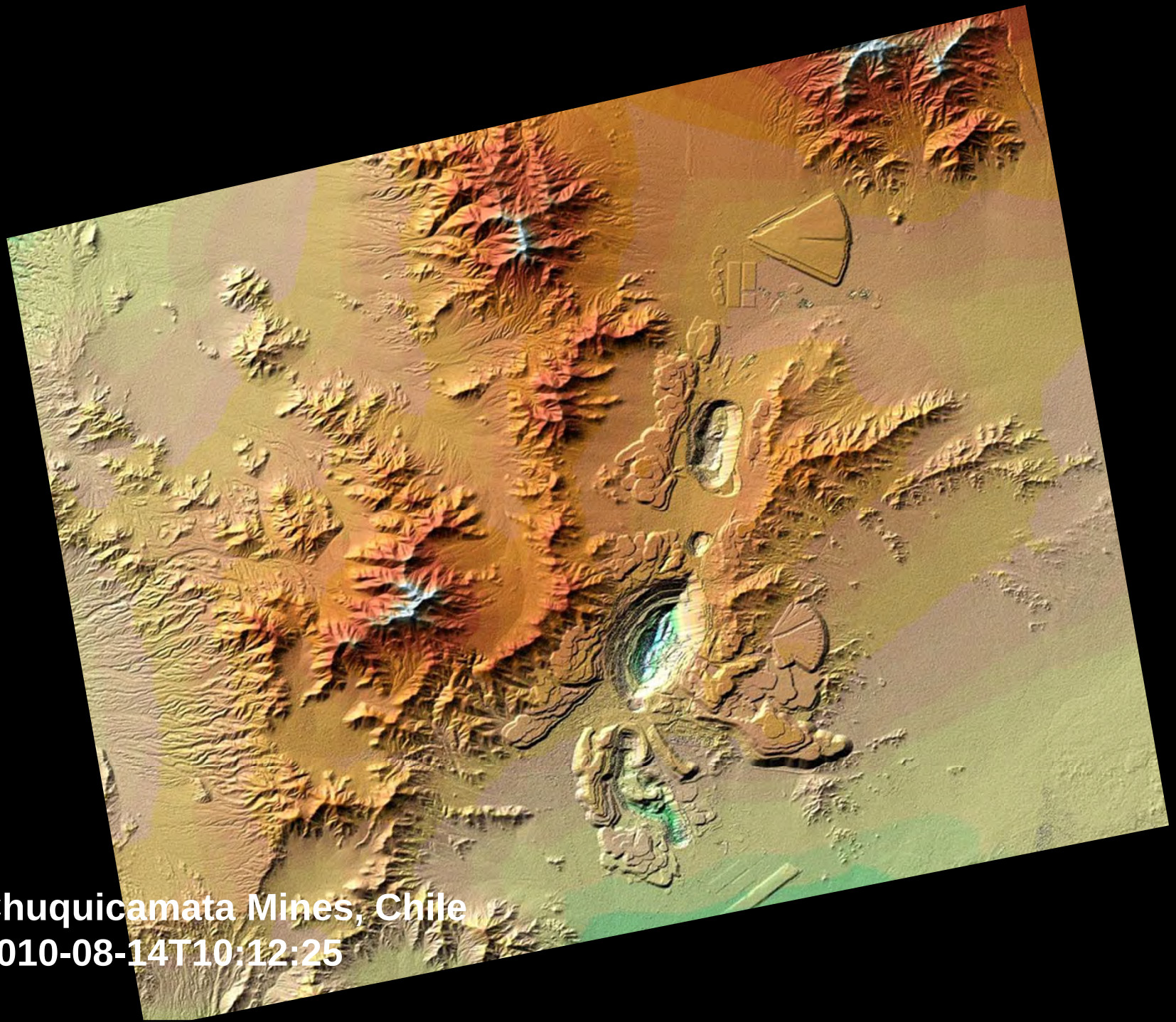




TanDEM-X Digital Elevation Model
Brown Coal Mining
Hambach, Germany


SRTM

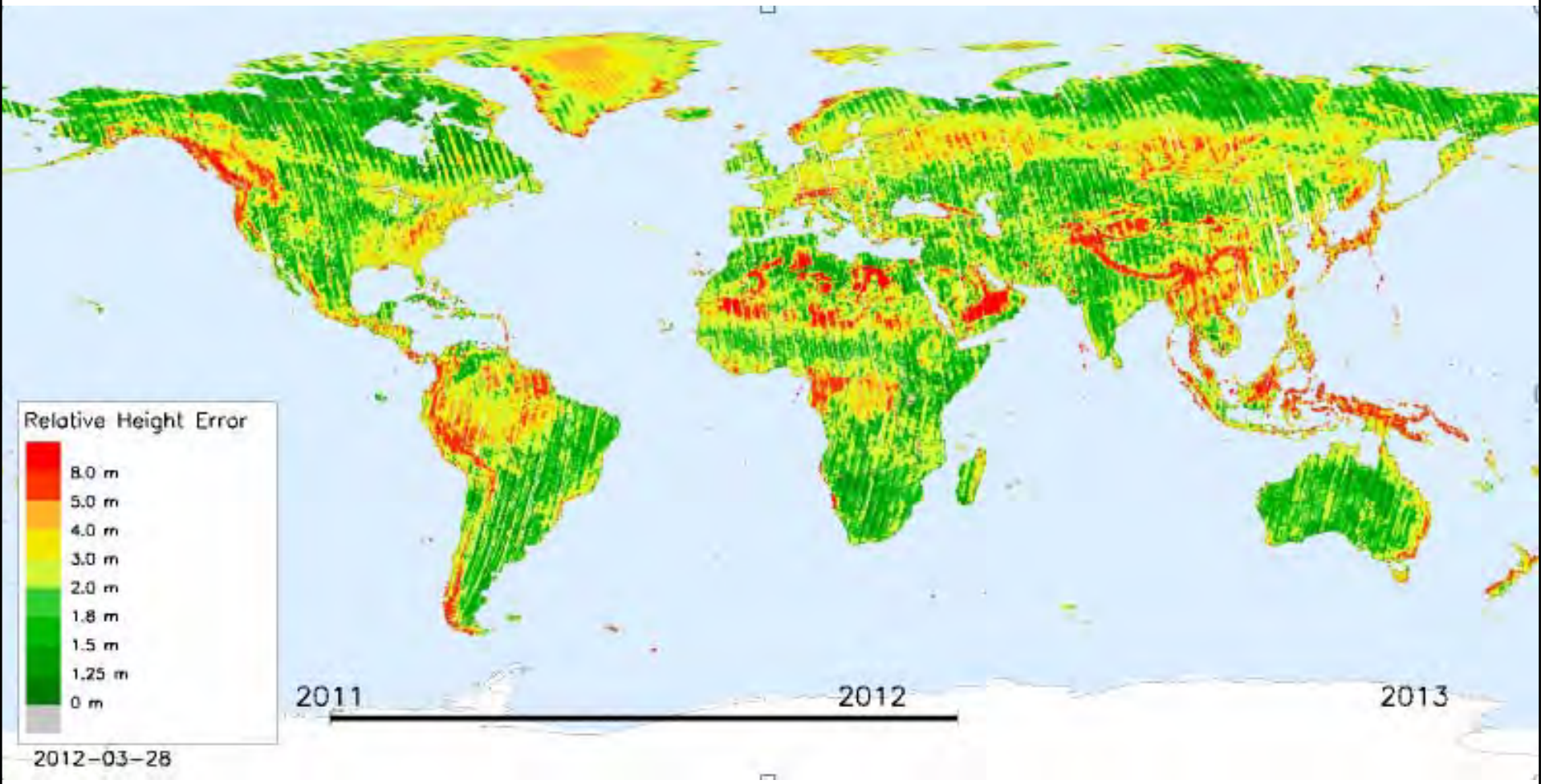

TanDEM-X



Chuquicamata Mines, Chile
2010-08-14T10:12:25

Iceland

Relative Height Error - First Coverage



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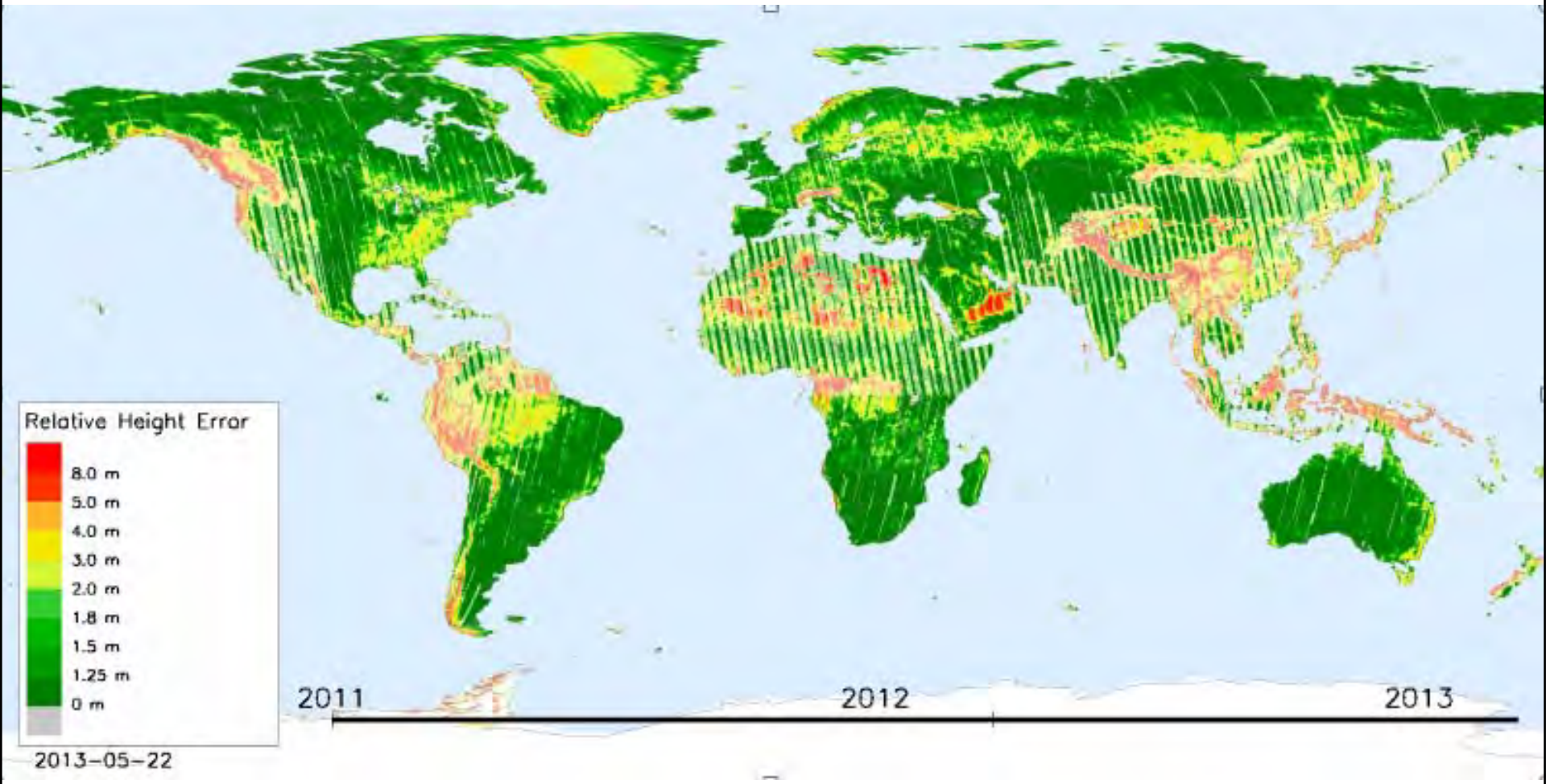
Relative Height Error - Second Coverage



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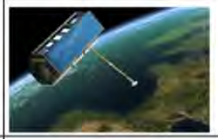
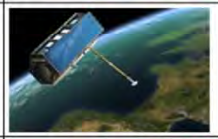
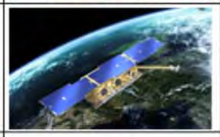
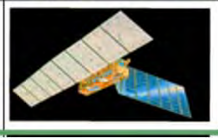
Terra Sar X & Tandem X, 28 Nov 2010; 17:01:22.30 - 17:01:32.35 UTC
Canon EOS 450D + EF 50/2.5 Macro @ F2.8, 800 ISO, 10.05s
Marco Langbroek, SatTrackCam Leiden (Cospar 4353)

Future SAR Systems

SAR Roadmap (X-Band)

Mission	Satellite	2006	2008	2010	2012	2014	2016	2018	2020	2022
TerraSAR-X										
TanDEM-X										
PAZ (Spain)										
TerraSAR-NG (WorldSAR)										
HRWS										

TerraSAR-NG – TerraSAR Next Generation

HRWS – High Resolution Wide Swath

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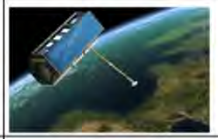
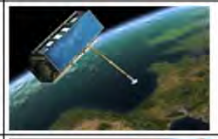
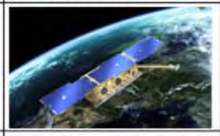
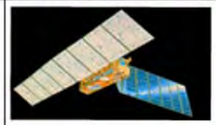
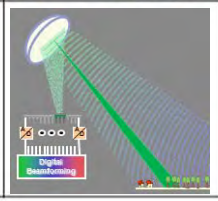
SAR Roadmap (X-Band und L-Band)

Mission	Satellite	2006	2008	2010	2012	2014	2016	2018	2020	2022
TerraSAR-X										
TanDEM-X										
PAZ (Spain)										
TerraSAR-NG (WorldSAR)										
HRWS										
Tandem-L										
Technology Line 2 multi-static, digital beamforming with reflector, new techniques										

Digital beamforming with reflector

Multi-static SAR, formation flight

Innovative techniques (polarimetric SAR interferometry, tomography)

future generation missions with focus on global monitoring and Earth dynamic processes

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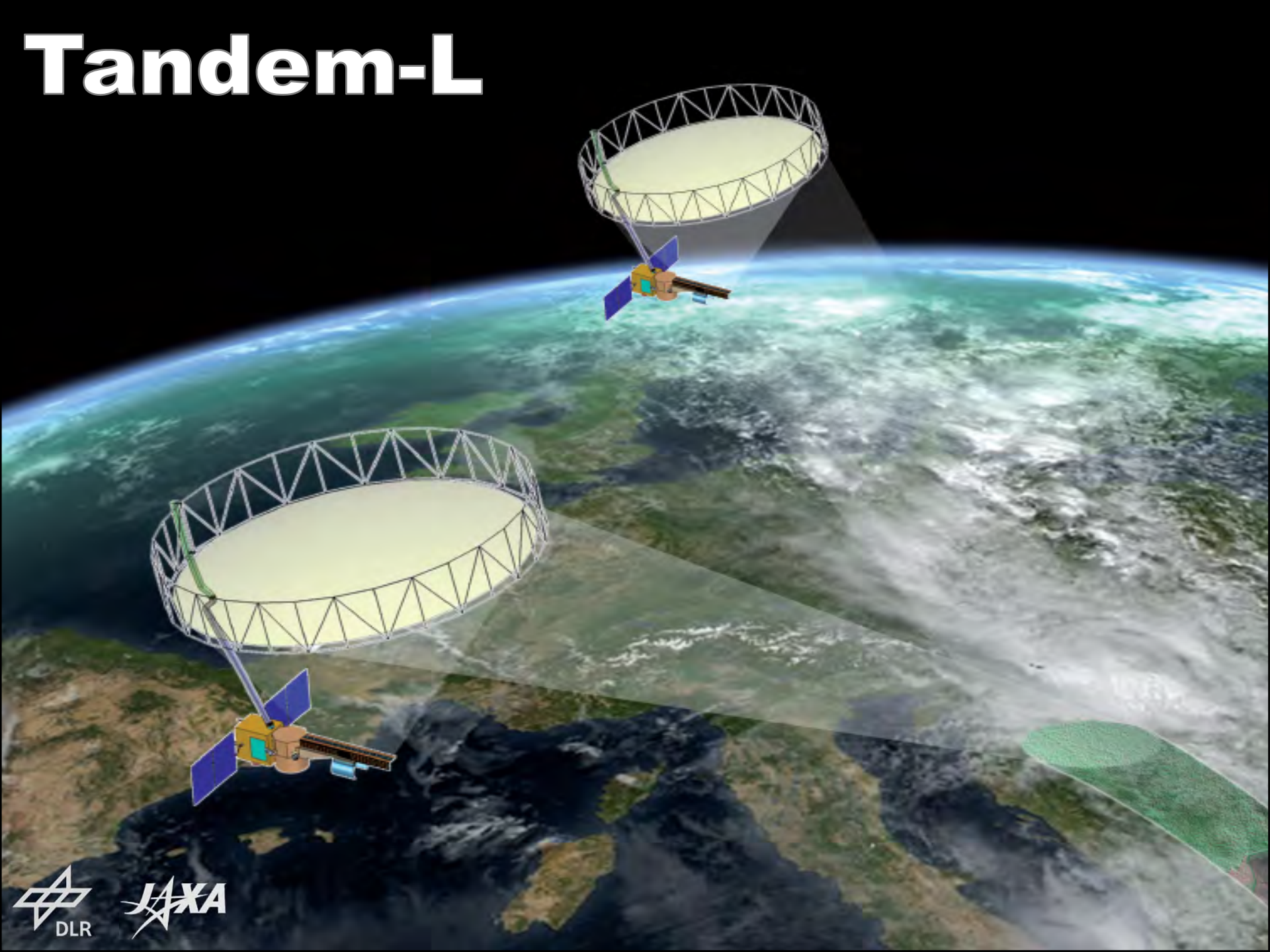
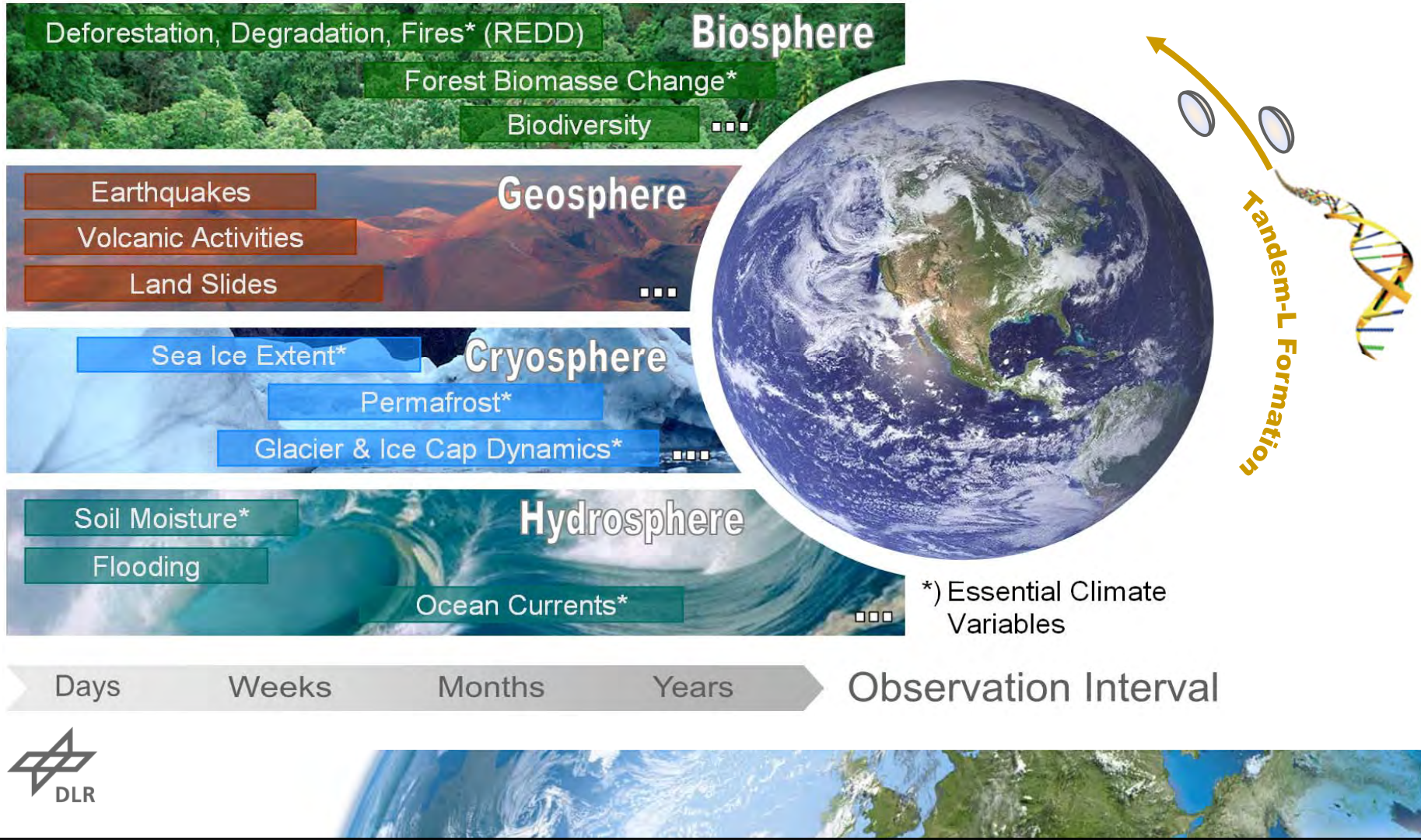

Tandem-L
DLR
JAXA

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



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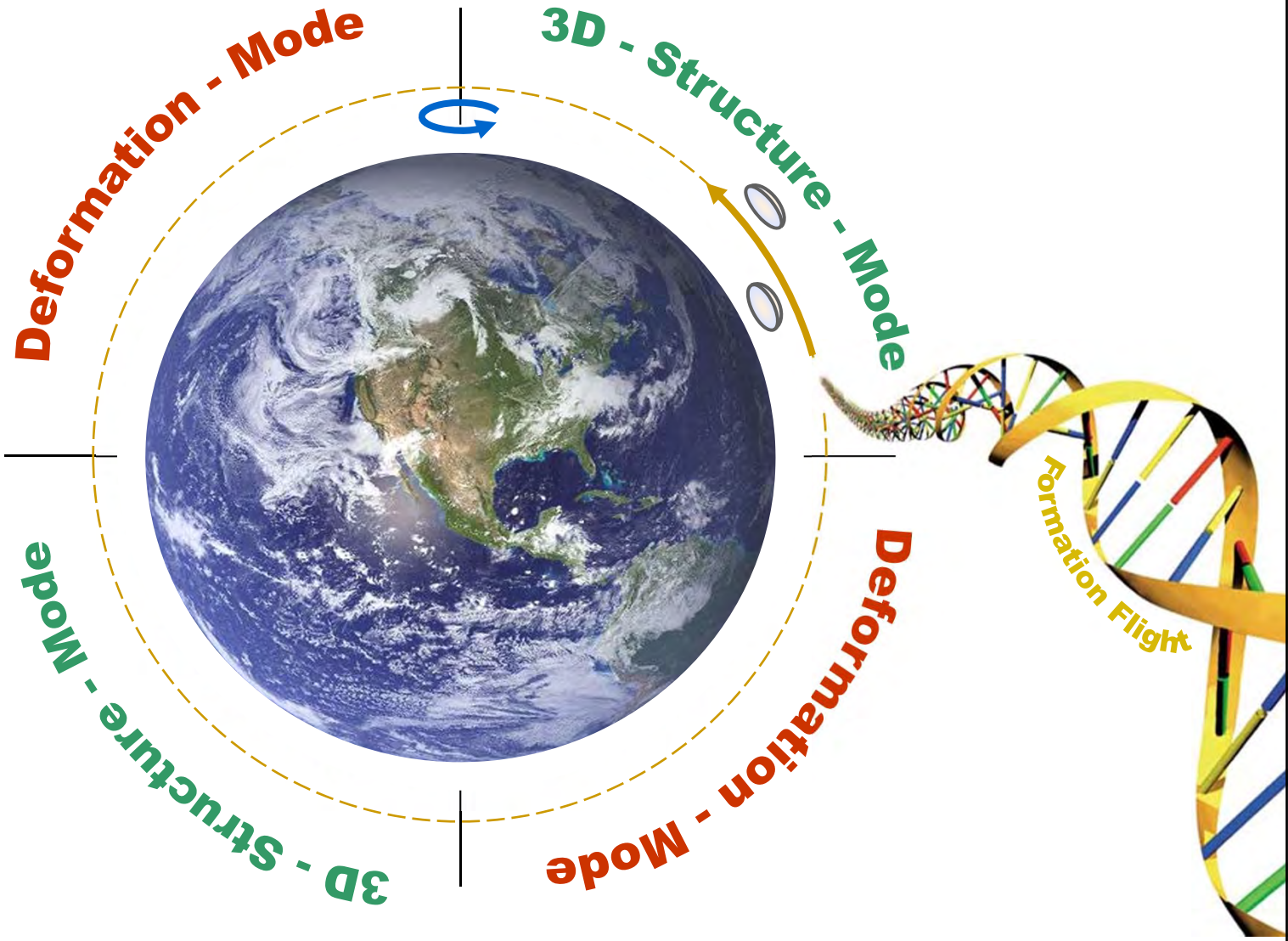
Mission Concept



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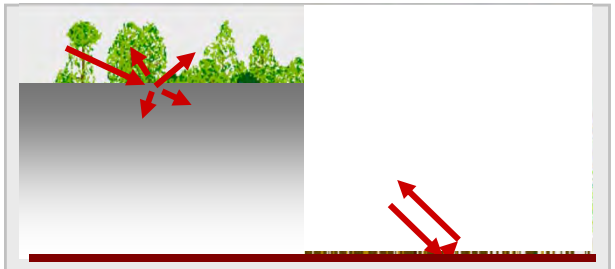
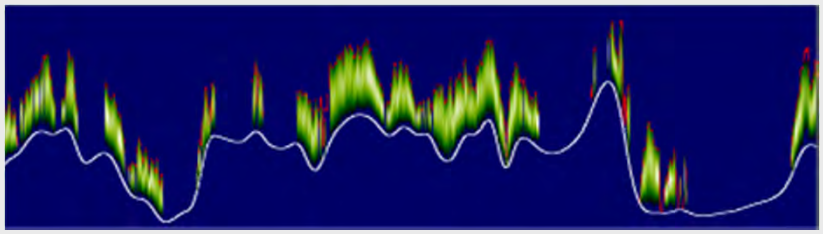
3-D Structure Mode

Polarimetric Backscattering



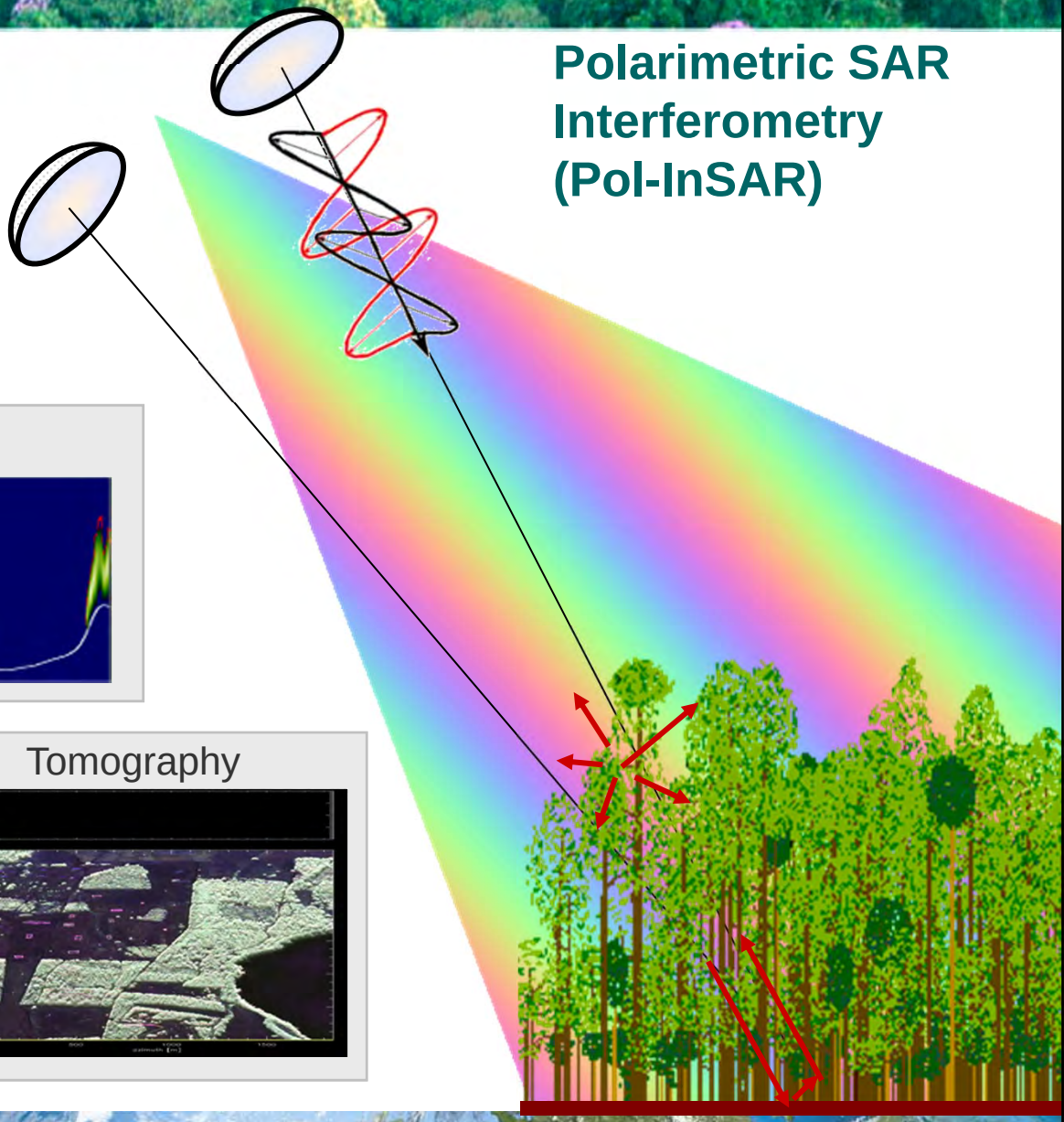
3-D Forest Structure



Forest height and Biomass

Tomography

Polarimetric SAR Interferometry (Pol-InSAR)



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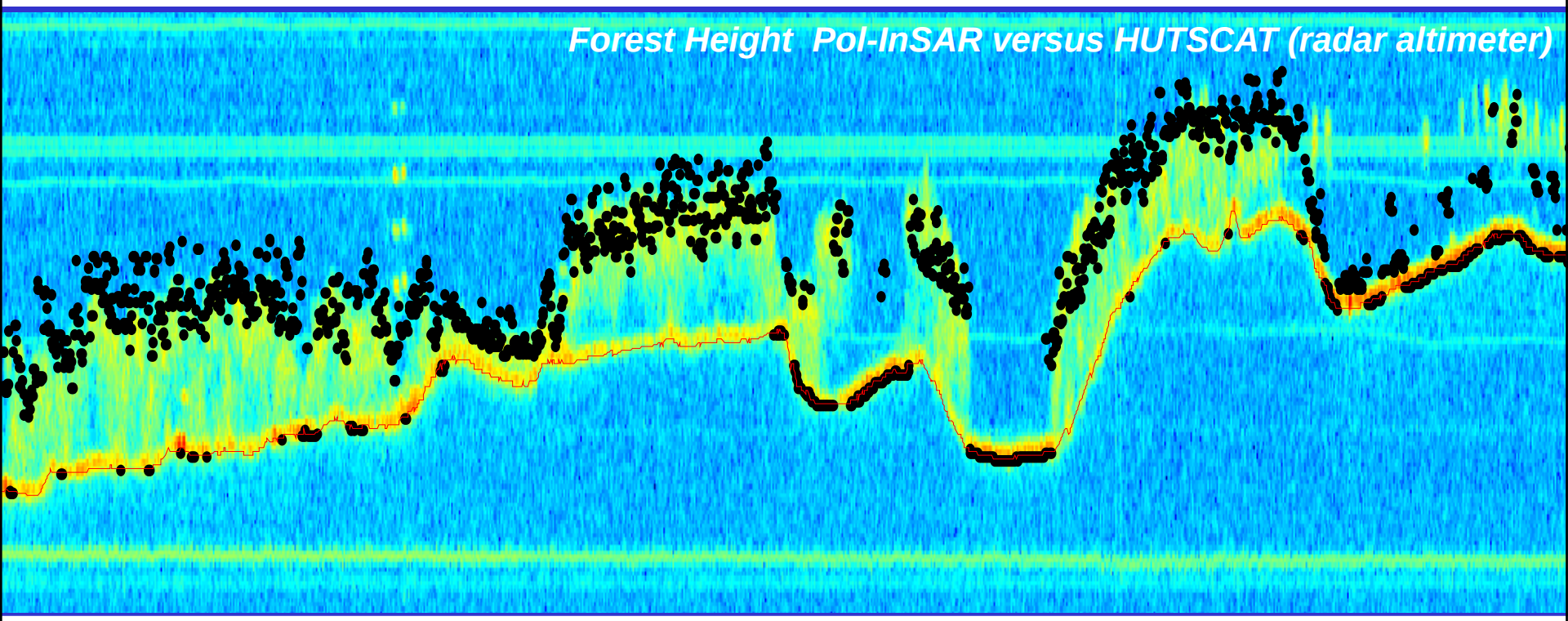
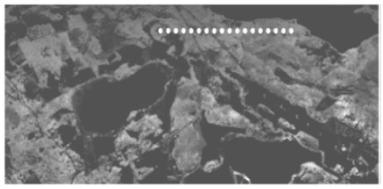
Validation of the Tree Height





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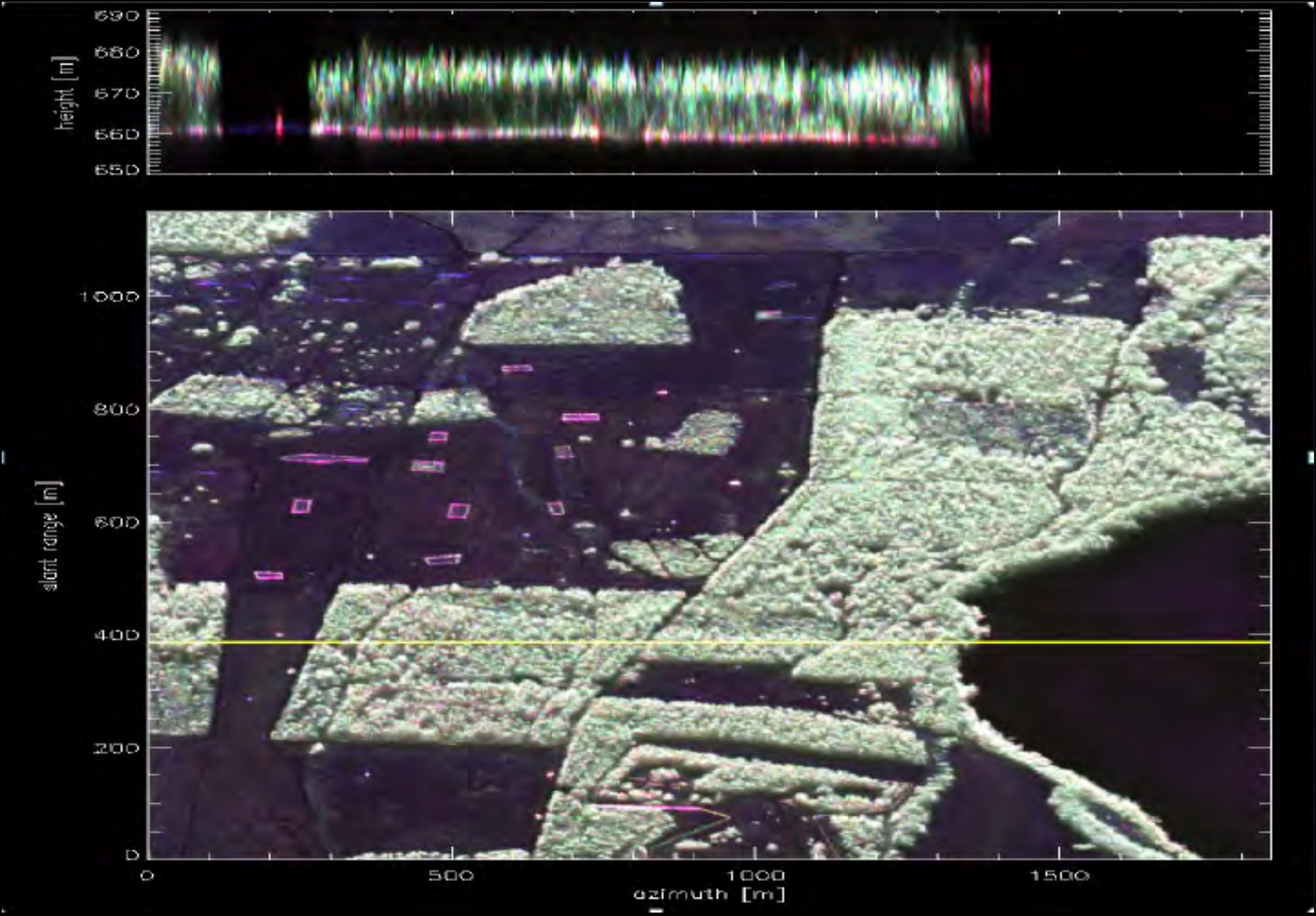
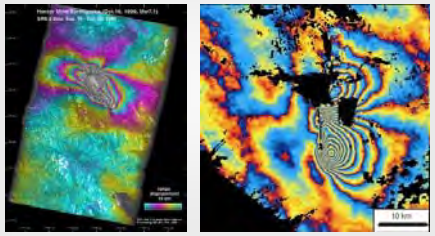


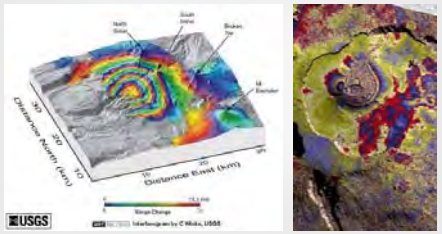
SAR Tomography, L-Band

Deformation Mode

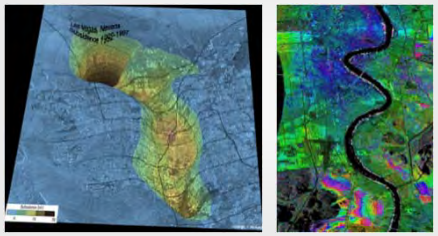
Earthquakes



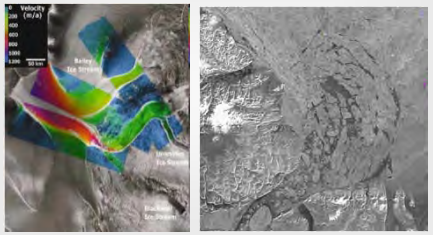
Volcanoes



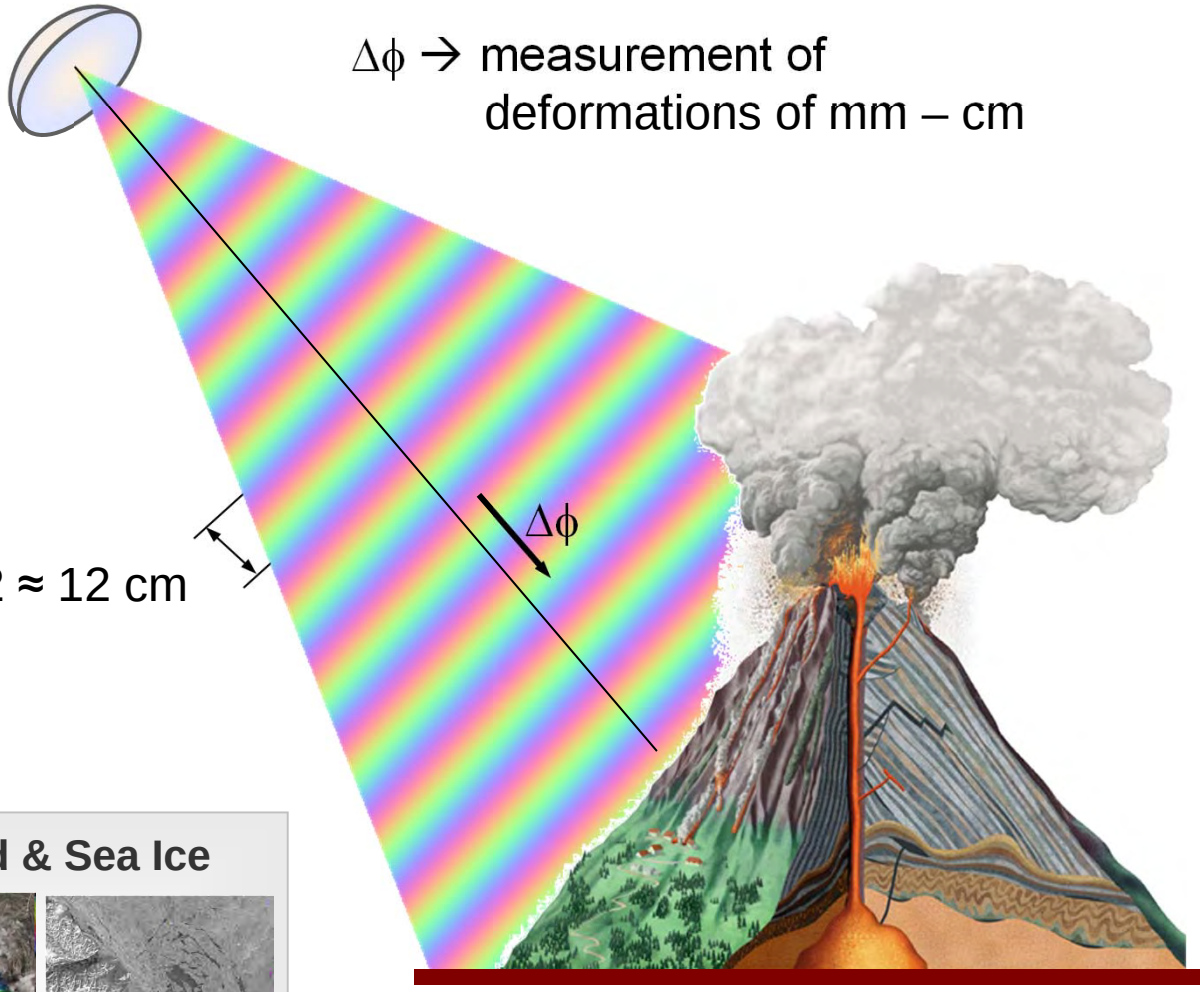
Subsidence



Land & Sea Ice



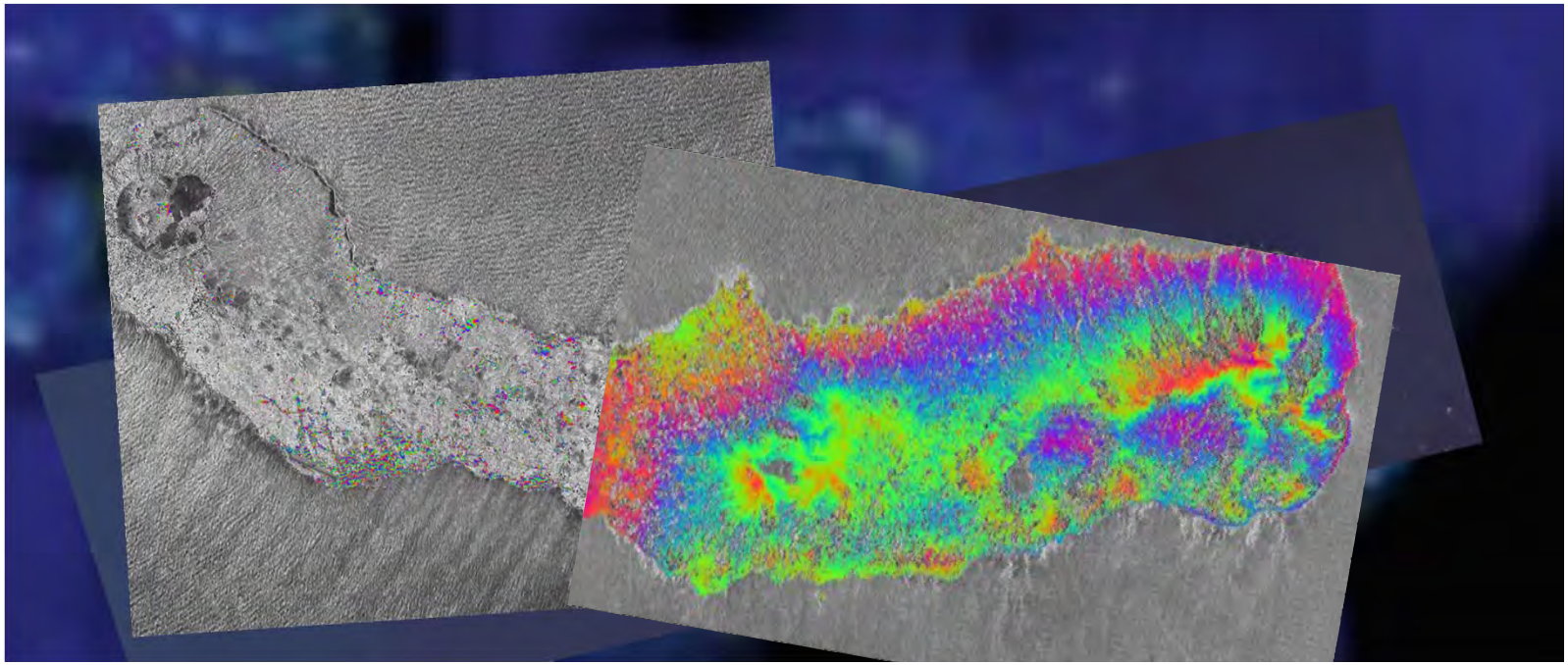
$\Delta\phi$ → measurement of deformations of mm – cm



systematic multi-temporal acquisitions (image stacks)

DLR

Vulcano Fogo, Sao Miguel, Azores



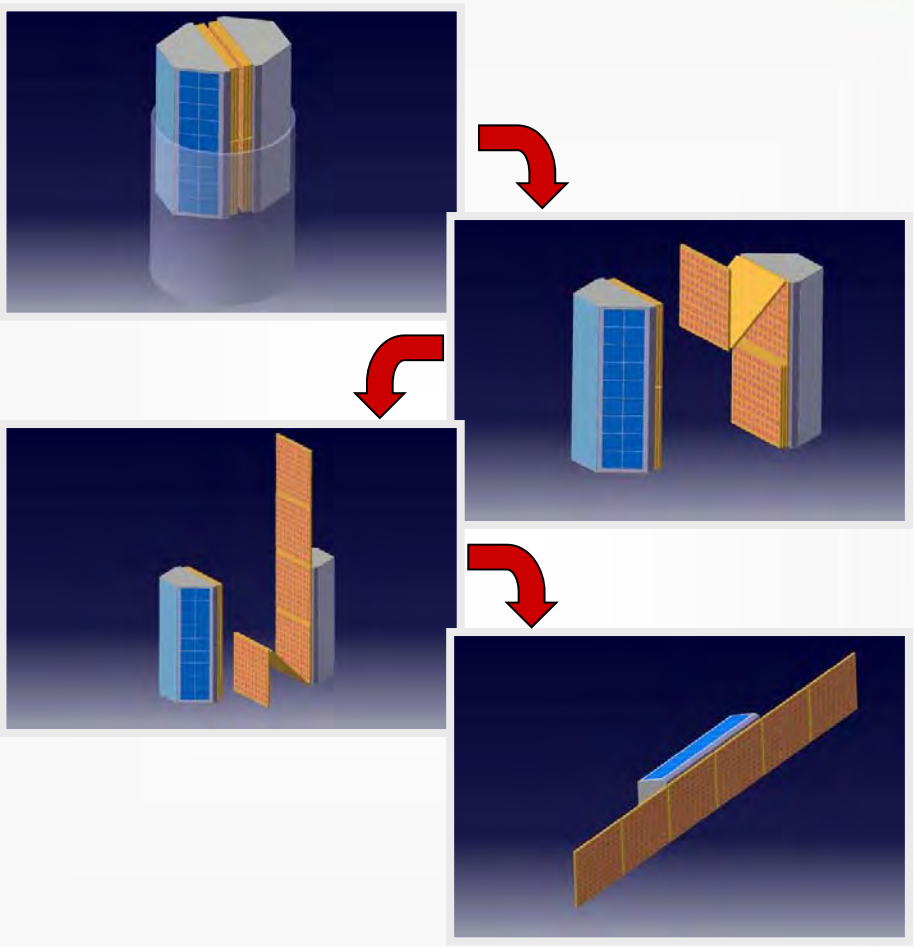
TerraSAR-X
Time interval = 22 days

ALOS (L-Band)
Time interval = 46 days

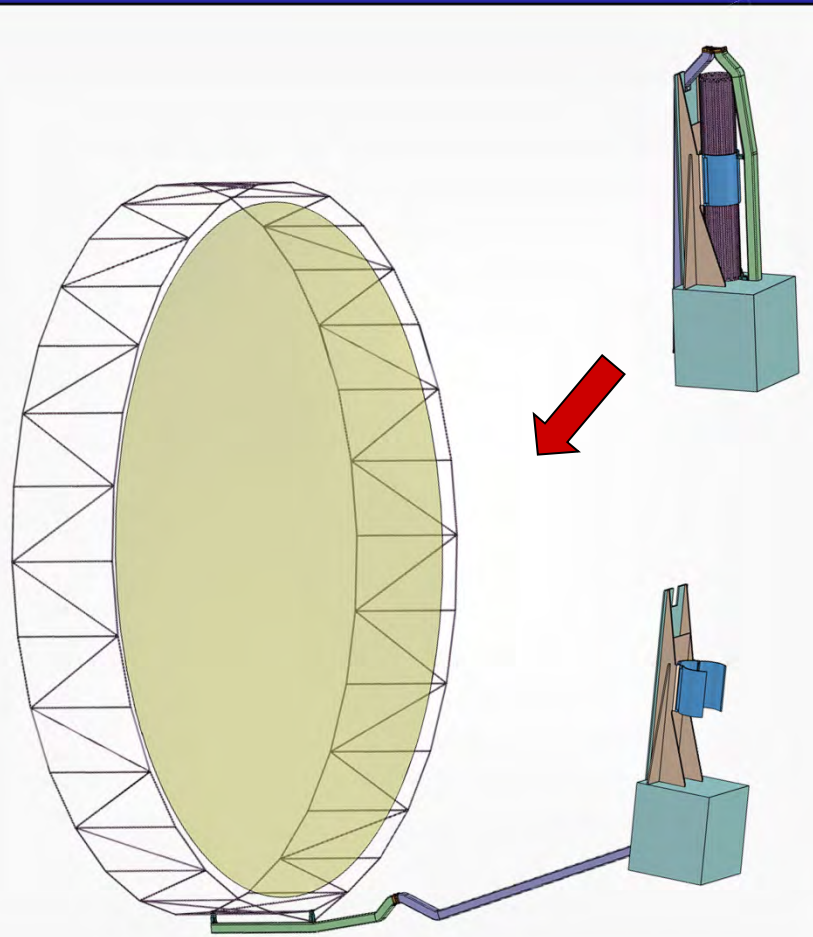
DLR

Possible Radar System Concepts for Tandem-L…

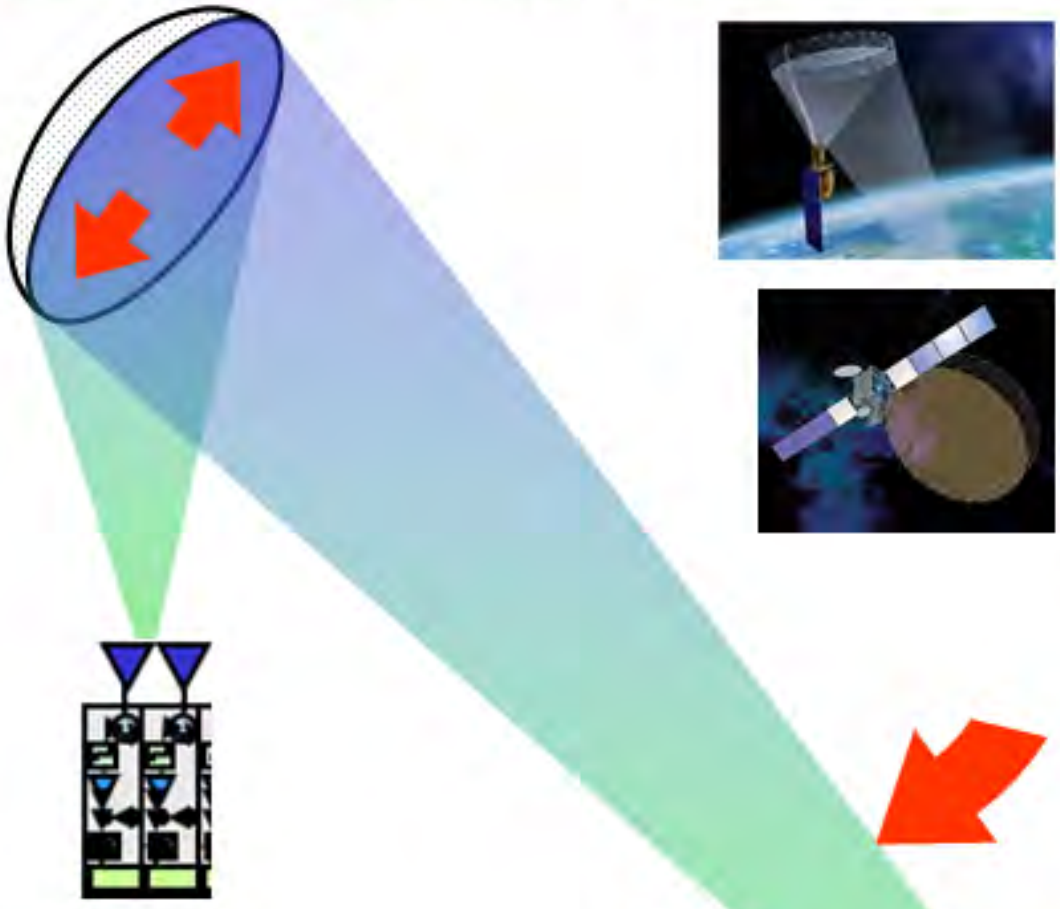
Planar Array with Digital Beamforming

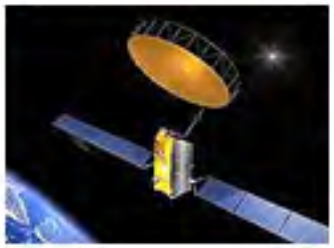


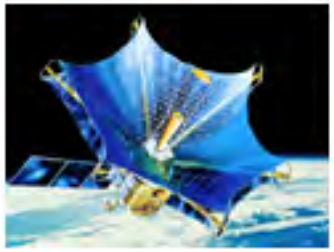
Reflector with Analog Beamforming

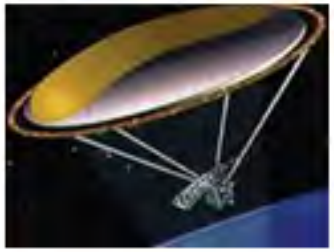


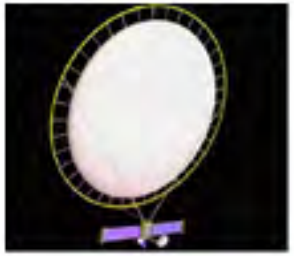
Deployable Reflector Antennas











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Digital Beamforming with Reflector Antennas

Digital Feed Array with T/R-Modules

DLR

Digital Beamforming with Reflector Antennas

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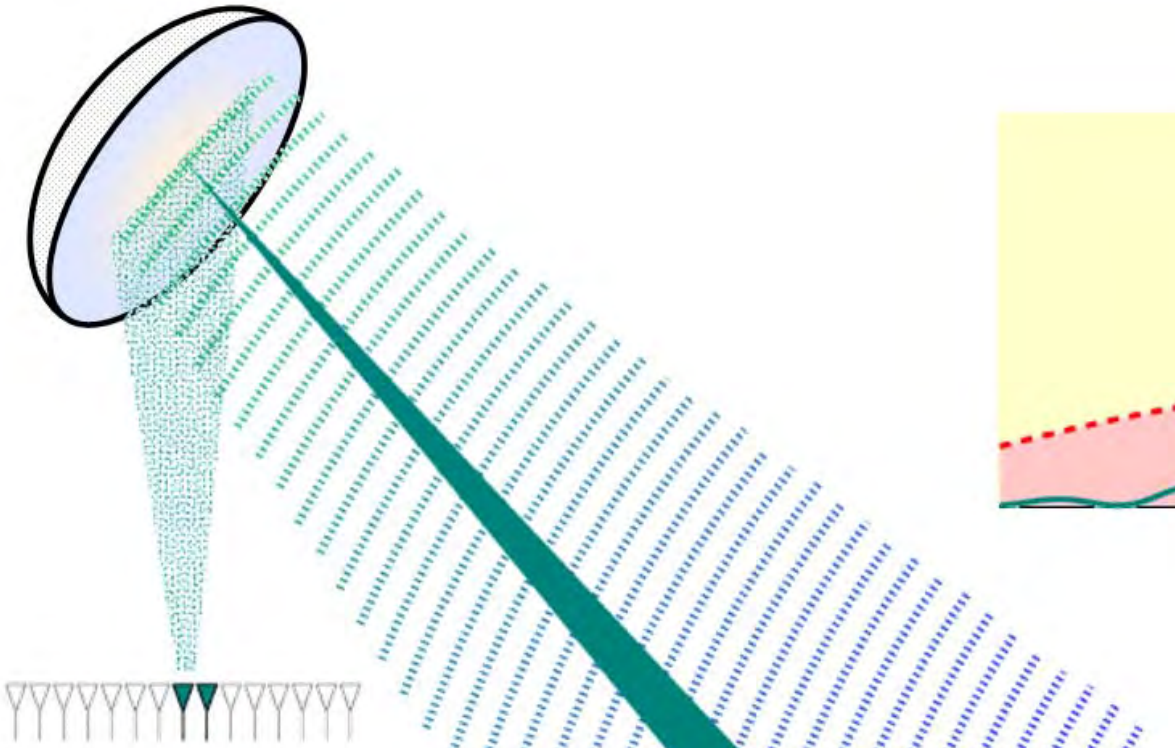
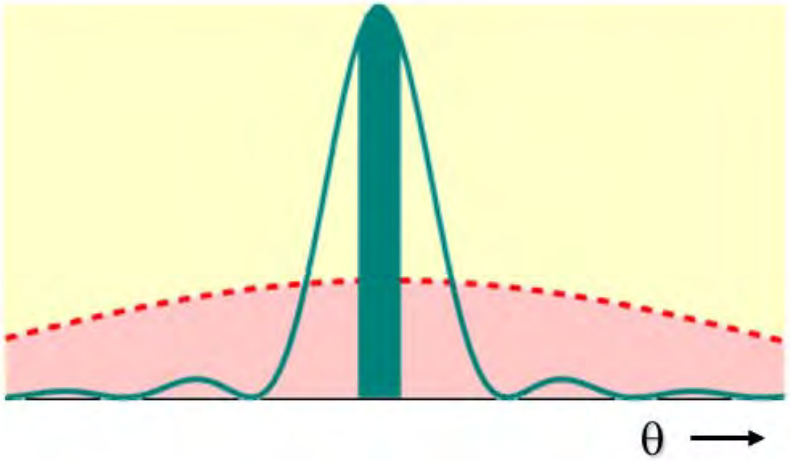
Digital Beamforming with Reflector Antennas





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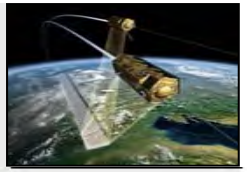
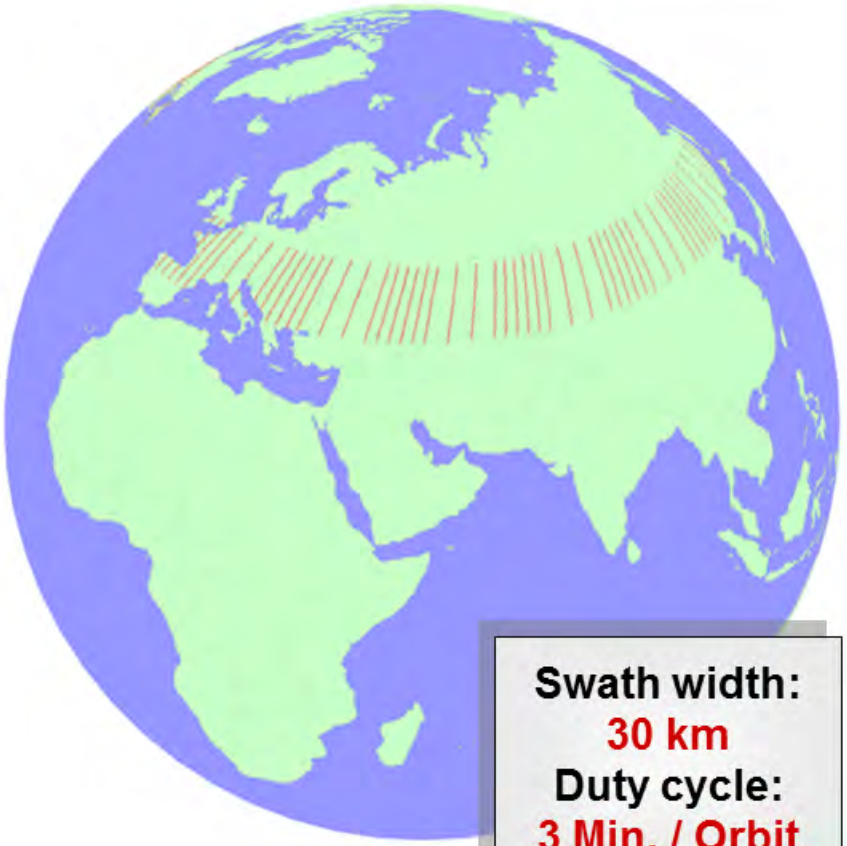
Comparison of Imaging Capability

TanDEM-X



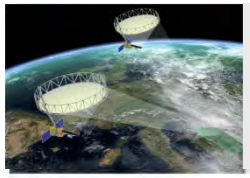
1 global coverage / year



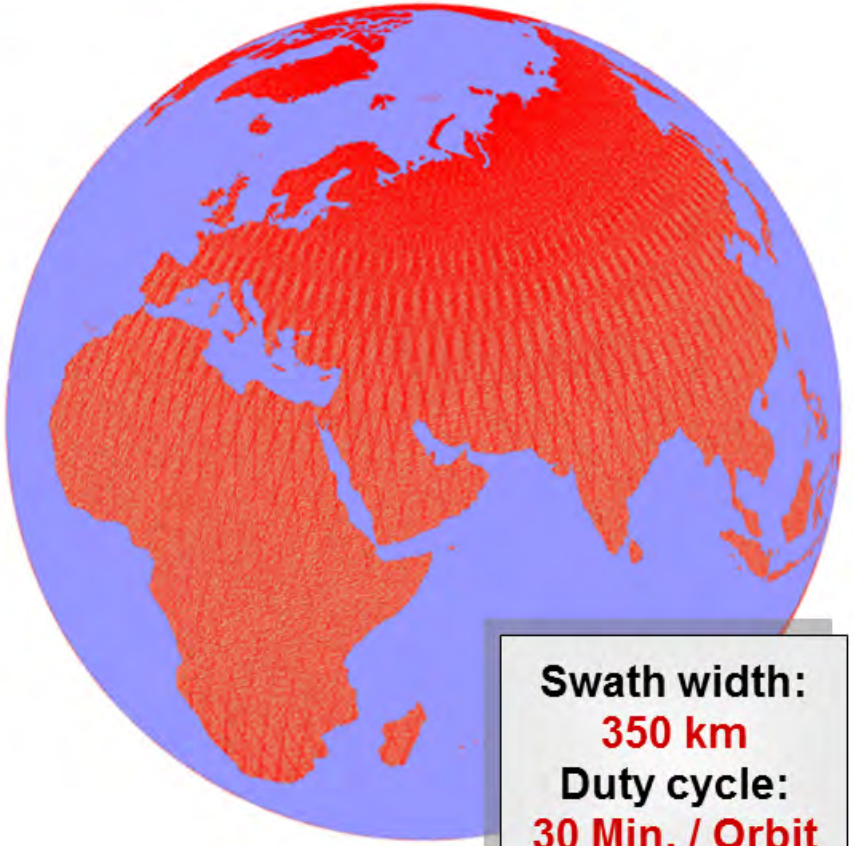
Swath width:
30 km
Duty cycle:
3 Min. / Orbit

Day
8

Tandem-L



2 global coverages / week



Swath width:
350 km
Duty cycle:
30 Min. / Orbit

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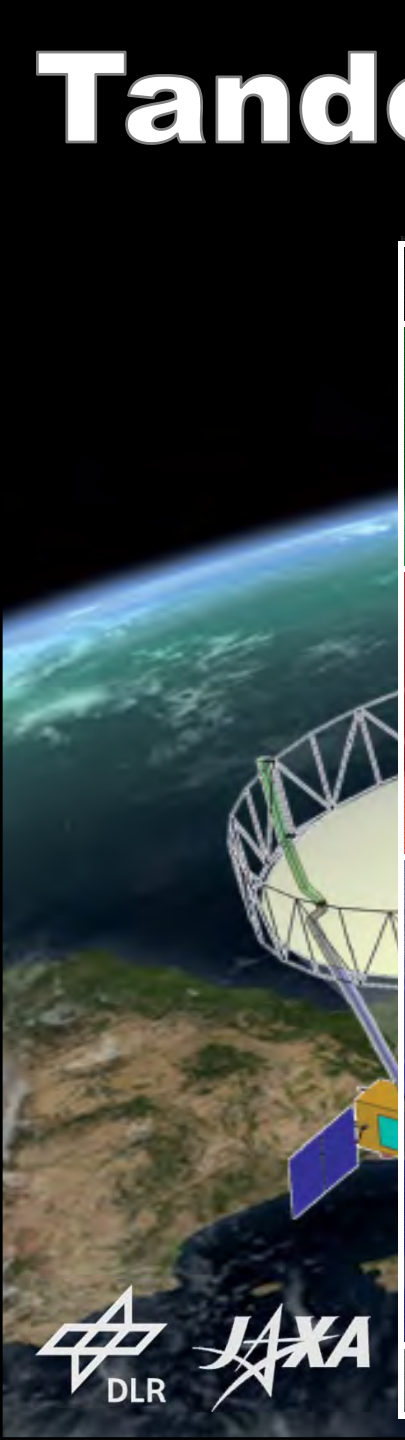
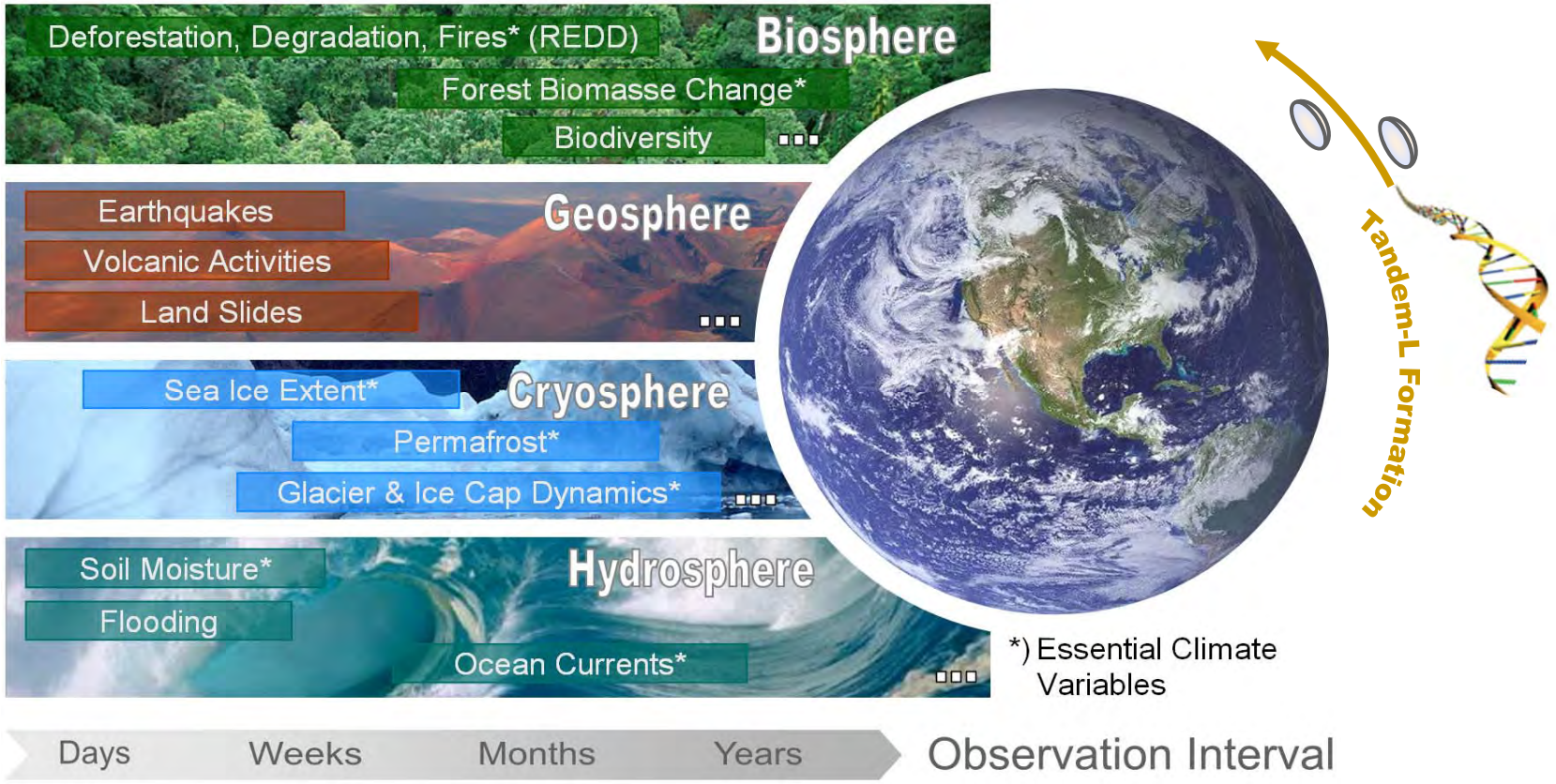
Tandem-L



	Tandem-L Science Products	Resolution	Revisit
Biosphere	Forest height	20 - 50 m	16 days - seasonal
	Above ground biomass		
	Vertical forest structure		
Geo-/ Lithosphere	Plate tectonics	5 - 100 m	weekly
	Volcanoes		
	Landslides		
	Deformation		
Cryo- & Hydrosphere	Glacier flow	50 - 500 m	weekly
	Soil moisture		weekly
	Water level change		on demand
	Snow water equivalent		seasonal
	Ice structure Change		seasonal
	Ocean Currents		weekly
Global	Digital Terrain and surface model	20 - 50 m	yearly

Monitoring of Dynamic Earth Processes

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



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Motivation for a Joint Mission

- Innovative mission with new techniques and technologies:
  - Digital beamforming with large reflector
  - Polarimetric SAR interferometry (Pol-InSAR) and Tomography
  - High imaging capacity, dynamic processes monitoring
  - Formation Flying for 3-D imaging
- Tandem-L concept for fulfilling scientific and application requirements in a most effective way (e.g. estimation of biomass)
- Broader science and applications team with complementary expertise
- Increasing cooperation between DLR and JAXA in Earth observation
- Several commonalities in the German and Japanese Radar programs

DLR JAXA

Helmholtz Alliance

Remote Sensing and Earth System Dynamics

HELMHOLTZ GEMEINSCHAFT

Helmholtz Alliance: Our Team

Helmholtz Centre for Environmental Research (**UFZ**), Forschungszentrum Jülich (**FZJ**), Helmholtz Centre Potsdam (**GFZ**), Helmholtz Zentrum München (**HGMU**), Karlsruhe Institute of Technology (**KIT**), Alfred Wegener Institute for Polar and Marine Research (**AWI**), Helmholtz Centre for Ocean Research Kiel (**GEOMAR**), German Aerospace Center (**DLR**), Max Planck Institute for Meteorology (**MPI-M**), Technical University of Munich (**TUM**), Friedrich Schiller University Jena (**FSU**), University of Innsbruck, Forest Stewardship Council International (**FSC**), Swiss Federal Institute of Technology Zürich (**ETH Zürich**), Potsdam Institute of Climate Research (**PIK**), University of Potsdam, Ludwig-Maximilians-Universität München (**LMU**), Federal Institute for Geosciences and Natural Resources (**BGR**), Philipps-University Marburg (**LCRS**), University Hamburg (**KlimaCampus**)

Principal Investigator

Prof. Dr. Alberto Moreira

Scientific Coordinators

Prof. Dr. Irena Hajnsek
DLR - Institut für Hochfrequenztechnik und Radarsysteme

Prof. Dr. Andreas Huth (Deputy)
UFZ - Helmholtz Centre for Environmental Research

HGF Alliance

HELMHOLTZ GEMEINSCHAFT

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

JÜLICH FORSCHUNGSZENTRUM

AWI

GEOMAR

KIT Karlsruhe Institute of Technology

DLR

GFZ Helmholtz-Zentrum Potsdam

HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt

Bayerische Staatsforsten Nachhaltig Wirtschaften.

universität bonn Rheinische Friedrich-Wilhelms-Universität Bonn

Technische Universität Dresden

Uni Freiburg

Universität Bremen

Norsk Polarinstitutt

Universitatis Islandiae Sigillum

東北大学 TOHOKU UNIVERSITY

The University of Edinburgh

BAW Bundesanstalt für Wasserbau
Kompetenz für die Wasserstraßen

Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen

TU Delft Delft University of Technology

Cranfield University

Politecnico Milano

Nationalpark Bayerischer Wald

Universitas Osloensis MDCCCXI

Philipps Universität Marburg

universität innsbruck

Technische Universität München

UNEP

EFI

NERSC

Umwelt Bundes Amt Für Mensch und Umwelt

UPC

PIK

Technical University of Denmark DTU

UC University of Canterbury
Te Whare Wānanga o Waitaha
Christchurch New Zealand

BSH Bundesamt für Seeschifffahrt und Hydrographie

LMU Ludwig-Maximilians-Universität München

Max-Planck-Gesellschaft

University of Zurich UZH

asi accreditation services international

Munich RE

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

Universität Potsdam

DMI

Prifysgol Aberystwyth University

Naval Research Laboratory Washington, DC

Sejong University

University of Manitoba

UHH

JRC European Commission

HNE Eberswalde
Hochschule für nachhaltige Entwicklung (FH)
Unser Name ist Programm

ZMAW

FSC

FAU Friedrich-Alexander Universität Erlangen-Nürnberg

TU Wien

ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Université de Savoie

Environmental Systems Science Centre

Natural Resources Canada

enveo

Aalto University
School of Science and Technology

British Antarctic Survey
Natural Environment Research Council

Wageningen UR
For quality of life

RSMAS

Gamma Remote Sensing

AEL consultants

Universiteit Utrecht

Australian Government
Department of Defence
Defence Science and Technology Organisation

Ifremer

EPFL
École Polytechnique Fédérale de Lausanne

APL The Johns Hopkins University Applied Physics Laboratory

Yonsei University

Université de Rennes 1

University of California Irvine

CHALMERS

BOKU

Universitat d'Alacant
Universidad de Alicante

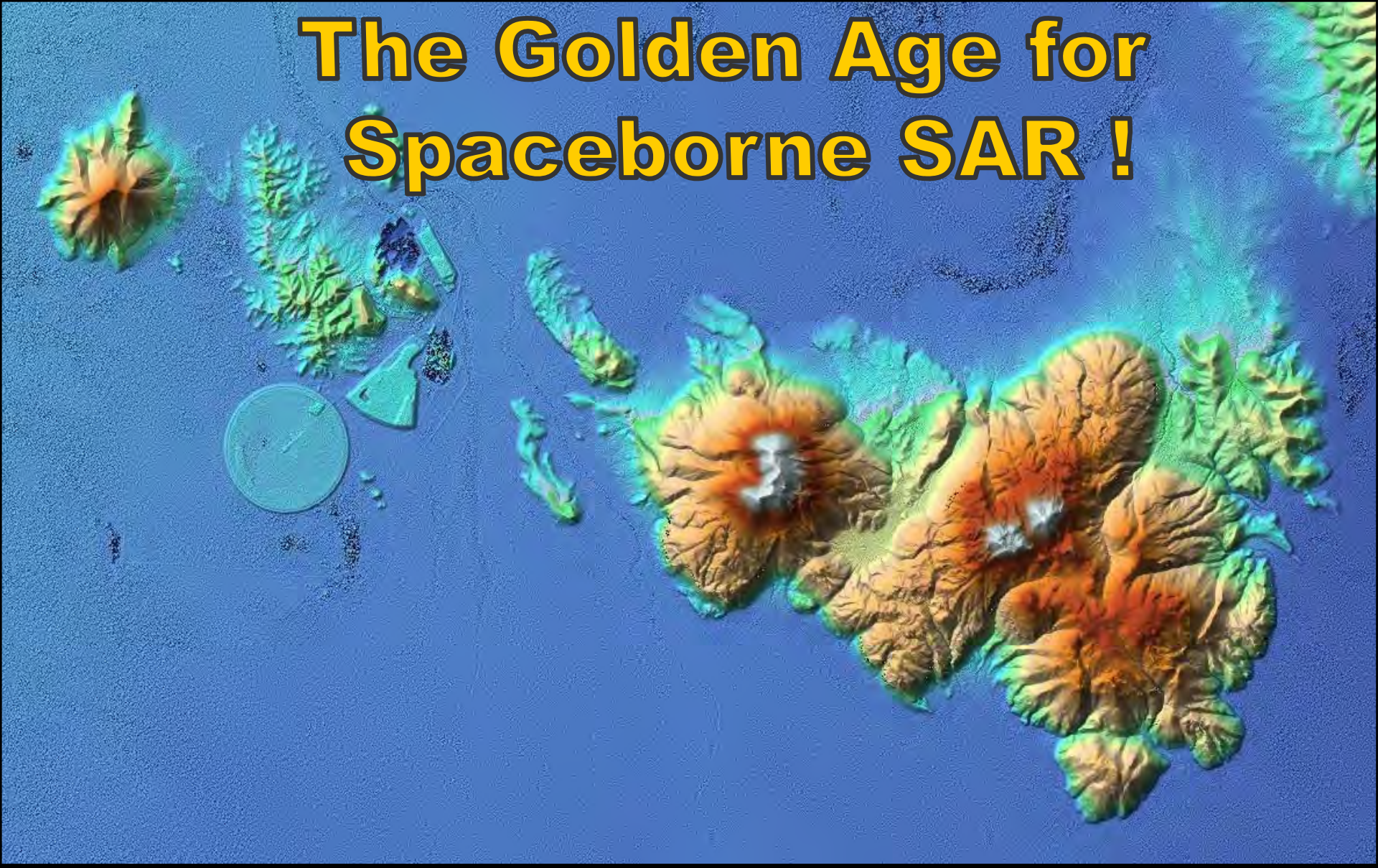
Alaska Satellite Facility ASF

norut Northern Research Institute

University of Bristol

JAXA Japan Aerospace Exploration Agency

The Golden Age for Spaceborne SAR !



Gold Mine, Kori Kollo, Bolivia

TanDEM