Tandem-L: Highly Innovative Radar Satellite Mission for Climate Research and Environmental Monitoring

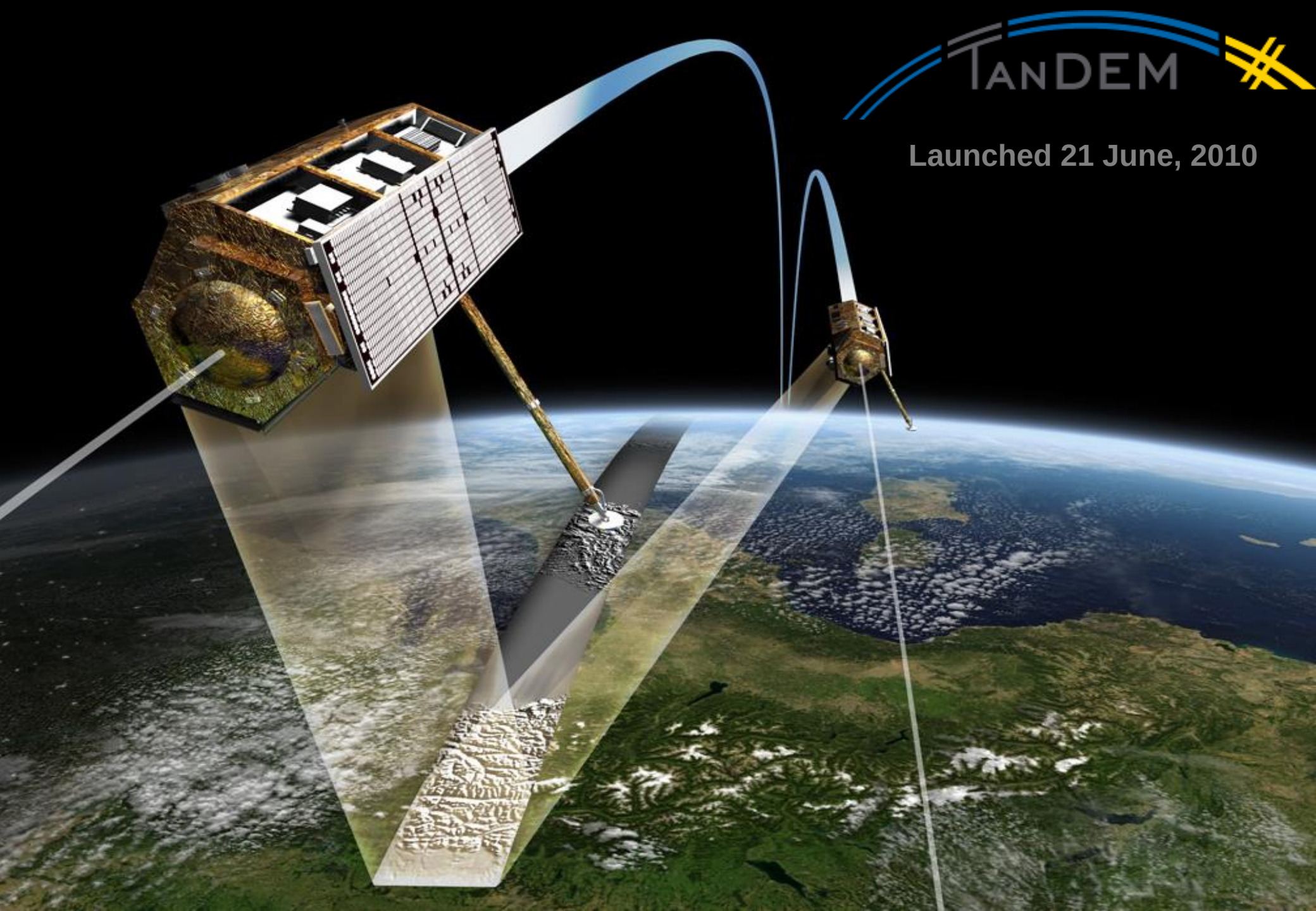
Alberto Moreira

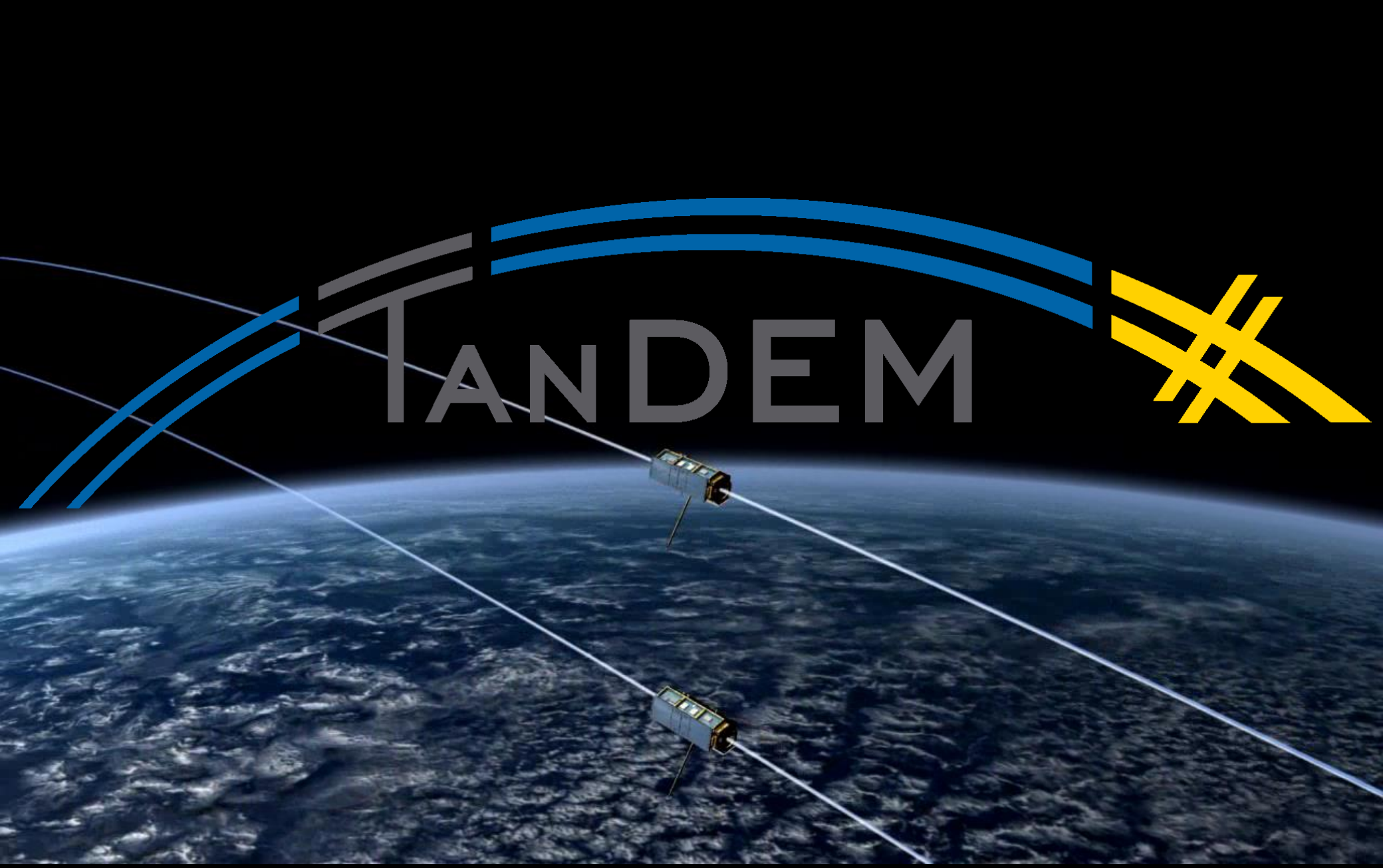
German Aerospace Center - DLR

Microwaves and Radar Institute

Oberpfaffenhofen

Germany


TanDEM
Launched 21 June, 2010

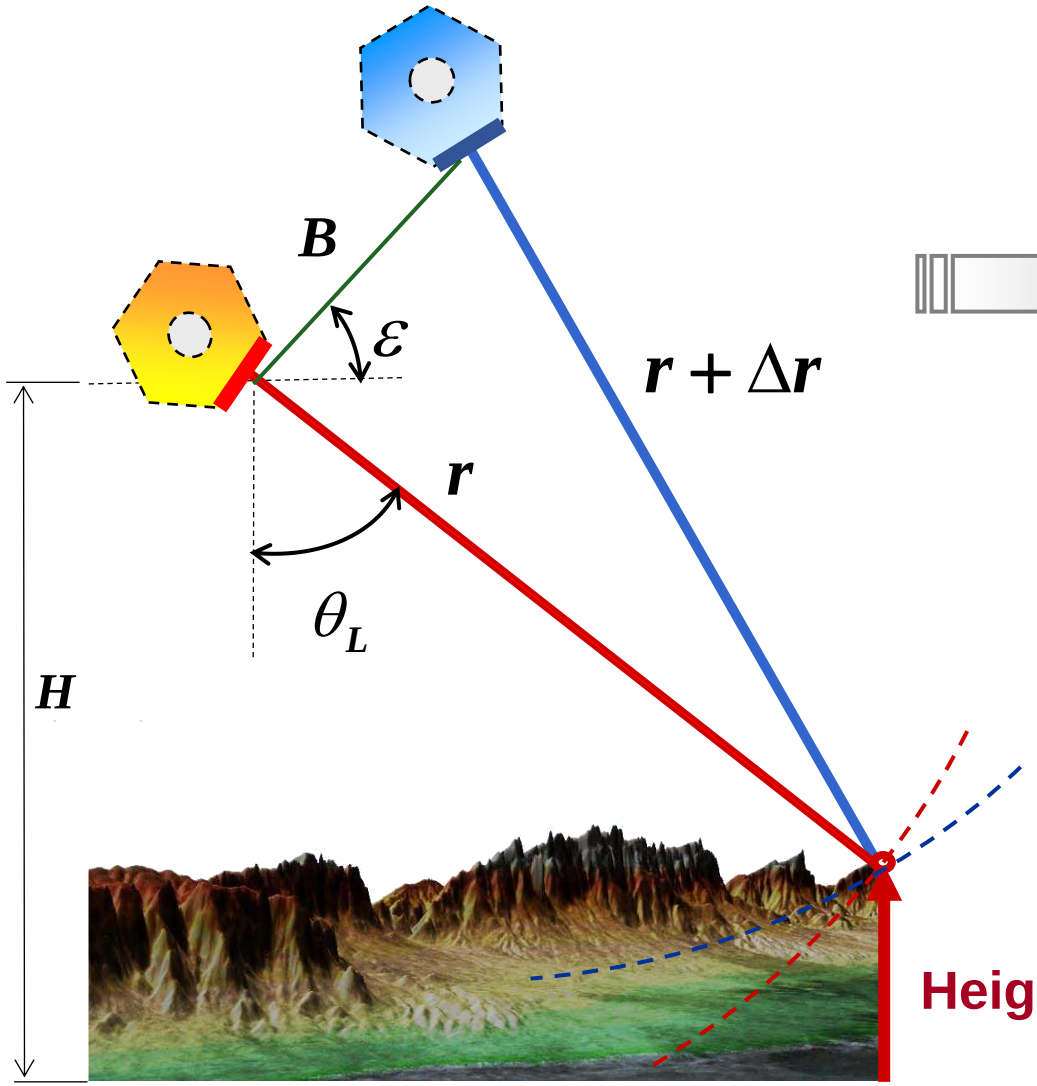

TanDEM

TanDEM-X

Interferometric Data Acquisitions (December 2010 – 2015)

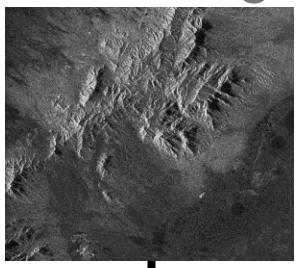
DLR

Synthetic Aperture Radar (SAR) Interferometry

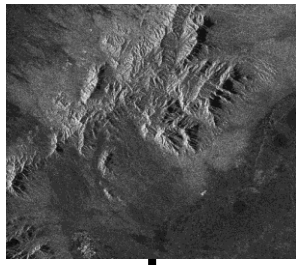


Data Processing

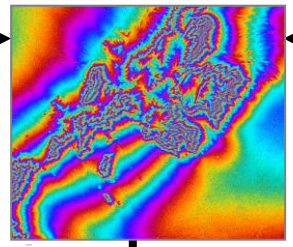
Radar image

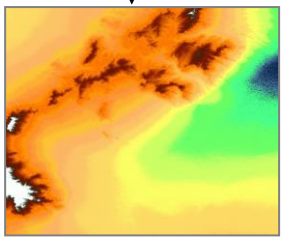


Radar image



Interferogram

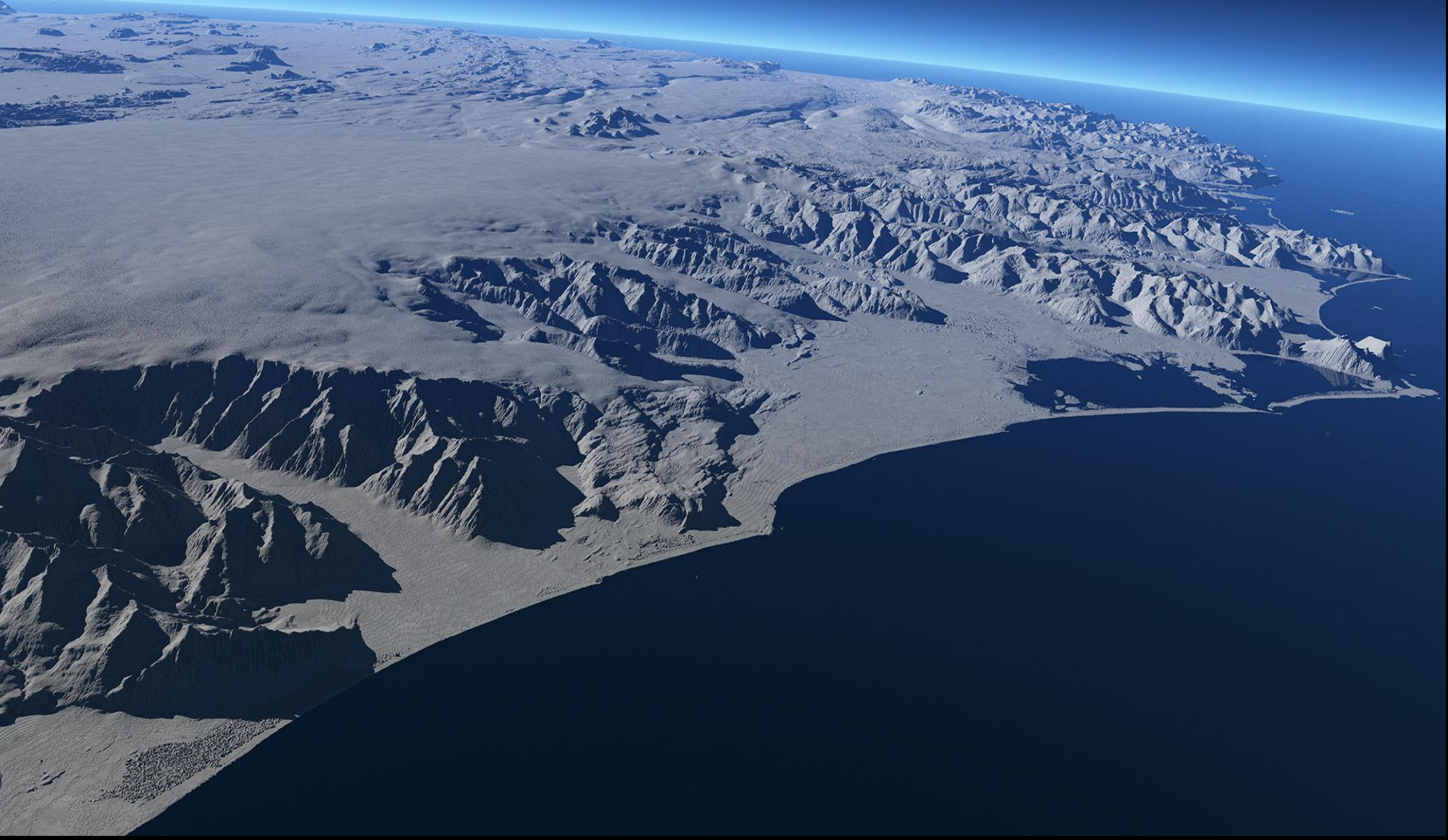




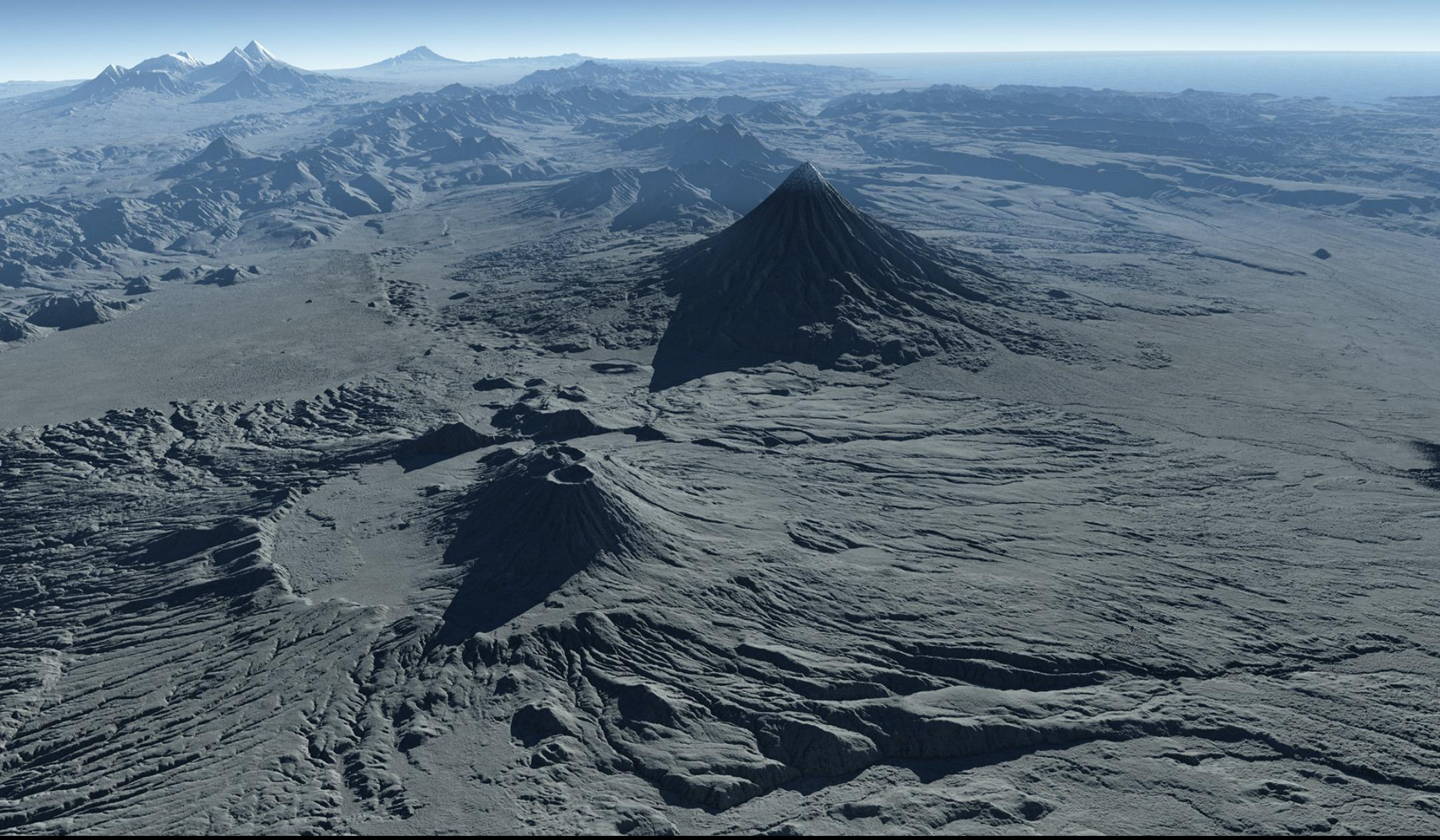
Digital Elevation Modell (DEM)

DLR

Australia, Finke Gorge National park



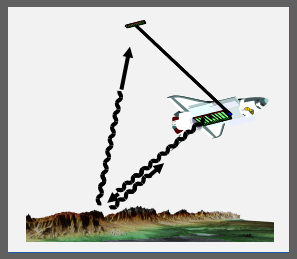
Iceland, 2014



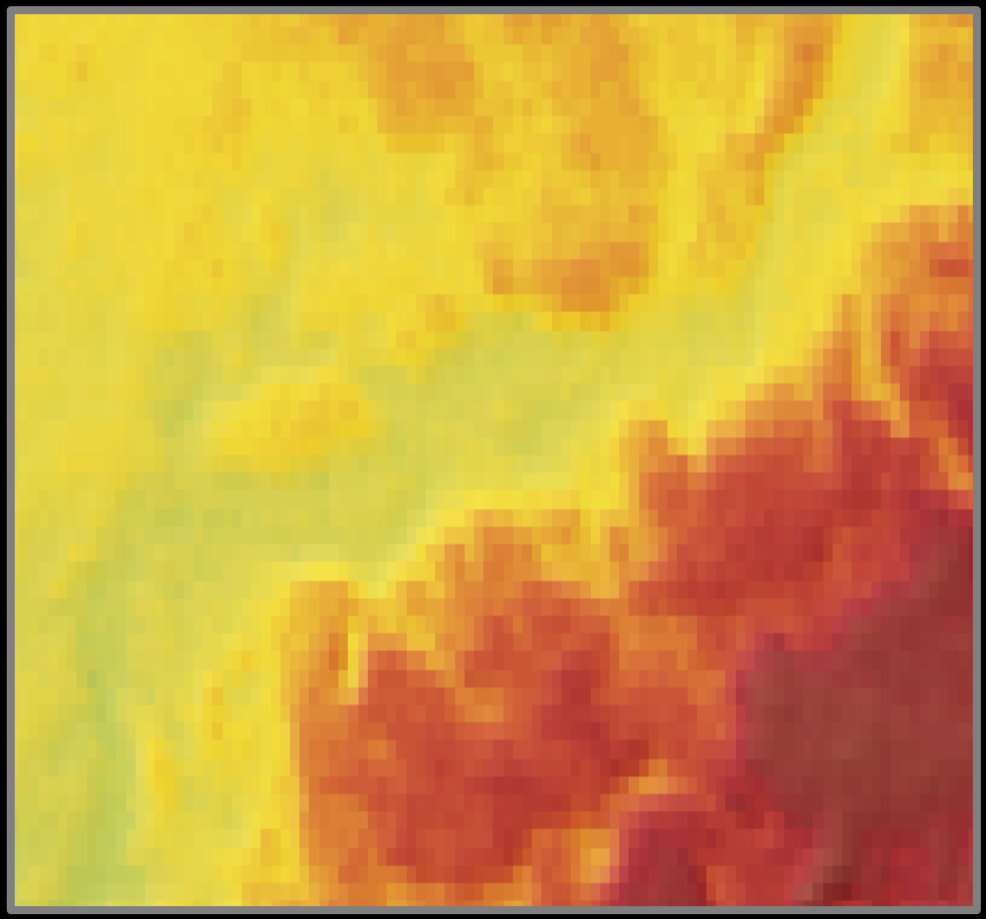
Kamchatka, Russia

Atacama Desert, Chile

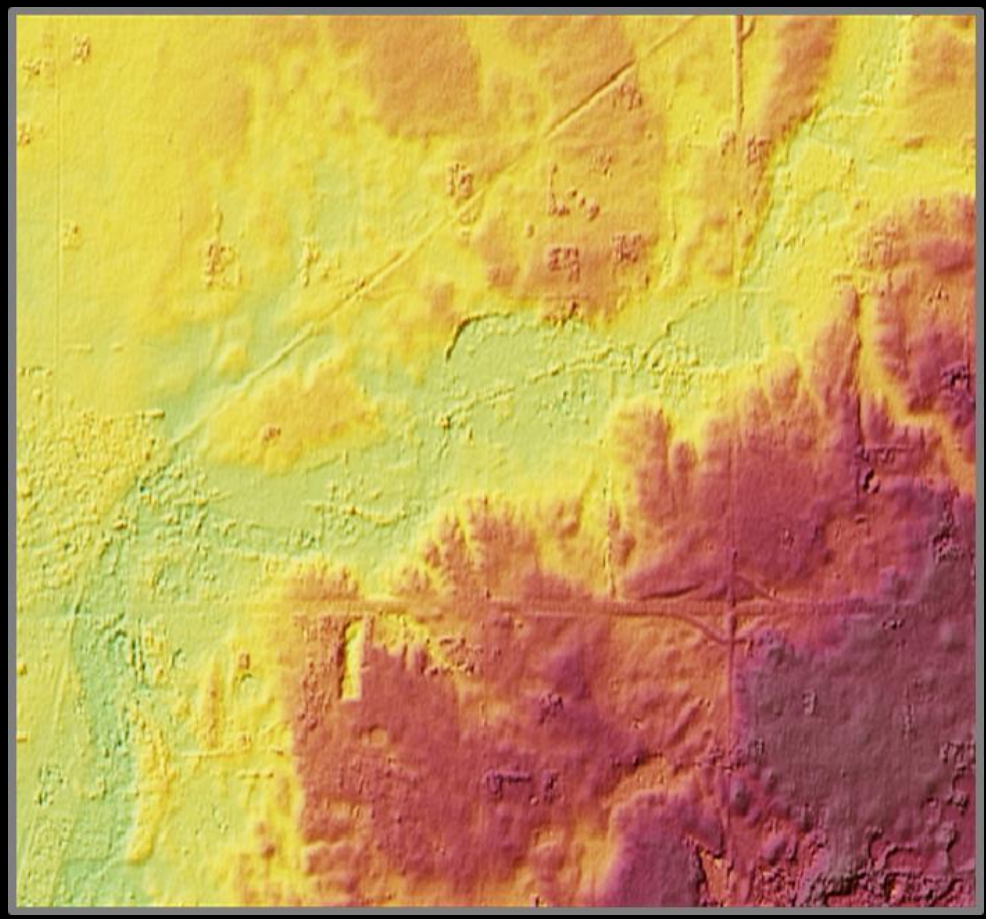
Comparison of Digital Elevation Models



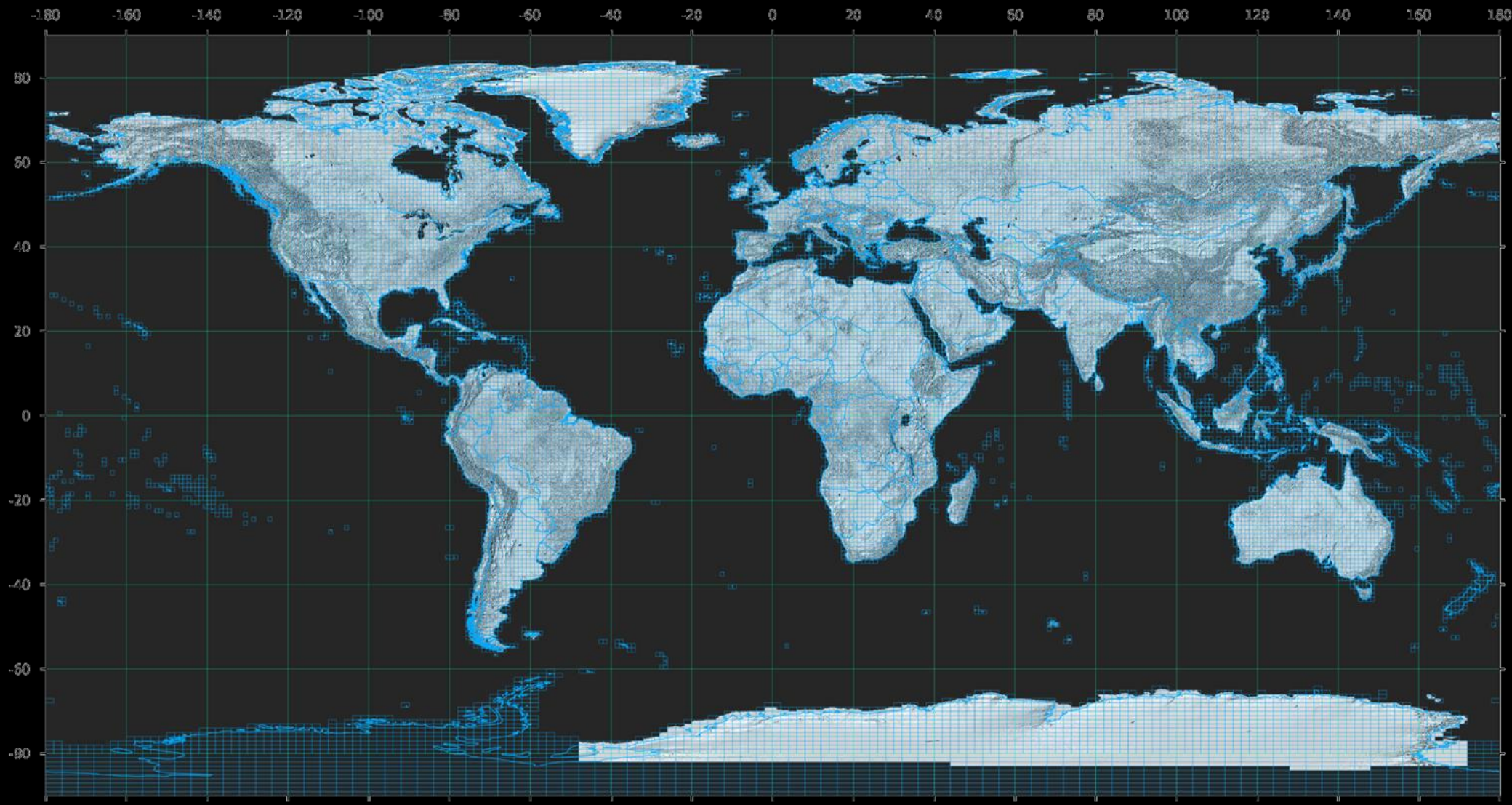
SRTM (2000)



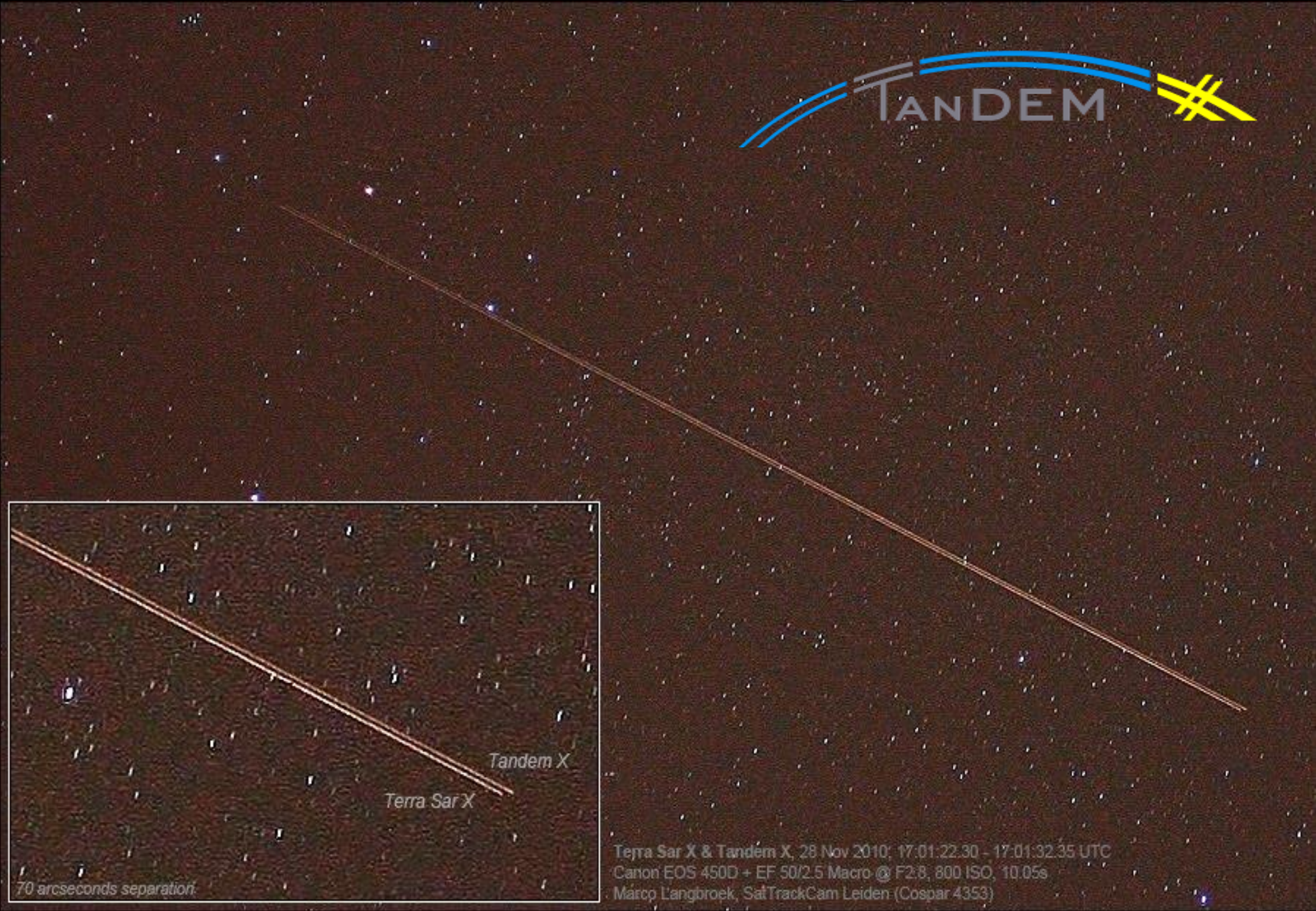
TanDEM-X (2013)



DEM Production Status (June 2016)



TanDEM


TanDEM
Tandem X
Terra Sar X
70 arcseconds separation
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)

Societal Challenges of Global Dimension

Climate Change

Environment

Resources

Sustainable Development

Megacities

Mobility

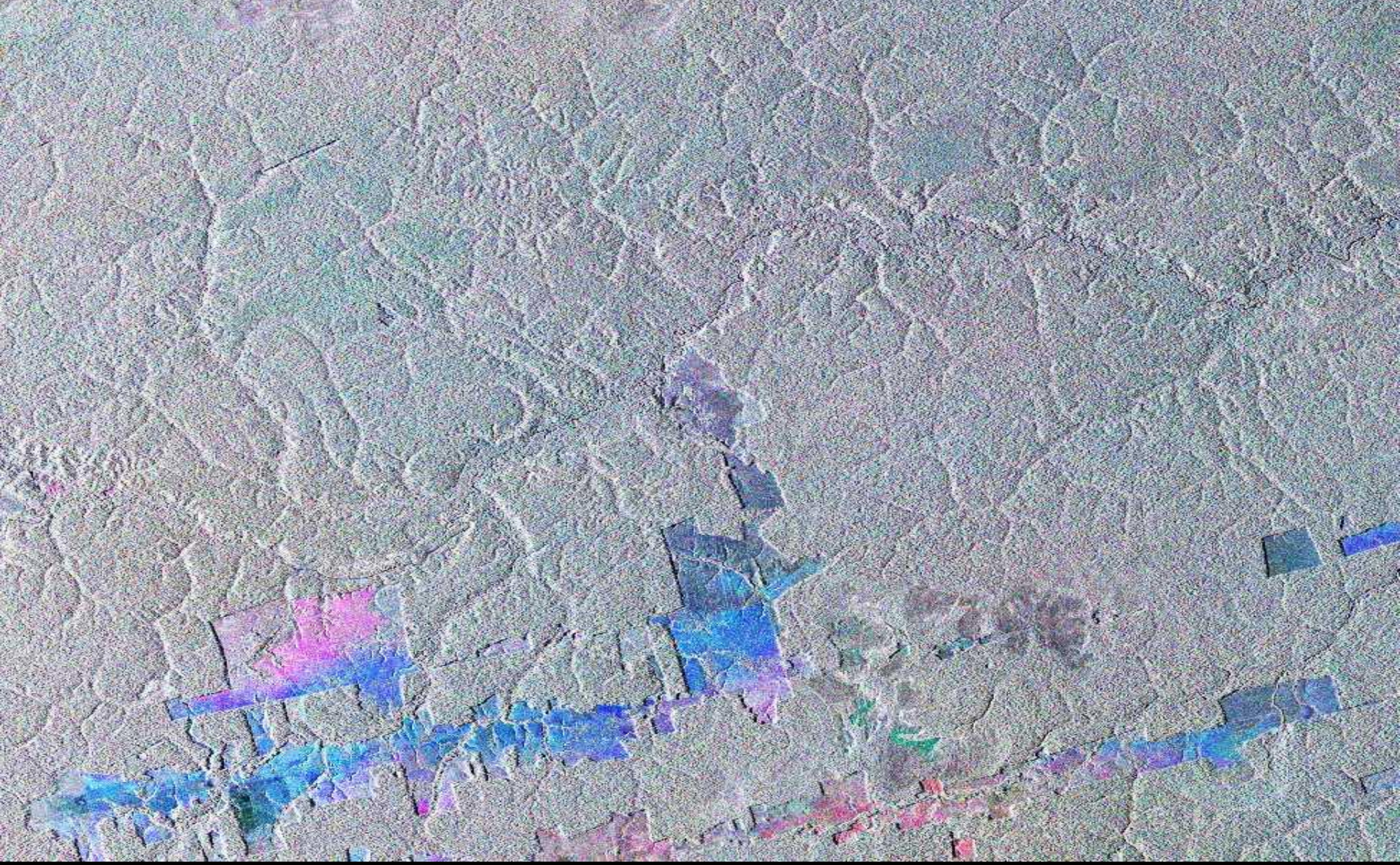
Hazards

Disaster

DLR

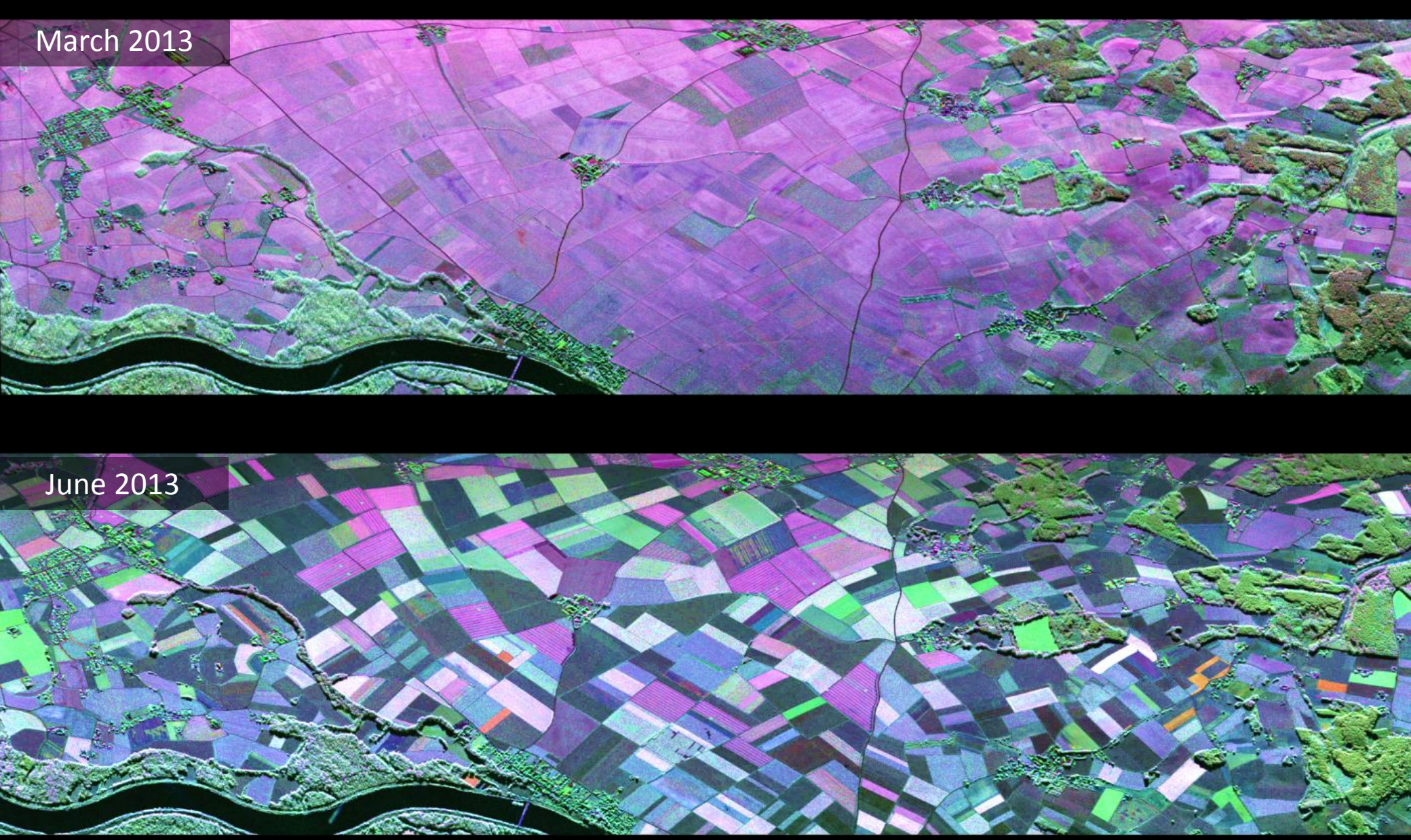
Las Vegas, USA (time series of 20 images)

TERRA SAR X

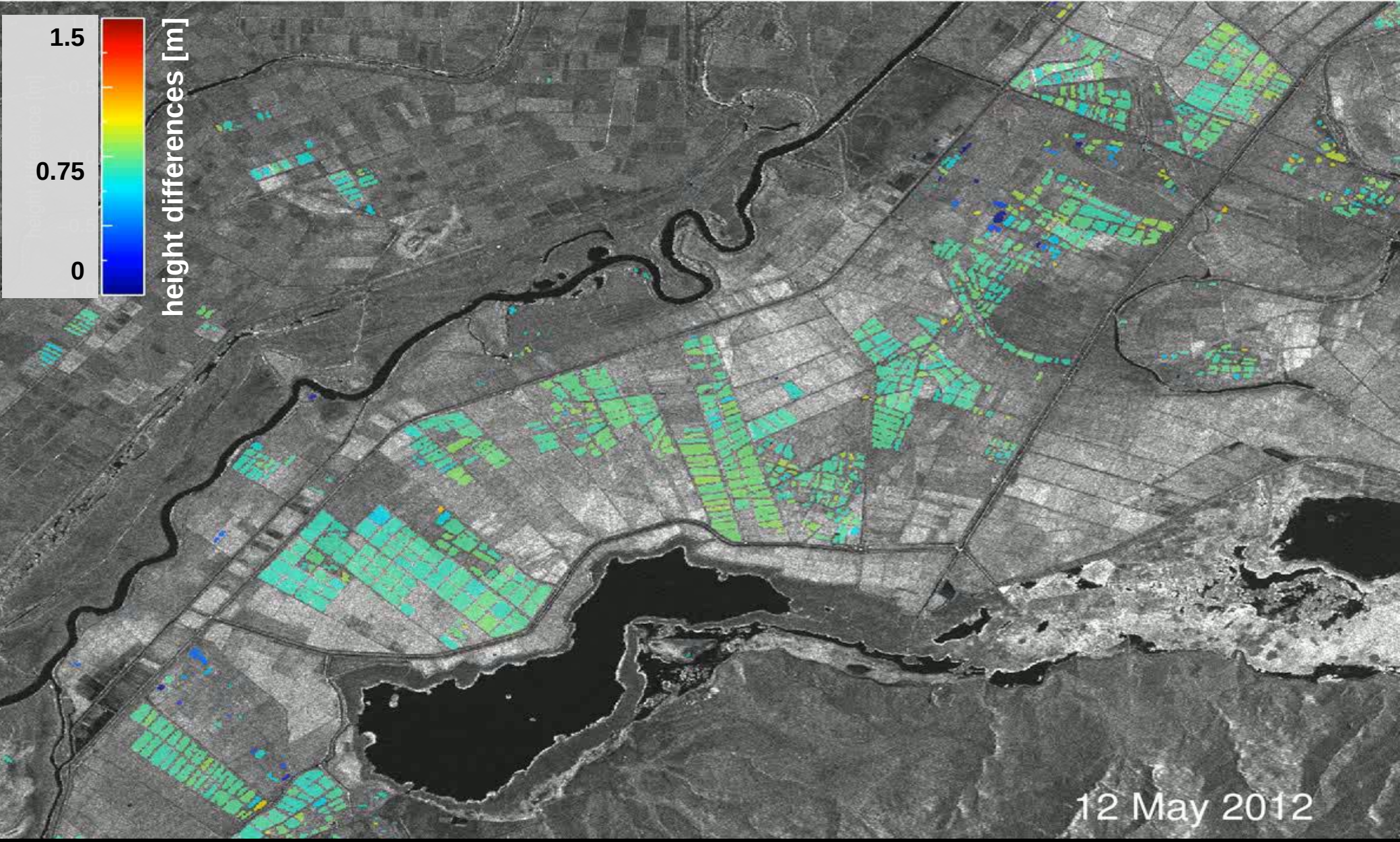


Mato Grosso, Brazil - Deforestation

TERRA SAR X



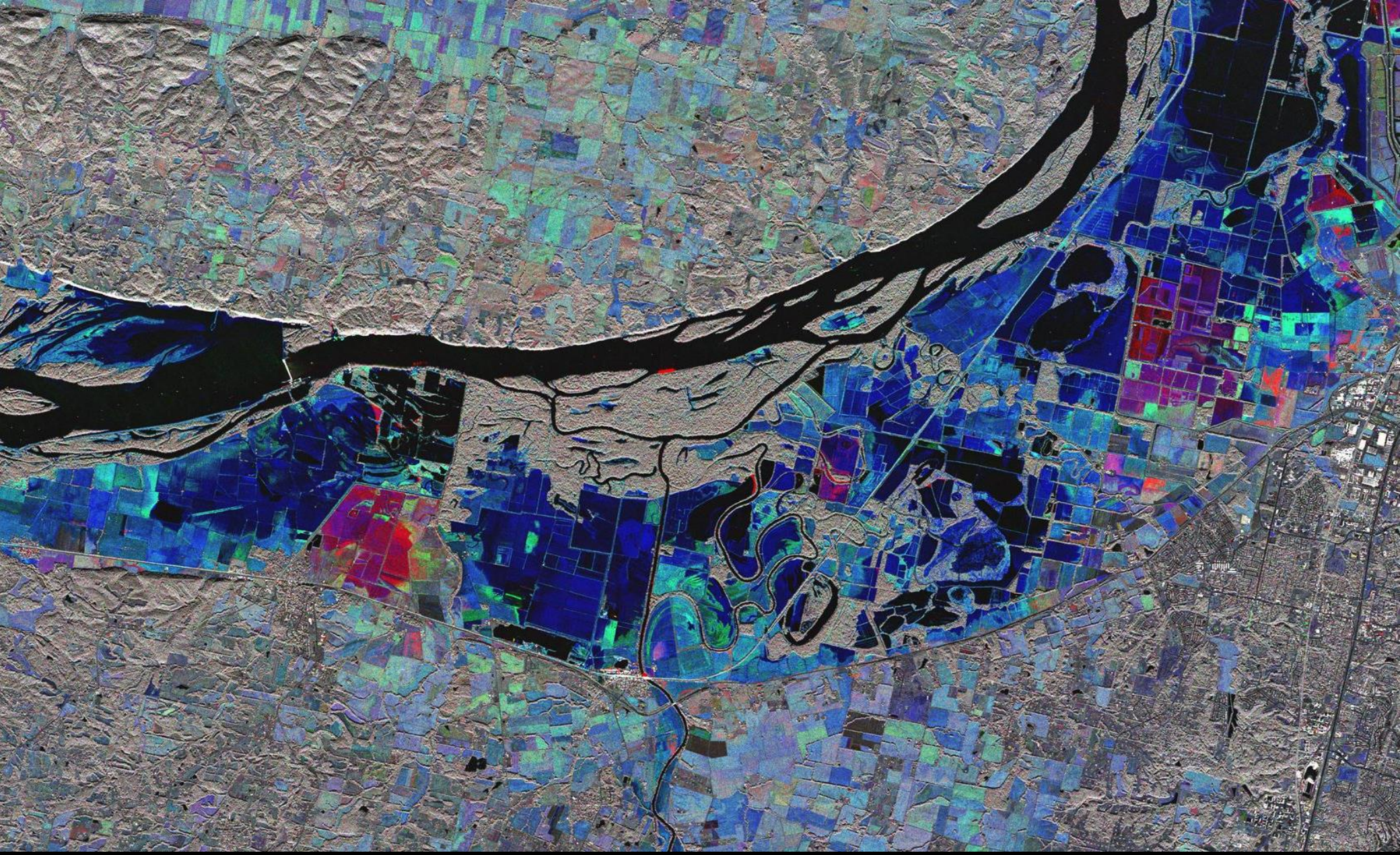
Crop Monitoring, Wallerfing, Germany (X-Band, F-SAR)



ITU/GEOMATICS
Geomatics Engineering

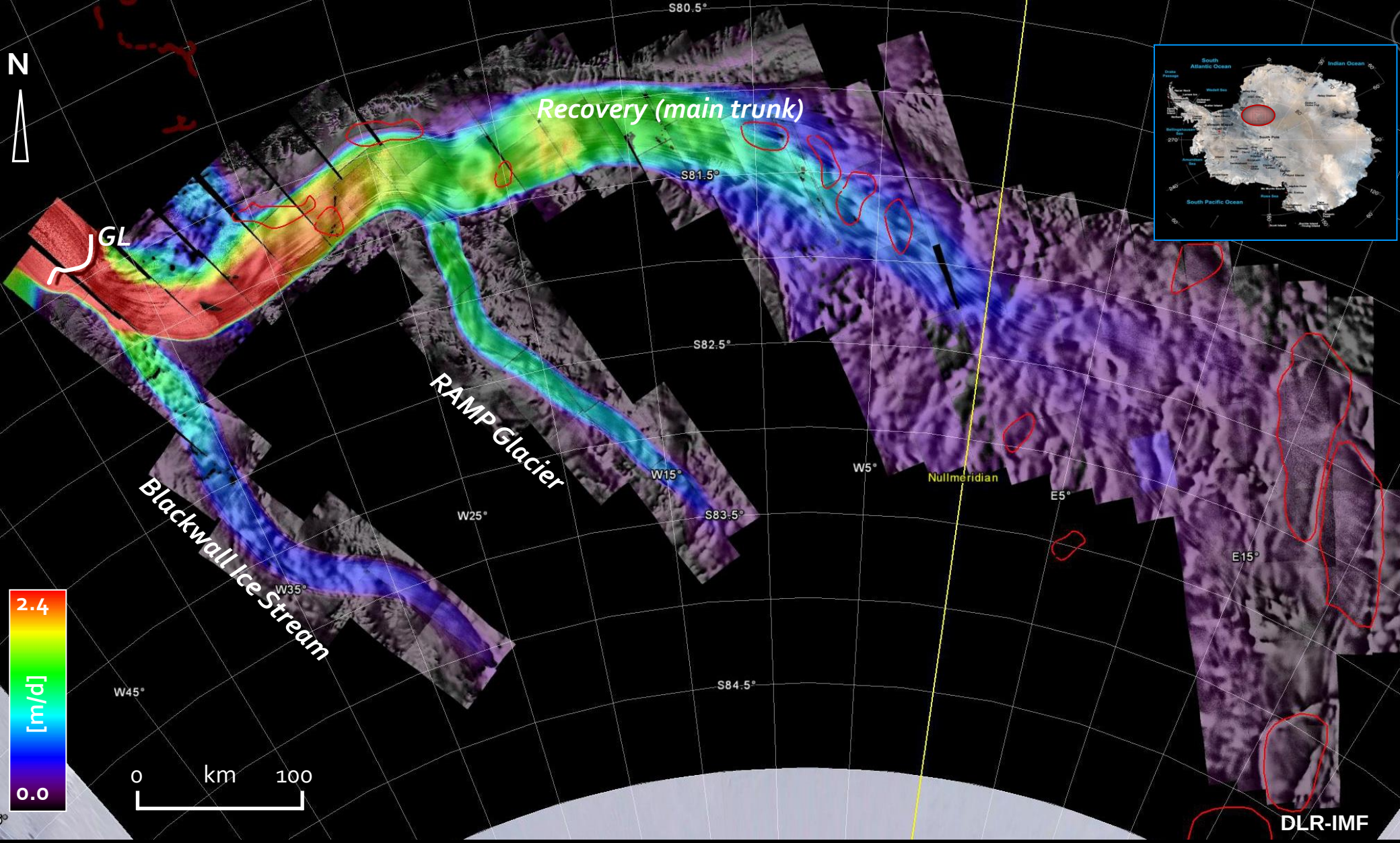
Paddy-Rice Monitoring

TanDEM



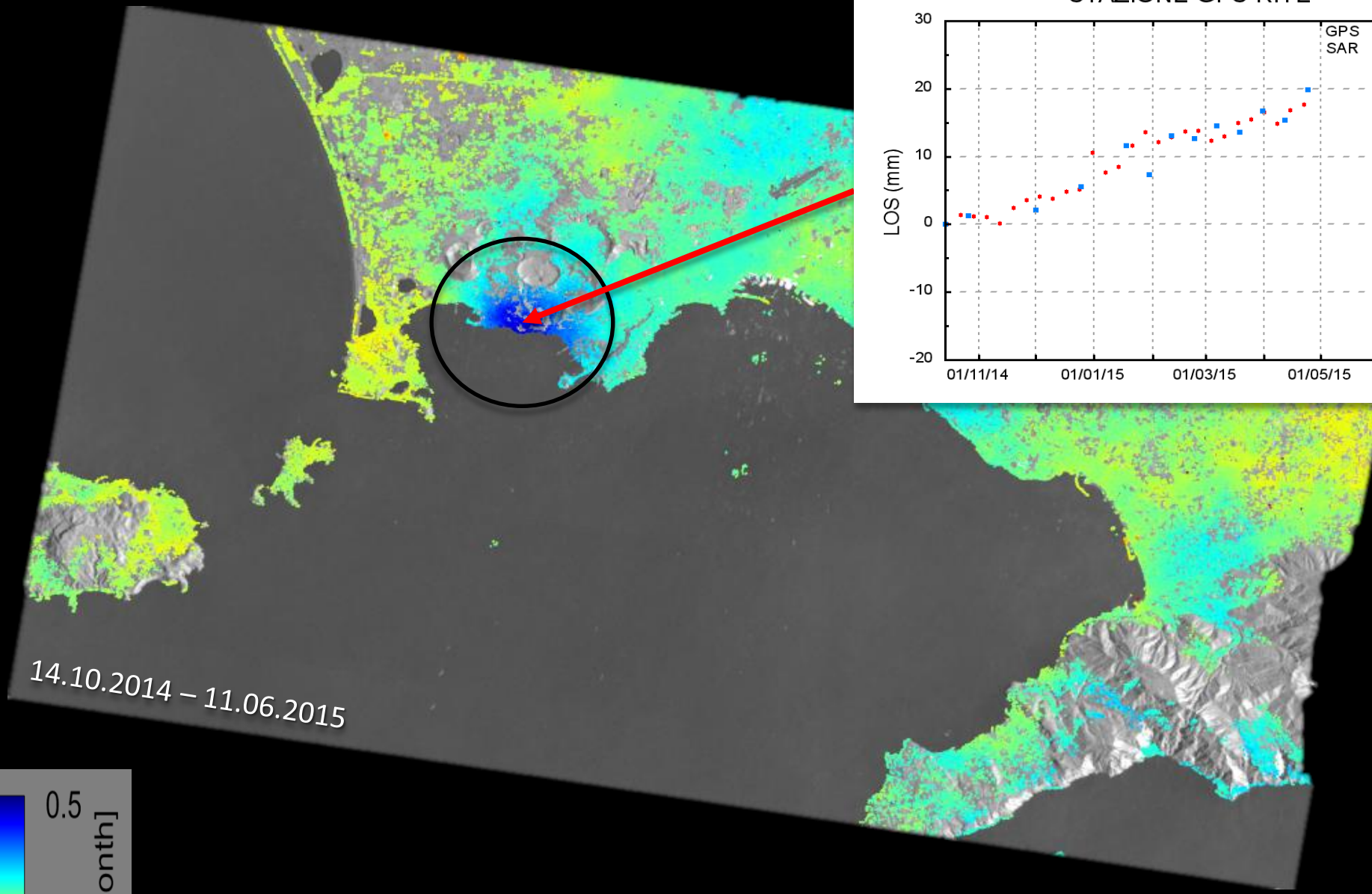
Mississippi, USA - Flooding

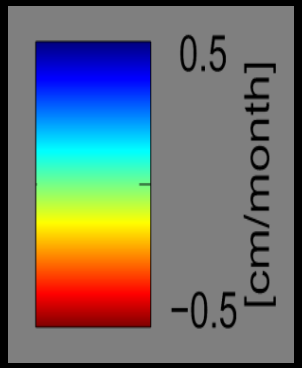
TERRA SAR X



Recovery Glacier, Ice Flow Veloctiy, Antarctica

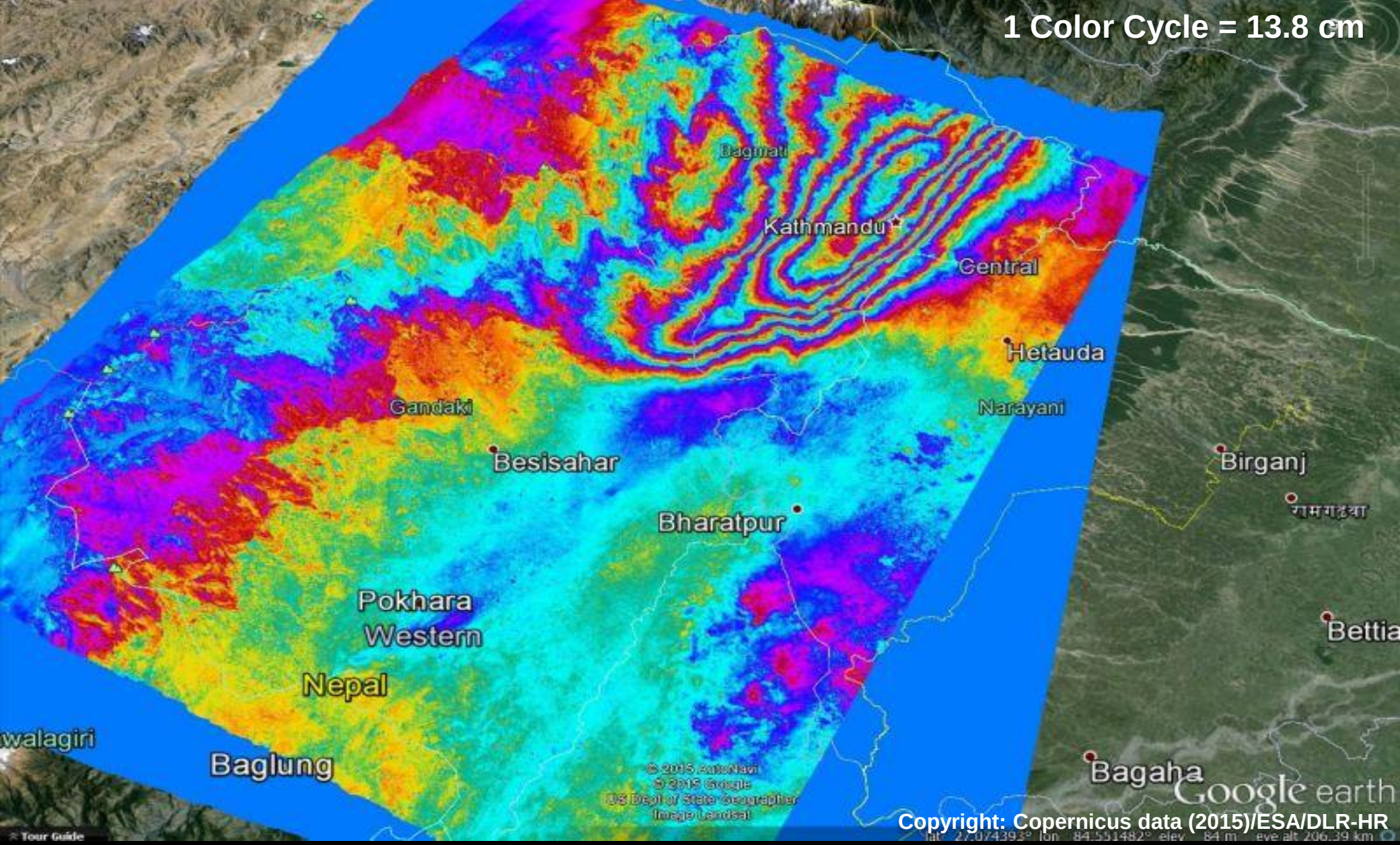
TERRA SAR X





Campi Flegrei, Vulcano Uplift

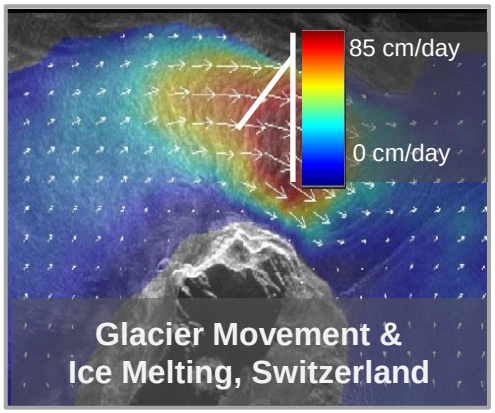
Copernicus data (2015), Sentinel-1, ESA/DLR-HR



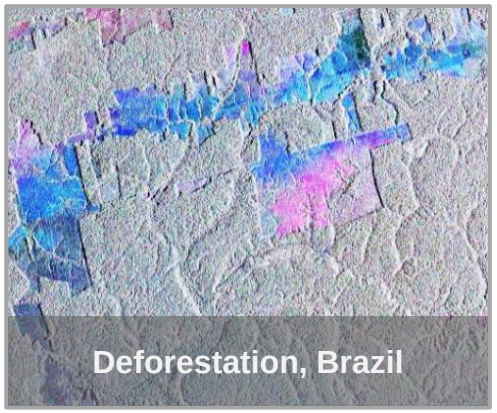
Nepal Gorkha Earthquake, April 25, 2015

Copernicus data (2015), Sentinel-1, ESA/DLR-HR

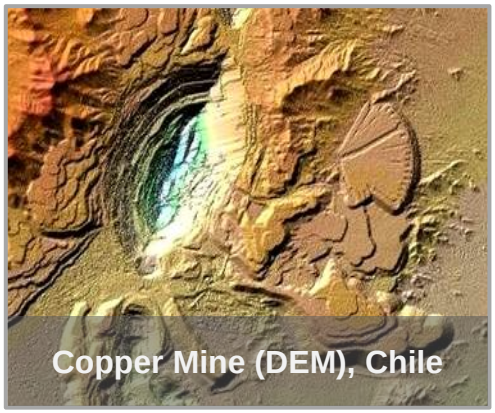
Radar Remote Sensing and Global Societal Challenges



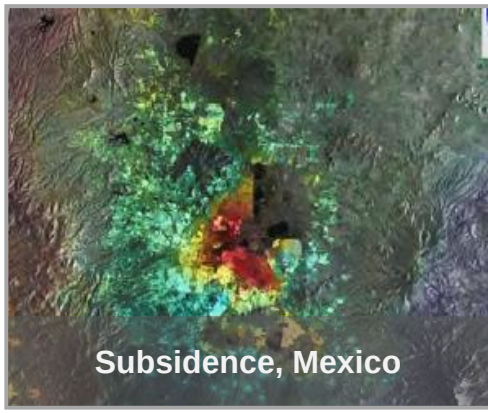
Climate Change



Environment

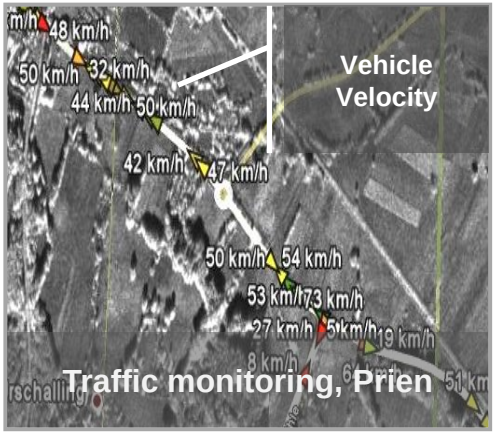


Resources

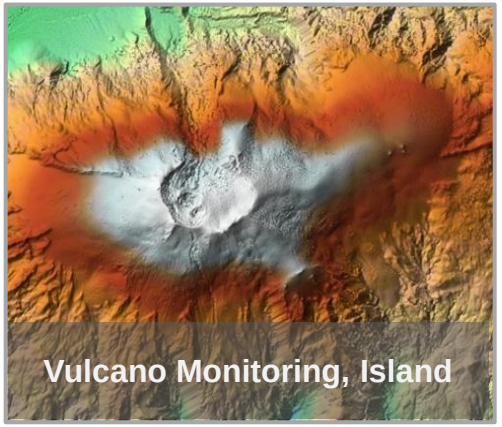


Sustainable Development

Megacities



Mobility



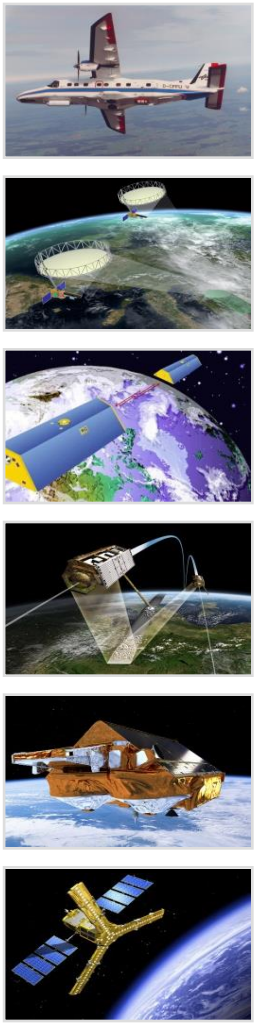
Hazards

Disaster

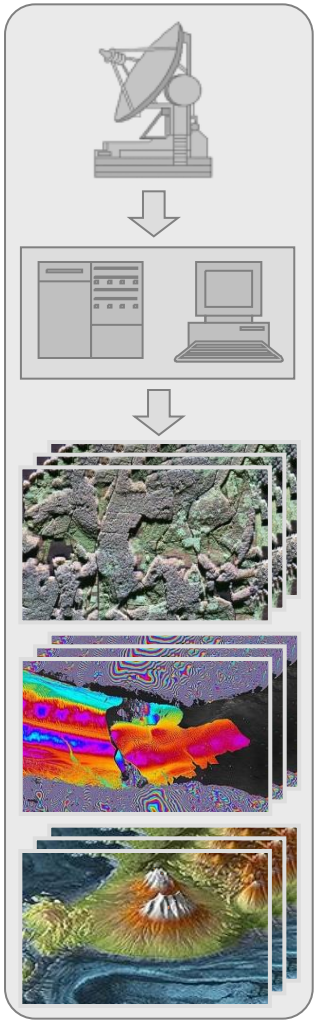
DLR

Future Spaceborne Radar Systems

Next Generation of Remote Sensing Satellites

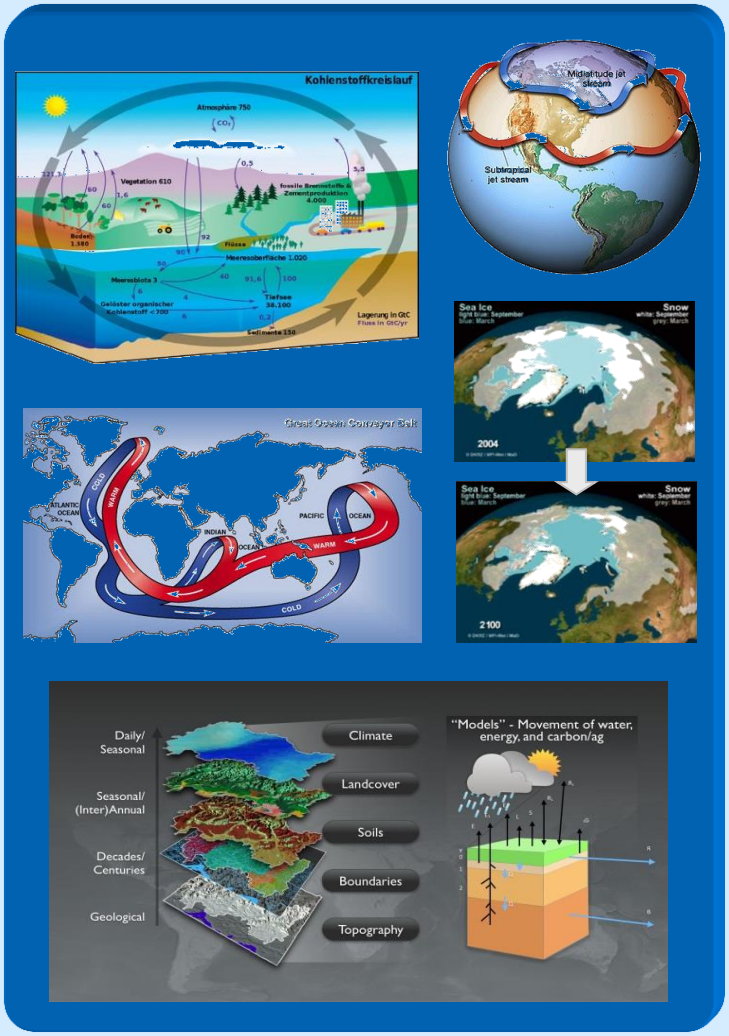


Satellites



Ground Segment

New Remote Sensing Products and Earth System Modelling



Societal Challenges

Helmholtz Alliance:
Remote Sensing and Earth System Dynamics

HELMHOLTZ ASSOCIATION

Dynamic Processes on the Earth Surface

Biosphere

- Deforestation, Degradation, Fires* (REDD)
- Forest Biomasse Change*
- Biodiversity
- ...

Geosphere

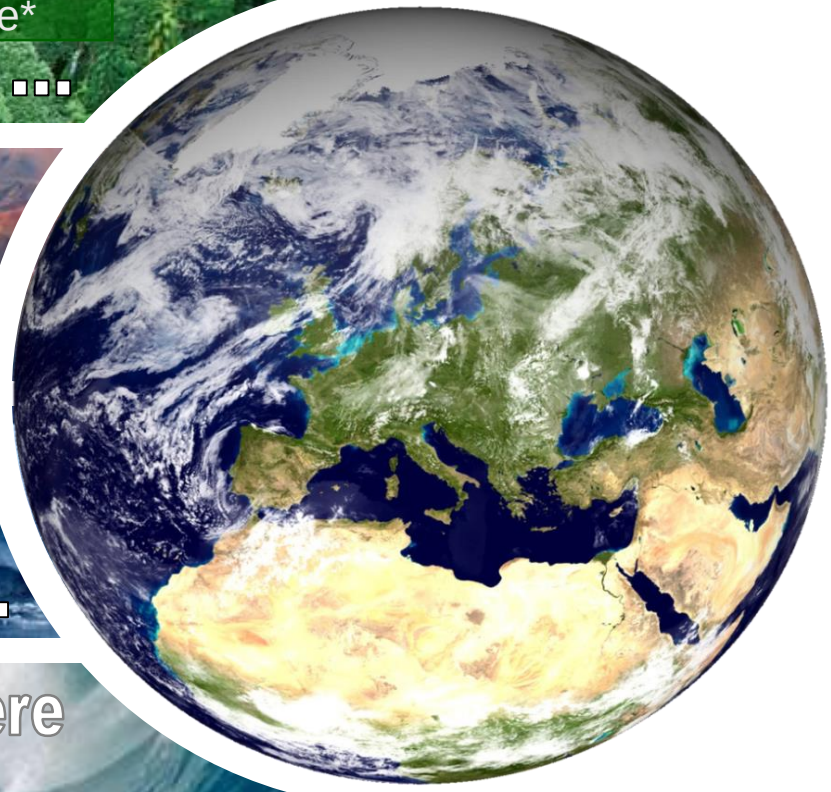
- Earthquakes
- Volcanic Activities
- Land Slides
- ...

Cryosphere

- Sea Ice Extent*
- Permafrost*
- Glacier & Ice Cap Dynamics*
- ...

Hydrosphere

- Soil Moisture*
- Flooding
- Ocean Currents*
- ...



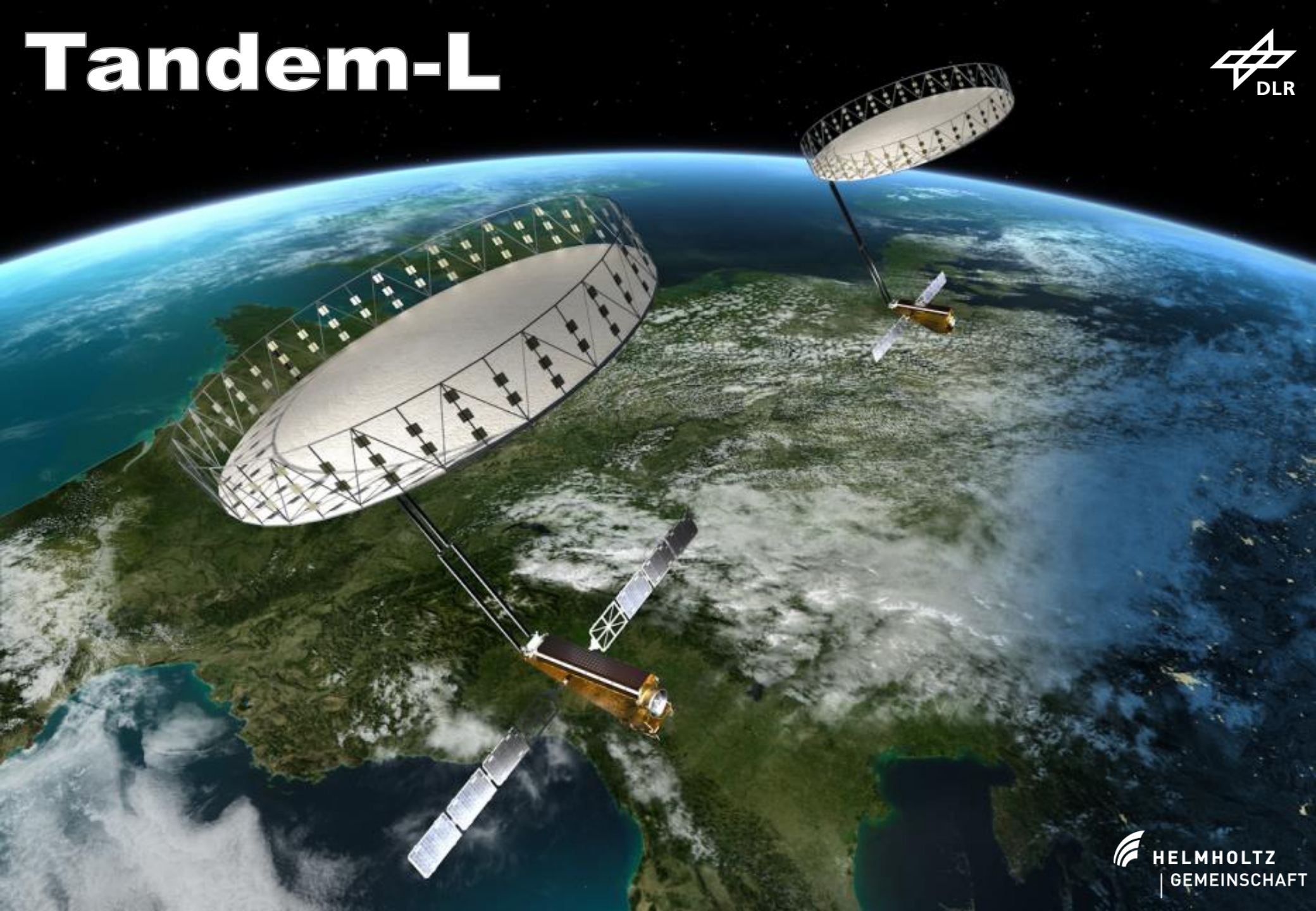
*) Essential Climate Variables

Days | Weeks | Months | Years → **Observation Interval**

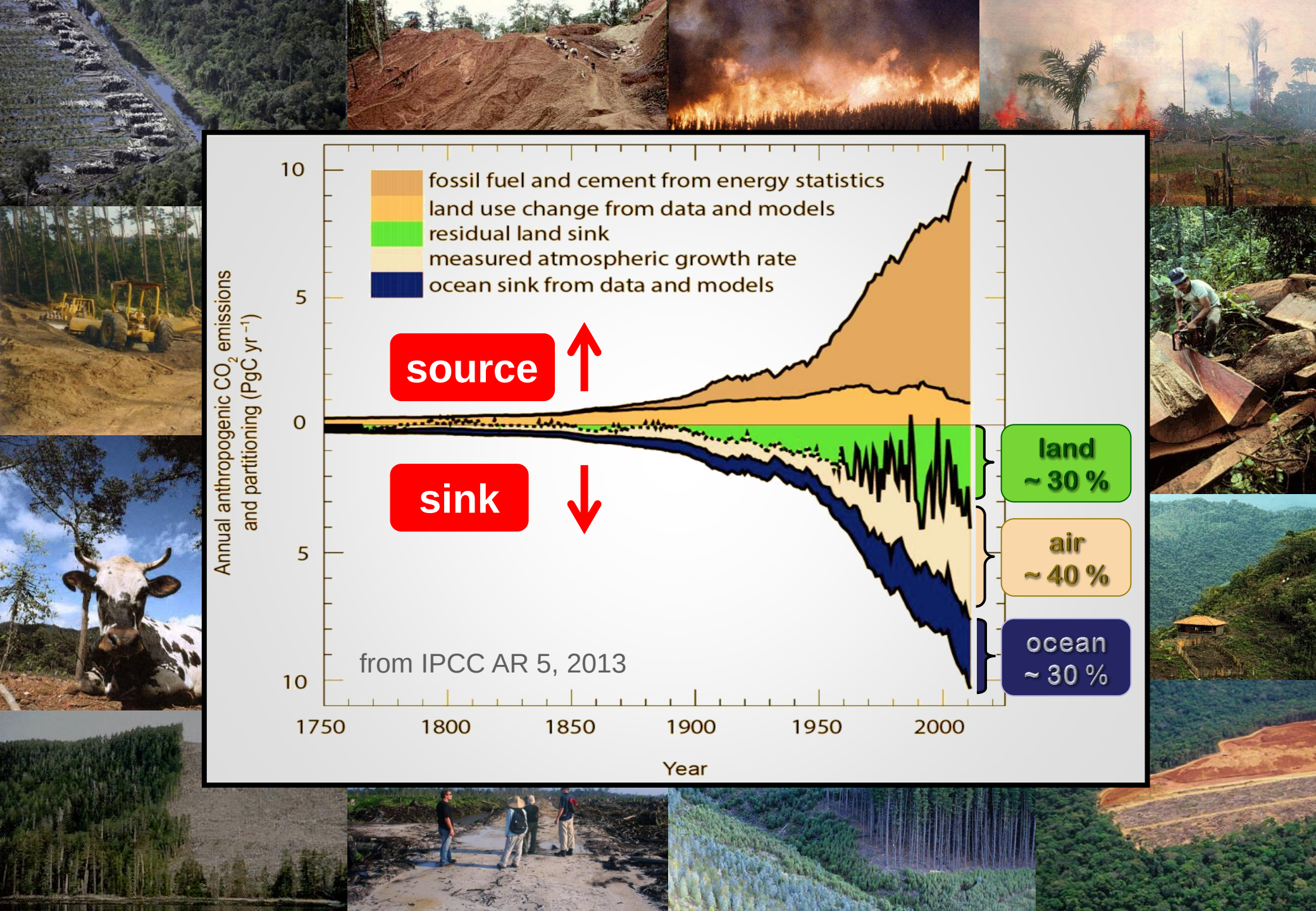
DLR

	Applications/Products	Coverage	Resolution	Accuracy	Repetition Rate
Biosphere	Forest Height	all forest areas	50 m (global) 20 m (regional) 10 m (local)	~ 10 %	every 16 days up to seasonal acquisitons and seasonal to annual produc delivery
	Above Ground Biomass		100 m (global) 50 m (regional)	~ 20 % (or 20 t/ha)	
	Vertical Forest Structure		50 m (global) 30 m (regional)	3 layers	
Geo-/ Lithosphere	Tectonics (3D Deformation Rate map)	high strain areas	50 m (global)	1 mm/year (after 10 years)	weekly acquisition and products seasonal to annual
	Volcanoes (Displacement map)	>1500 land volcanos 50x50 km	50 m	10 mm	
	Landslides (PSI)	risk areas	7 m	1 mm/year (after 10 years)	
	Subsidence (PSI)	urban areas	7 m	1 mm/year (after 10 years)	
Cryosphere	Glacier Flow	worldwide	50 – 500 m	cm – m/year	seasonal
	Ice Structure Change	Greenland	100 m	> 1 layer	annual
	Ice Sheet Elevation	worldwide	50 m	0.5 – 1 m	half a yearly
	Sea Ice	Arctic/Antarctic	5 – 50 km	Thickness <0.5-1m Type 5-20%	every 16 days up to monthly
Hydrosphere	Soil Moisture	selected areas	50 – 100 m	5 – 10 %	weekly
	Ocean Currents	selected areas	4 – 20 km	5 cm/s	weekly
	Wind Speed Velocity	selected areas	4 – 20 km	2 m/s	weekly
	Ocean Surface Waves	selected areas	5 km	0.1 – 0.25 m / 10°	weekly
Global	Digital Terrain & Surface Models	global/local	12 m	2 m (bare) 4 m (vegetation)	global:annual local: on demand
Emergency	Risk areas	local	1 m	-	on demand

Tandem-L

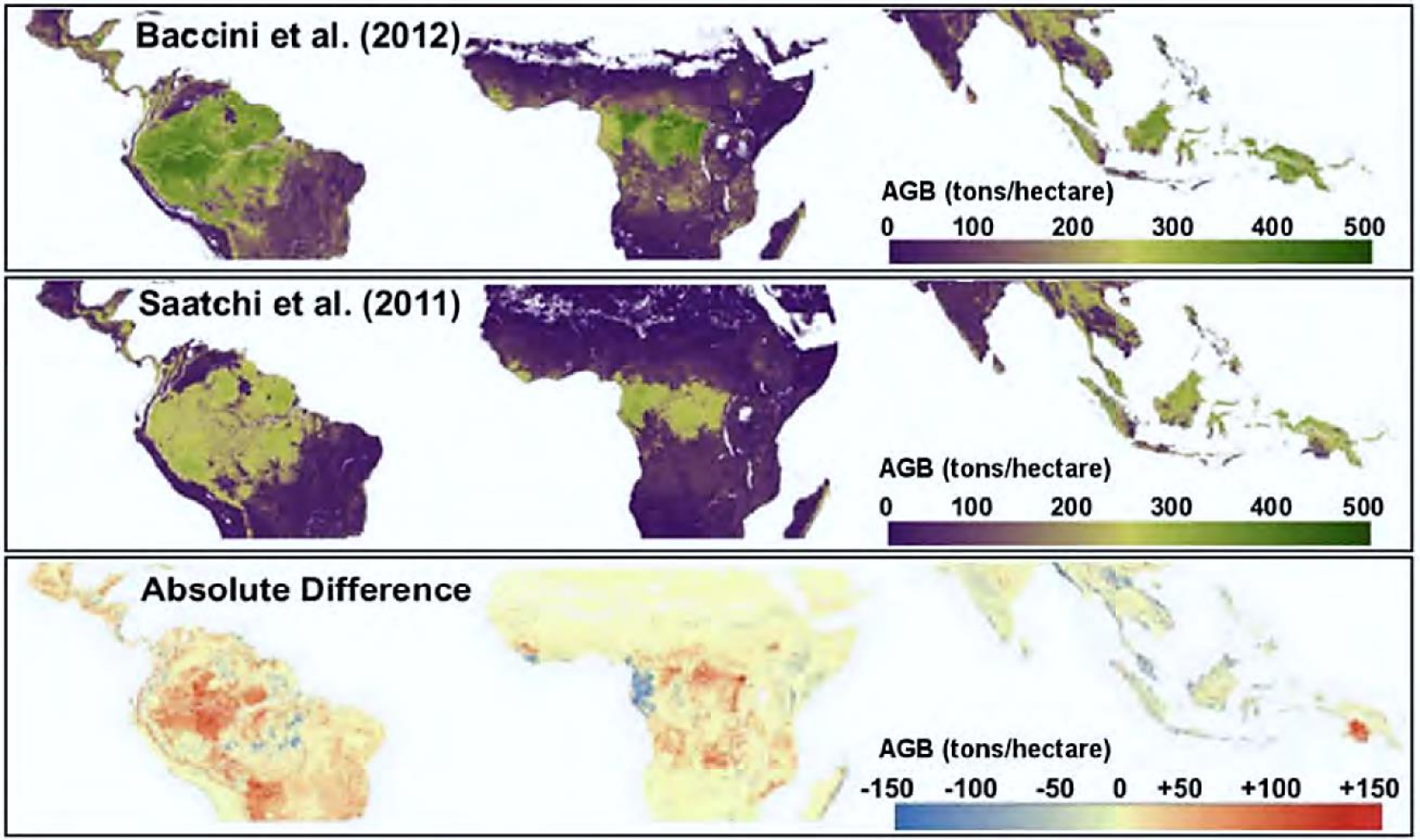


Biosphere


fossil fuel and cement from energy statistics
land use change from data and models
residual land sink
measured atmospheric growth rate
ocean sink from data and models
source
sink
land
~ 30 %
air
~ 40 %
ocean
~ 30 %
from IPCC AR 5, 2013
Annual anthropogenic CO_2 emissions and partitioning (PgC yr^{-1})
10
5
0
5
10
1750
1800
1850
1900
1950
2000
Year

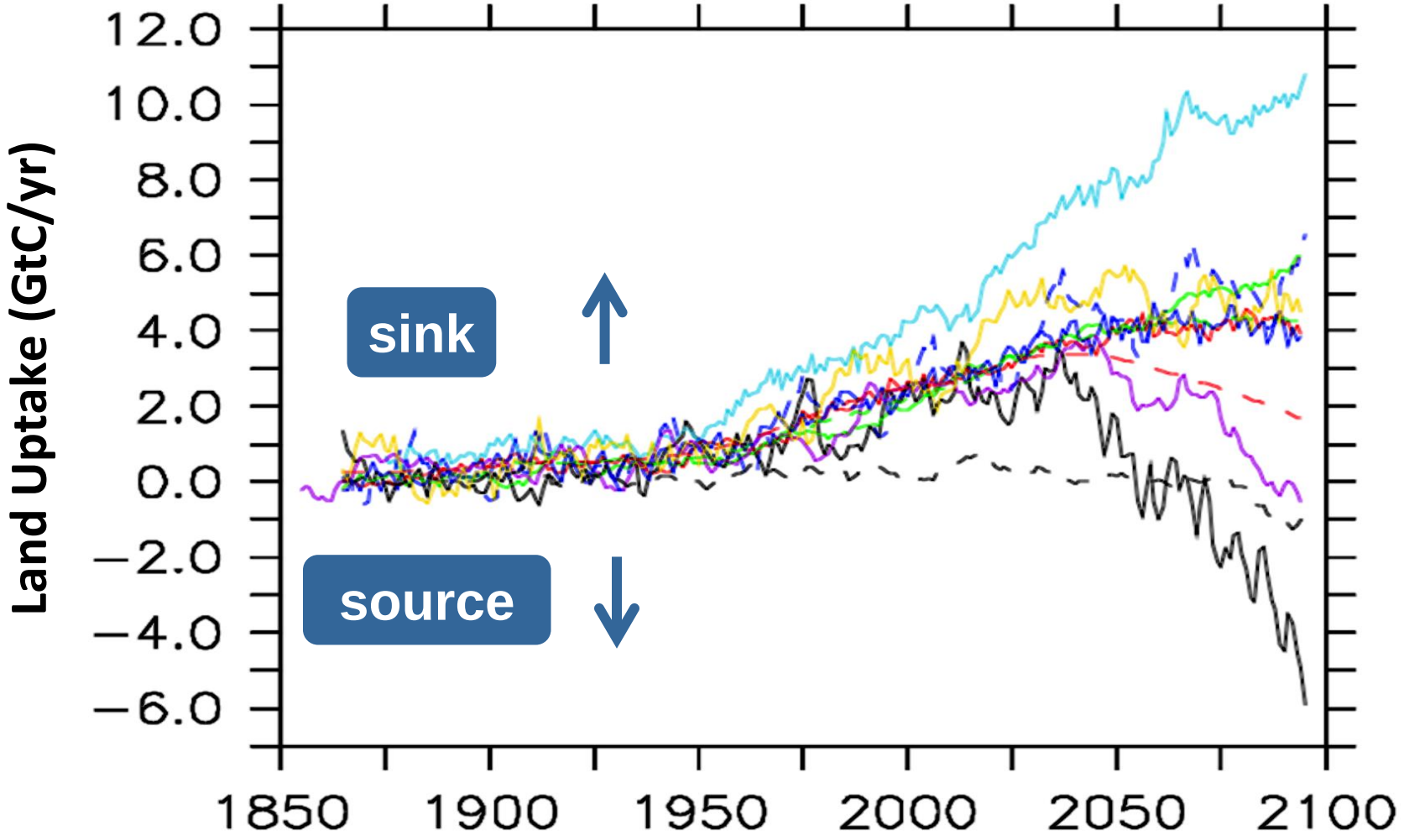
Forest and Carbon

Global biomass distribution and its dynamic are widely unknown!



DLR

Atmospheric CO_2 – Terrestrial Sink / Source

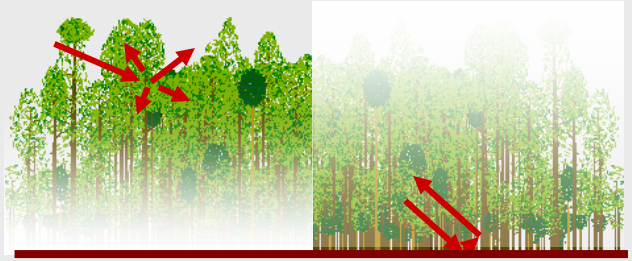


Friedlingstein, P. et al, Journal of Climate, 2014

DLR

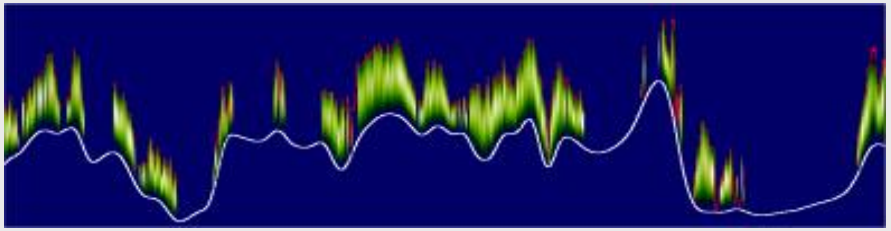
Polarimetric SAR Interferometry

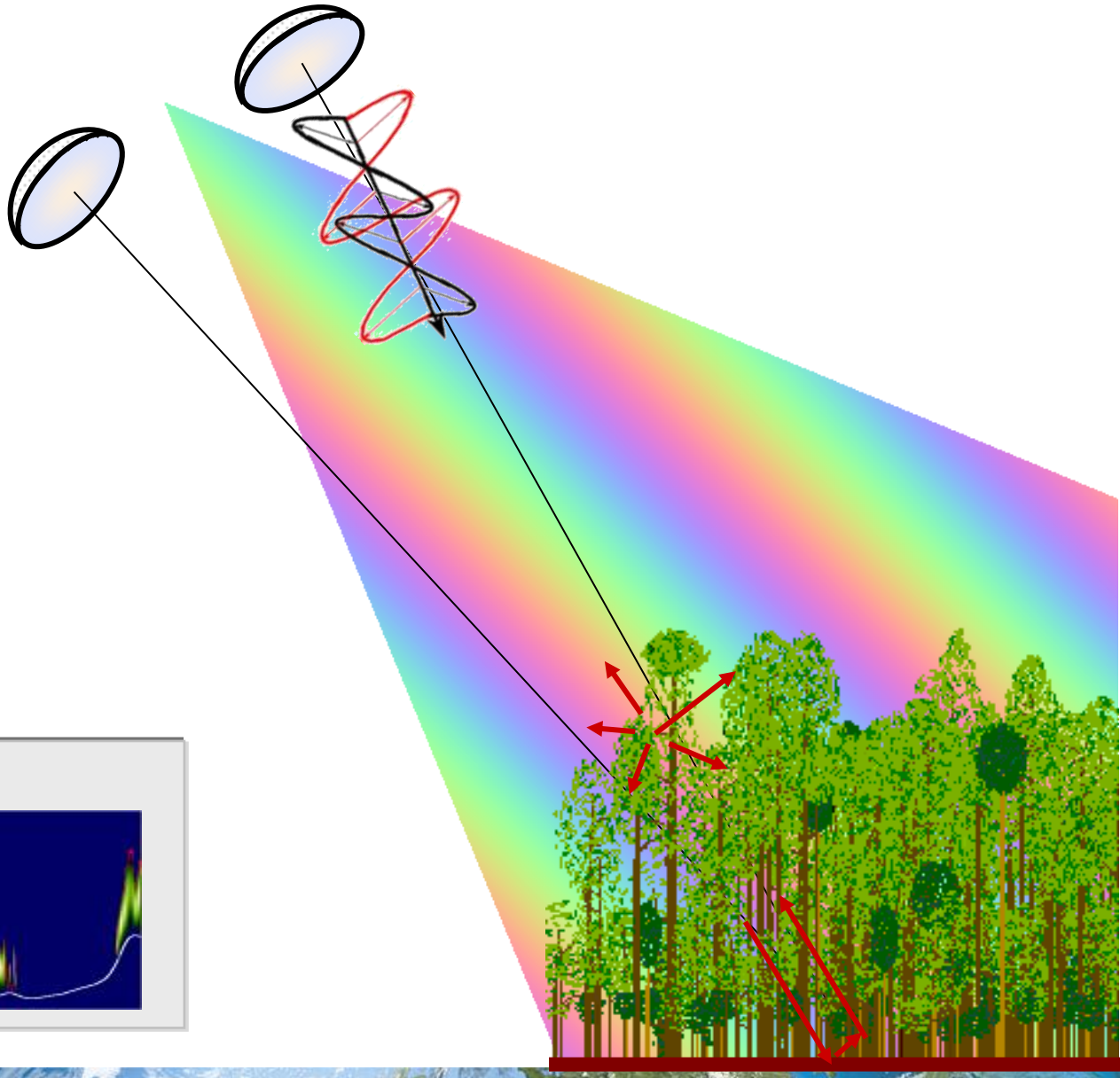
Polarimetric Backscattering



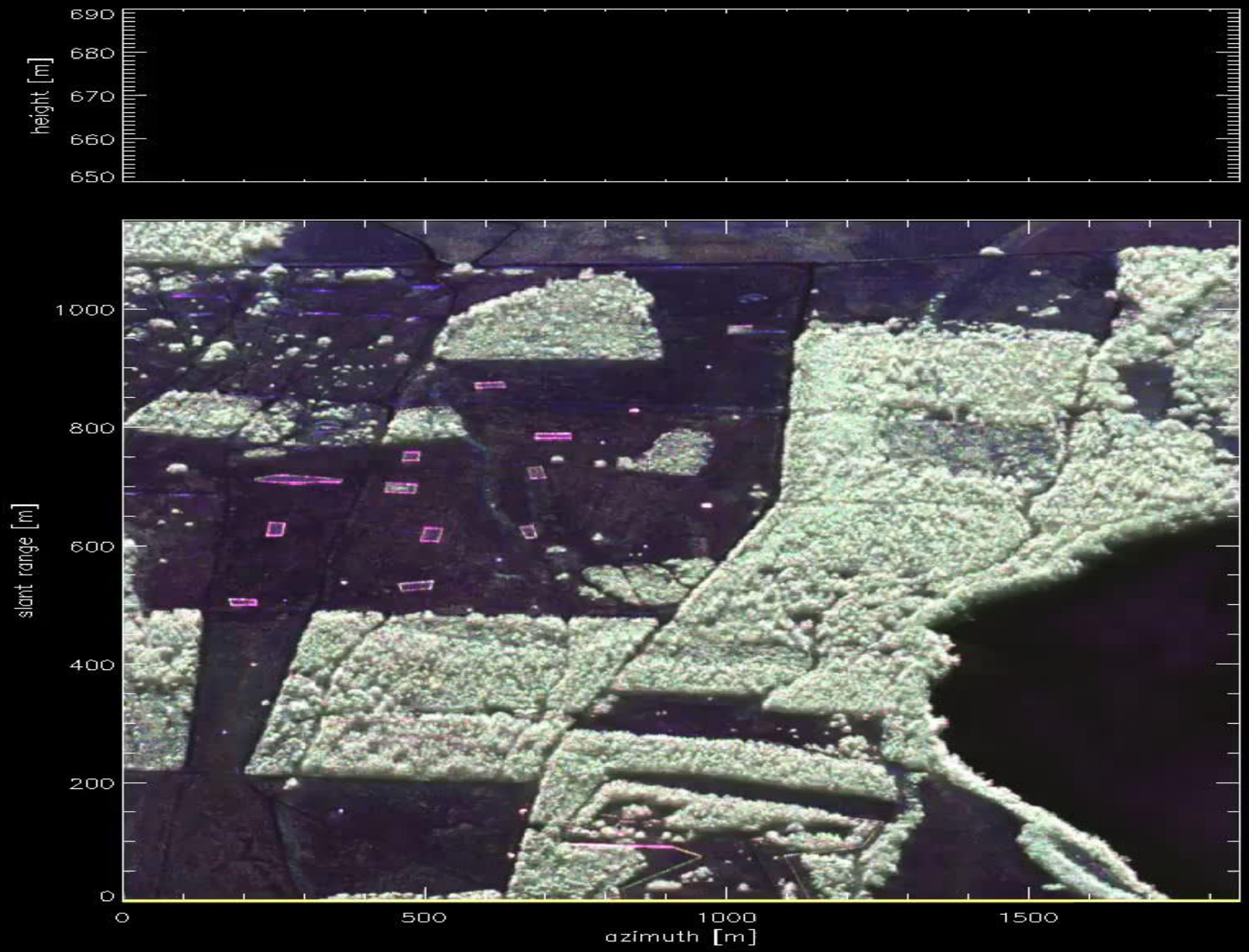
Forest height and Biomass

3-D Forest Structure

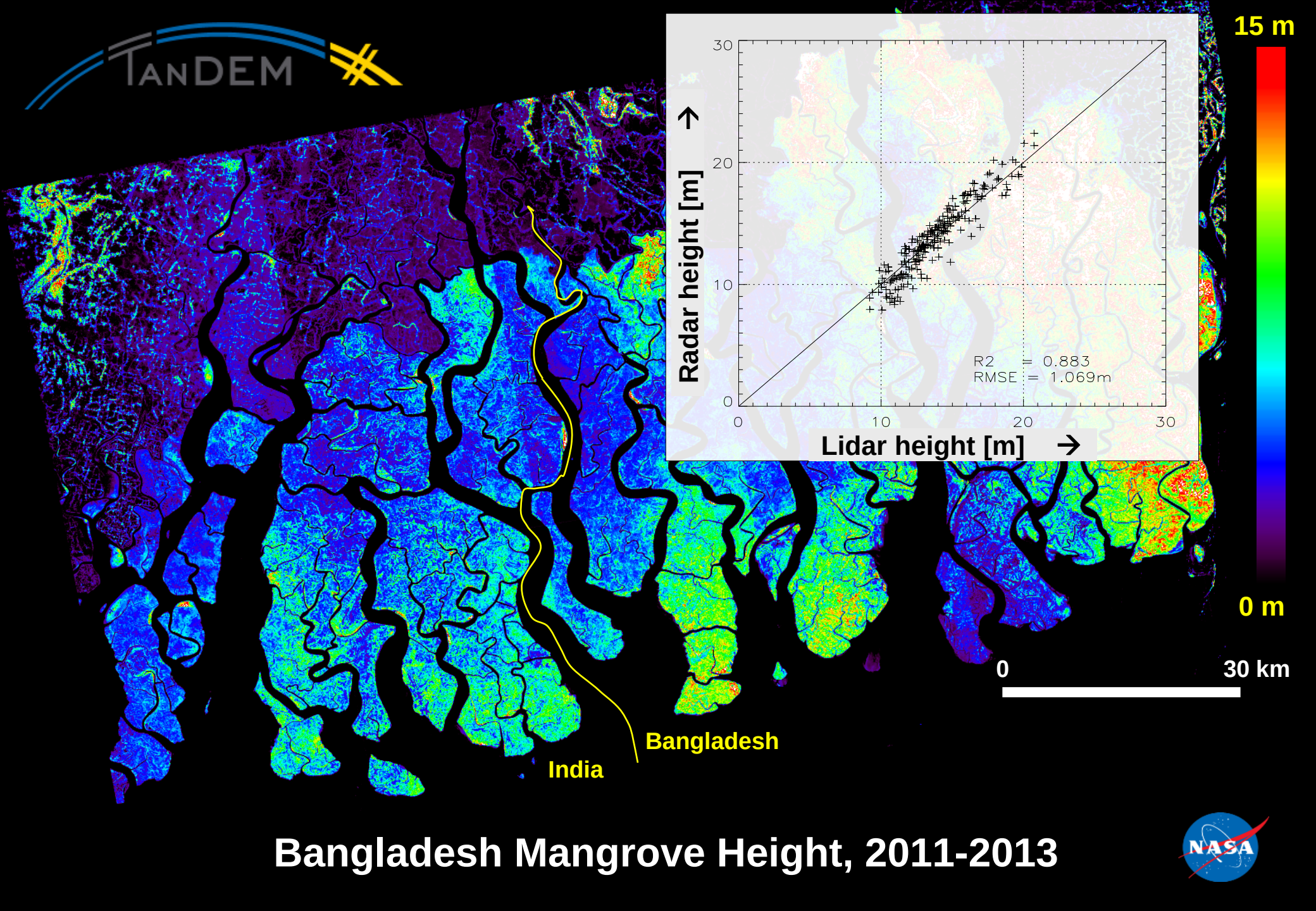




DLR



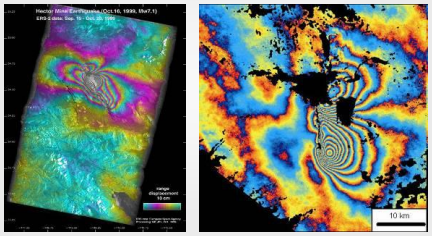
Radar Tomography – Forest Profile in L-band


TanDEM
15 m
0 m
Radar height [m]
Lidar height [m]
0
10
20
30
R2 = 0.883
RMSE = 1.069m
0
30 km
India
Bangladesh
Bangladesh Mangrove Height, 2011-2013
NASA

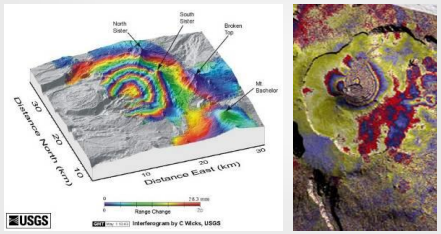
Geosphere

Deformation Mode

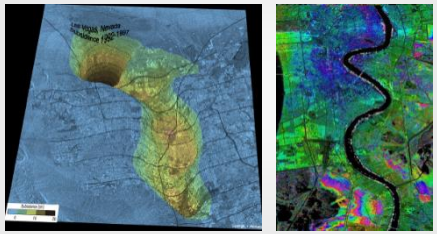
Earthquakes



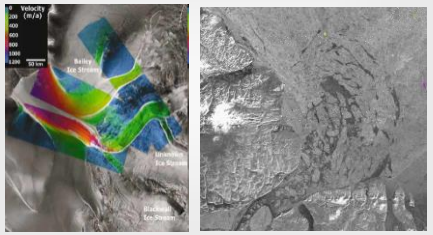
Volcanoes

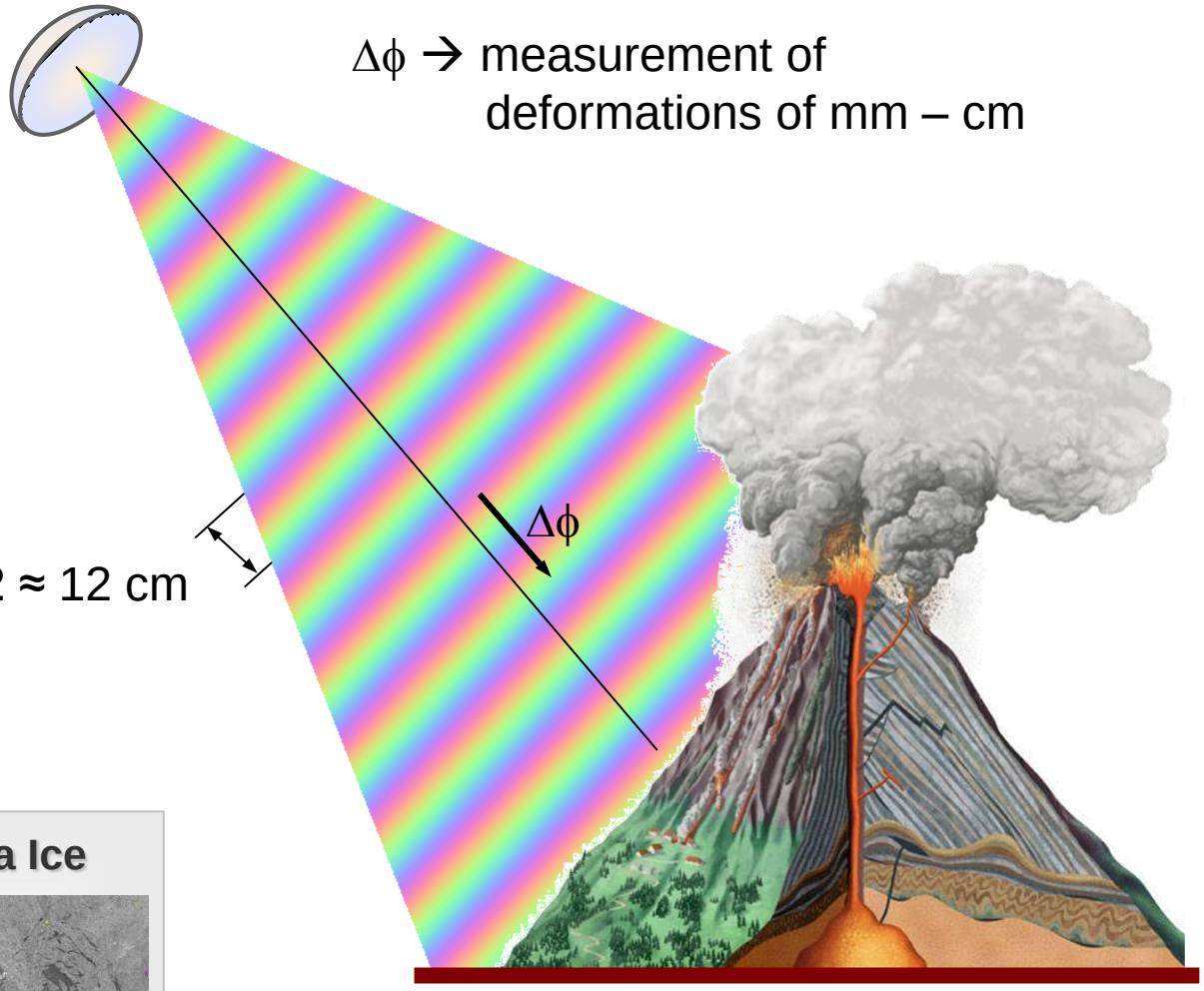


Subsidence



Land & Sea Ice

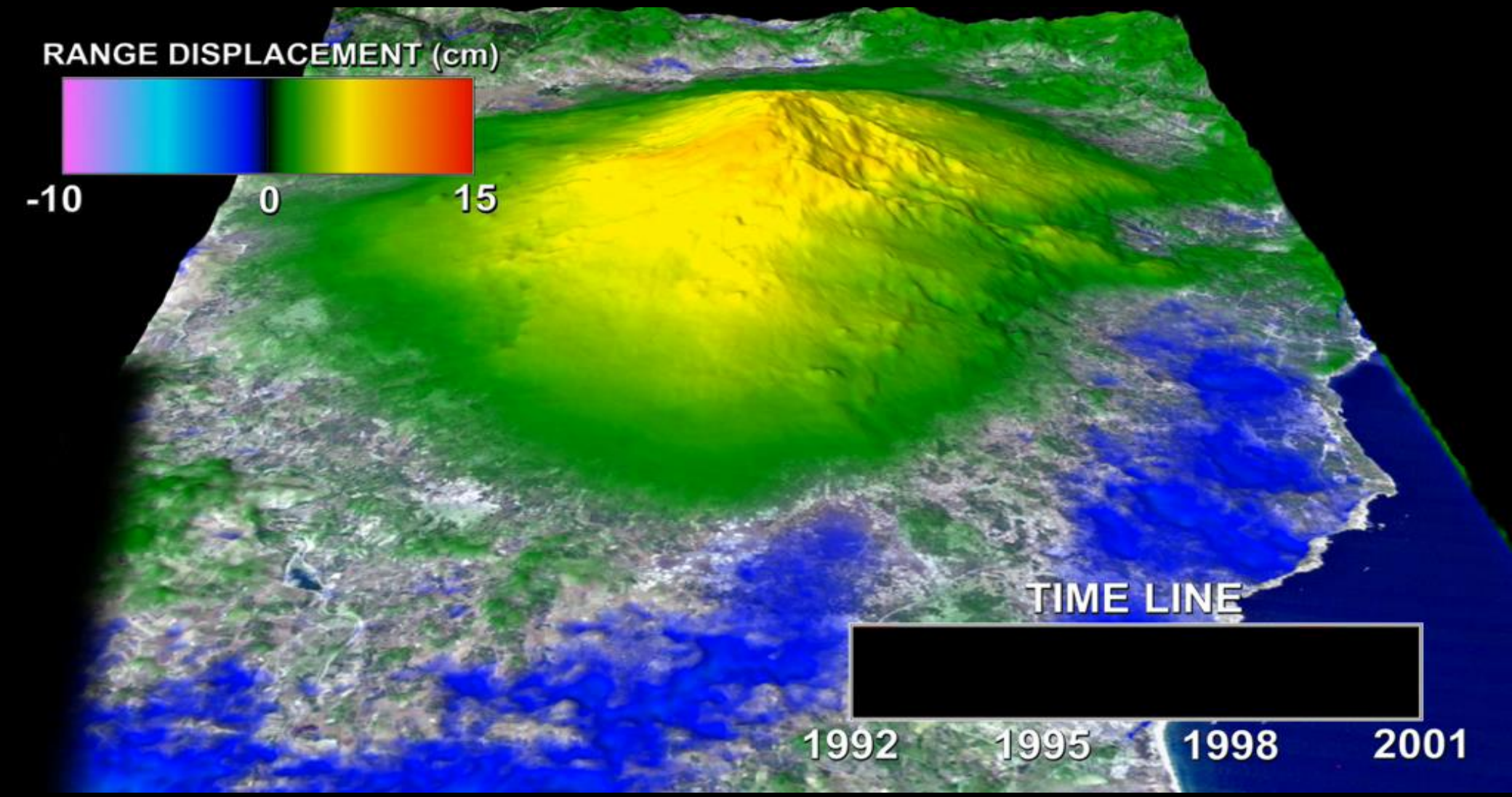




systematic multi-temporal
acquisitions (image stacks)

DLR

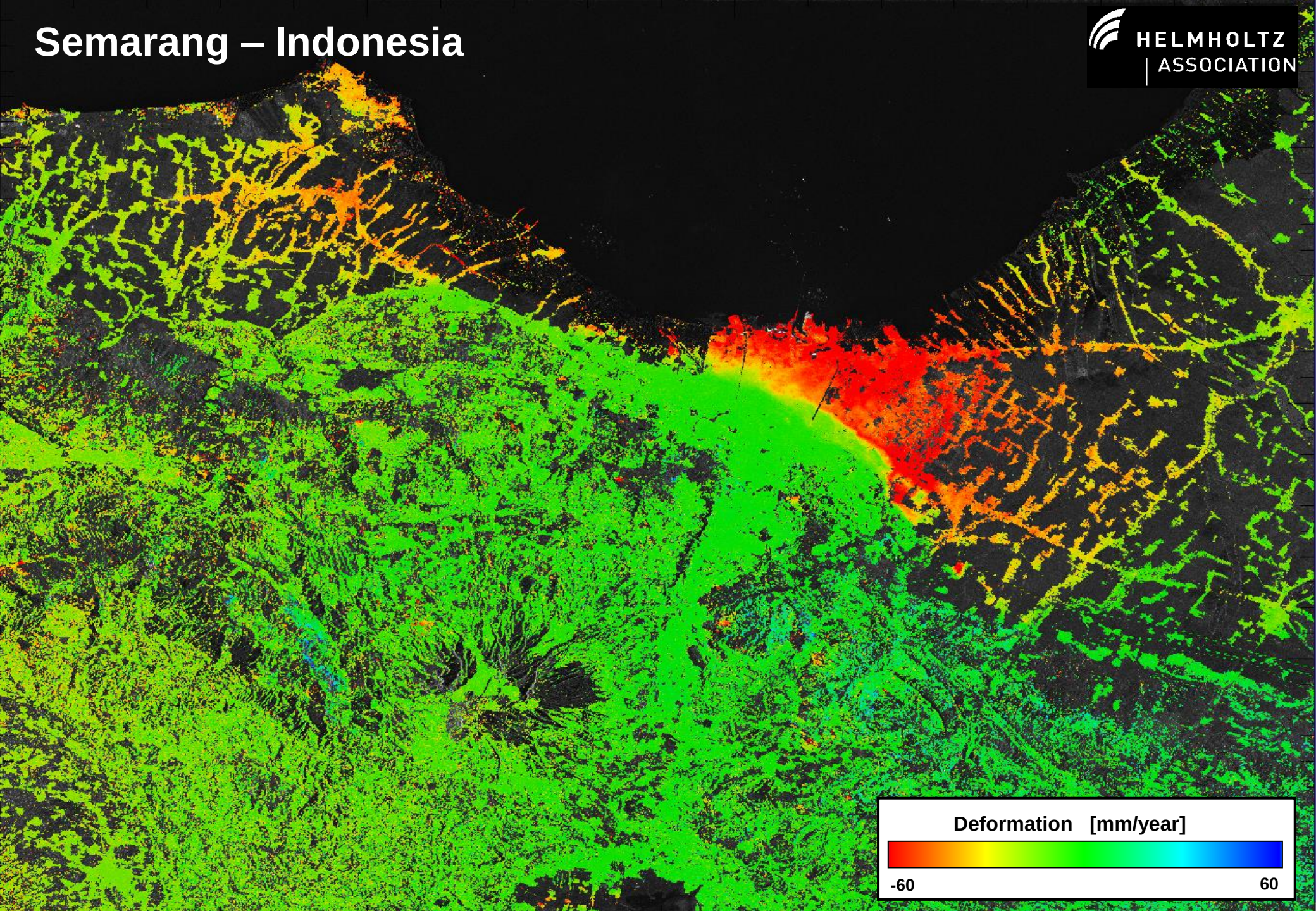
Etna Volcano (1992 - 2001)

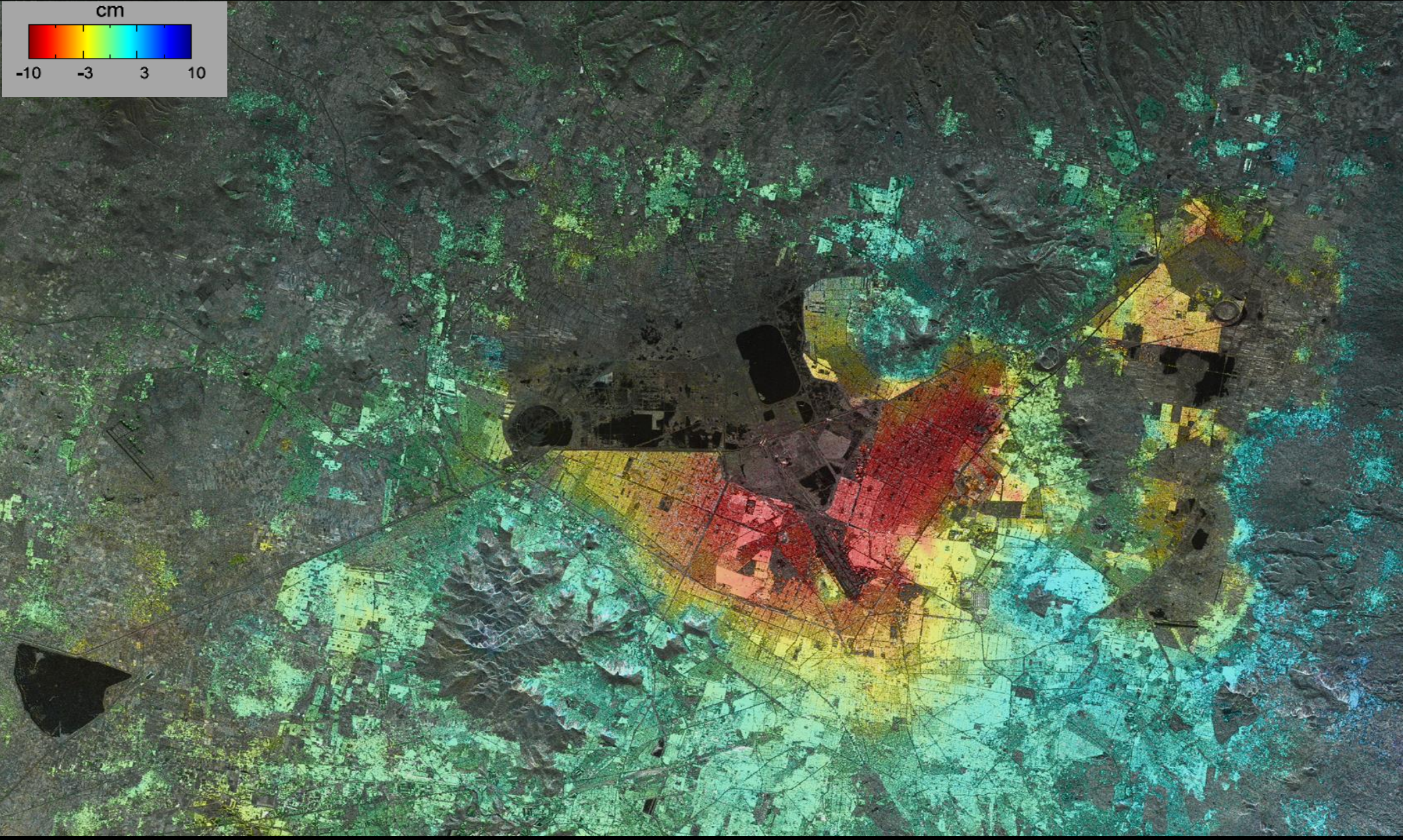


Time series of 200 SAR images (ERS-1/2) *(P. Lundgren, NASA JPL)*

Semarang – Indonesia

HELMHOLTZ ASSOCIATION





Mexico City - Subsidence

TERRA SAR X

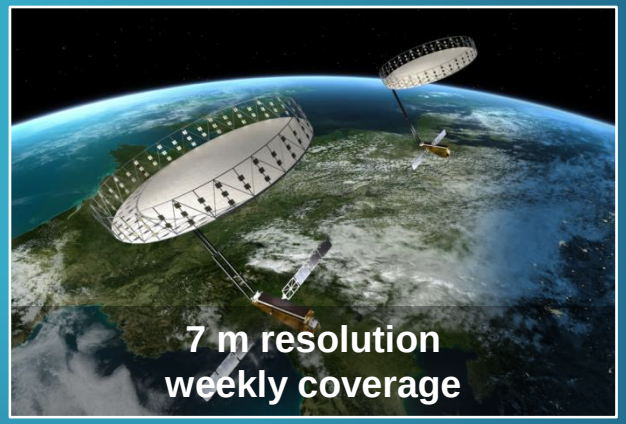
Hydrosphere

Hydrosphere

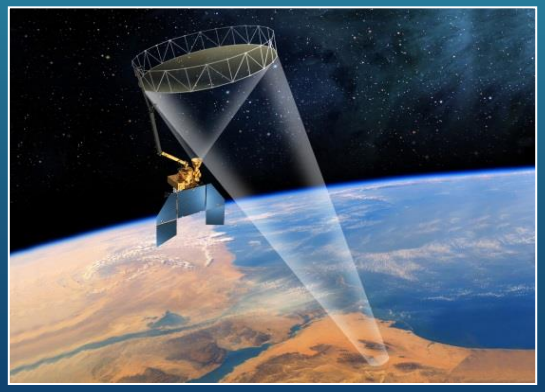
SMOS

35 km resolution

Tandem-L



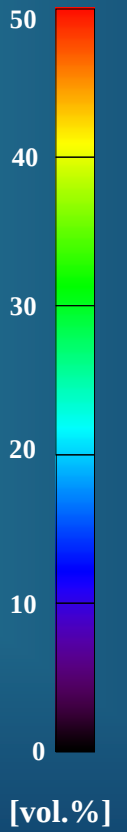
SMAP

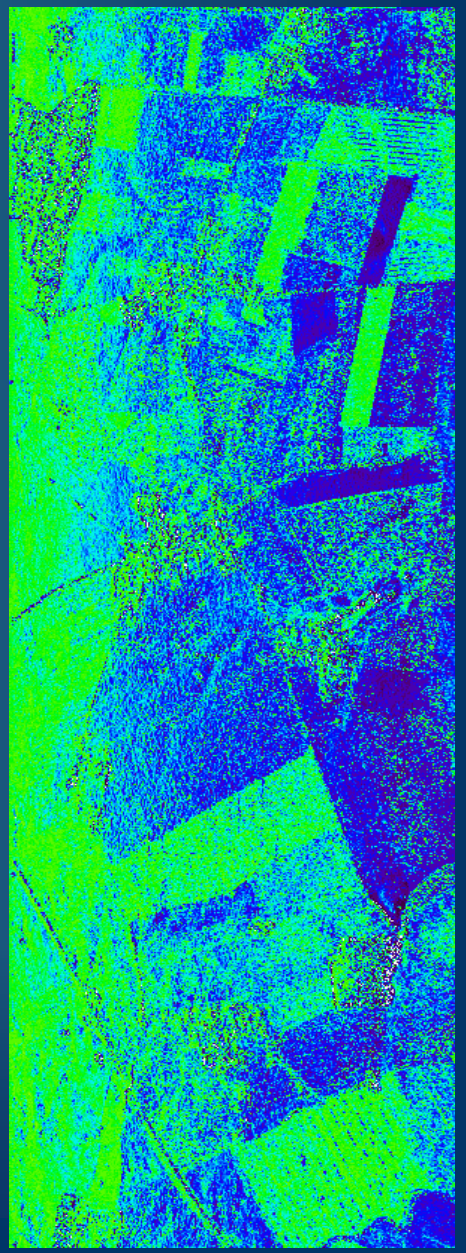


10-40 km resolution

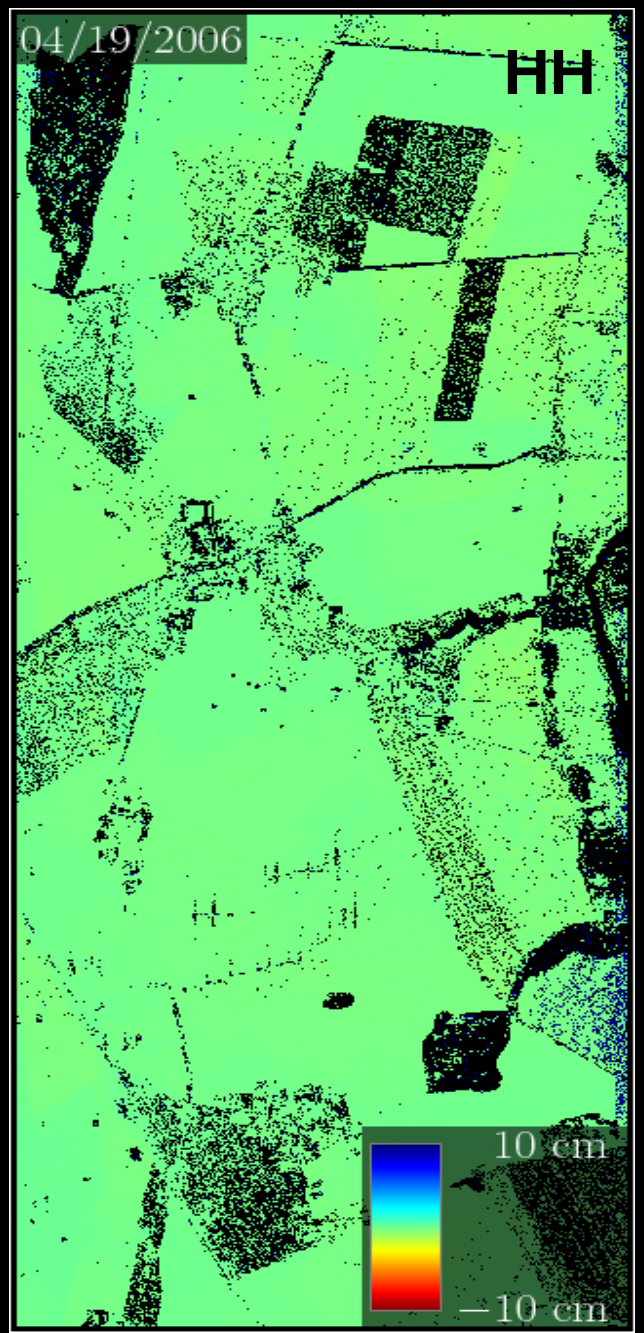
Tandem-L provides unique & complementary information:

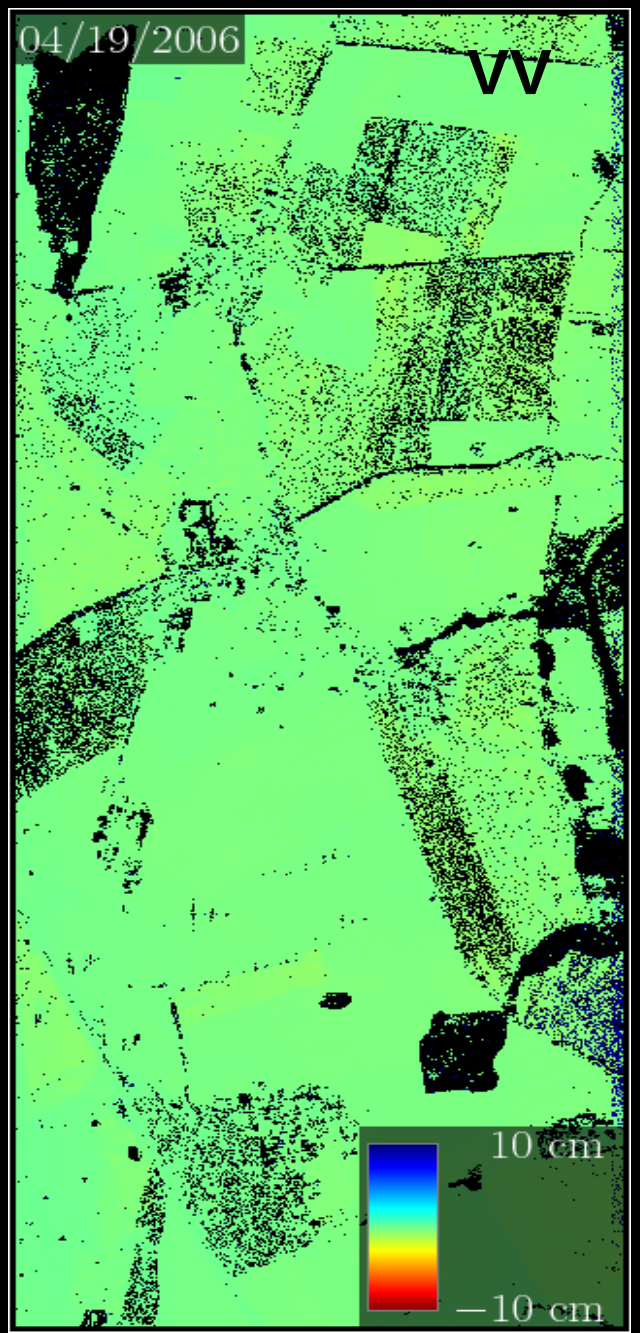
- ***high spatial resolution and frequent coverage***
- ***soil moisture (also below vegetation)***
- ***water level changes and DEMs below vegetation***
- ***ocean waves, wind & currents***

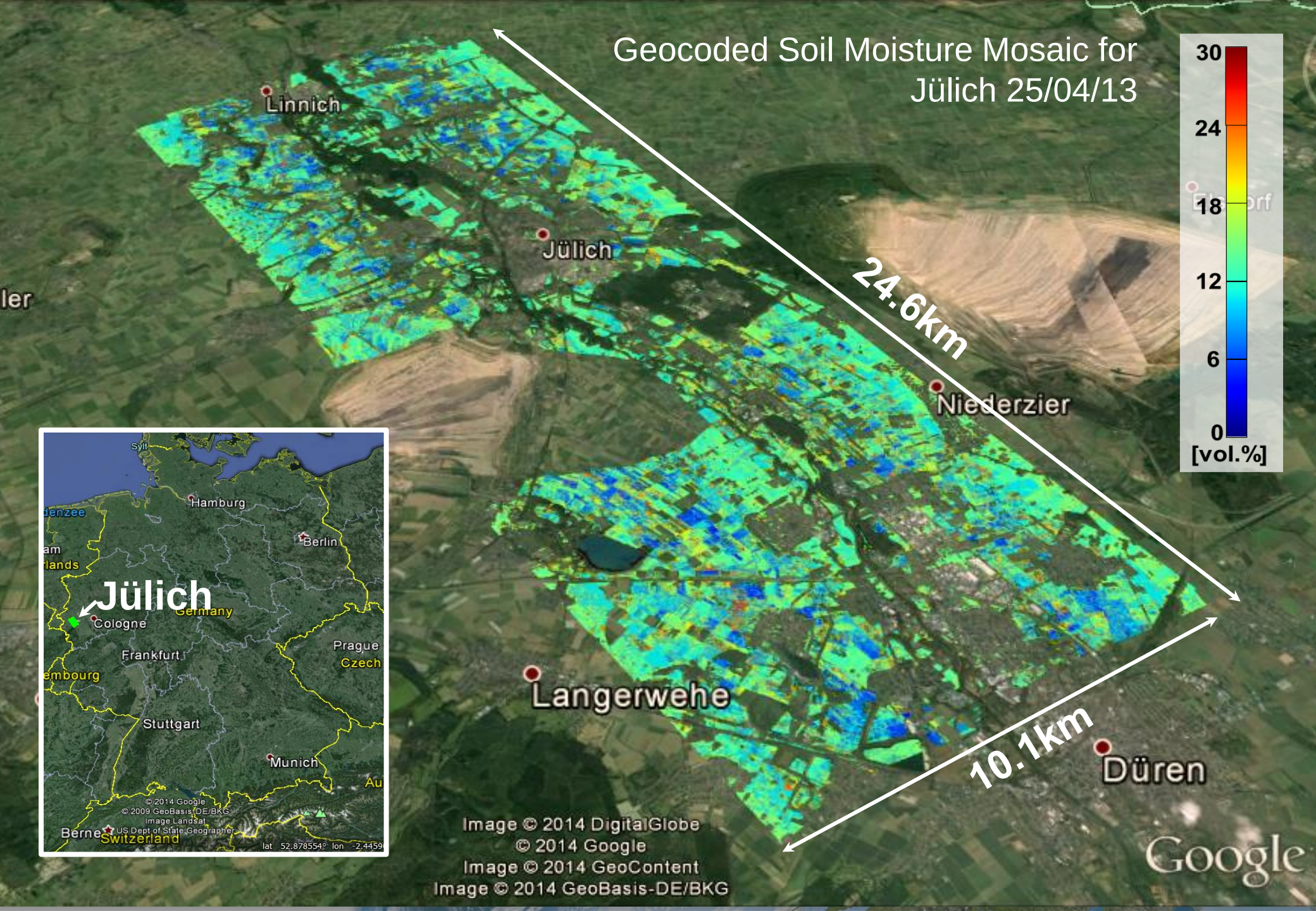




Fully Polarimetric Soil Mapping with High Spatial amd Temporal Resolution

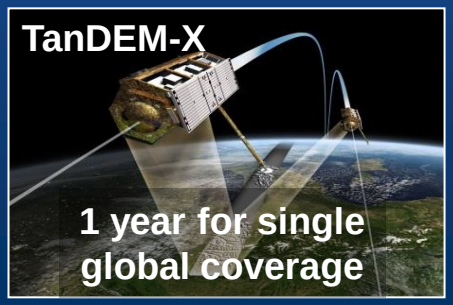


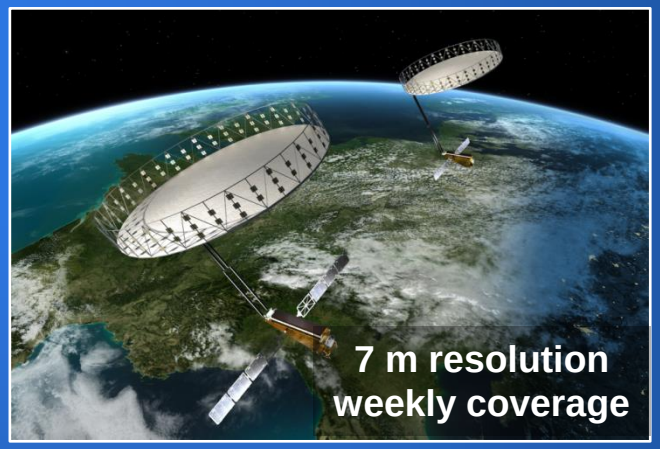



Geocoded Soil Moisture Mosaic for
Jülich 25/04/13
30
24
18
12
6
0
[vol.%]
Linnich
Jülich
Niederzier
Langerwehe
Düren
24.6km
10.1km
Jülich
Germany
Cologne
Frankfurt
Stuttgart
Munich
Hamburg
Berlin
Prague
Czech
Switzerland
Image © 2014 DigitalGlobe
© 2014 Google
Image © 2014 GeoContent
Image © 2014 GeoBasis-DE/BKG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

Cryosphere

Cryosphere

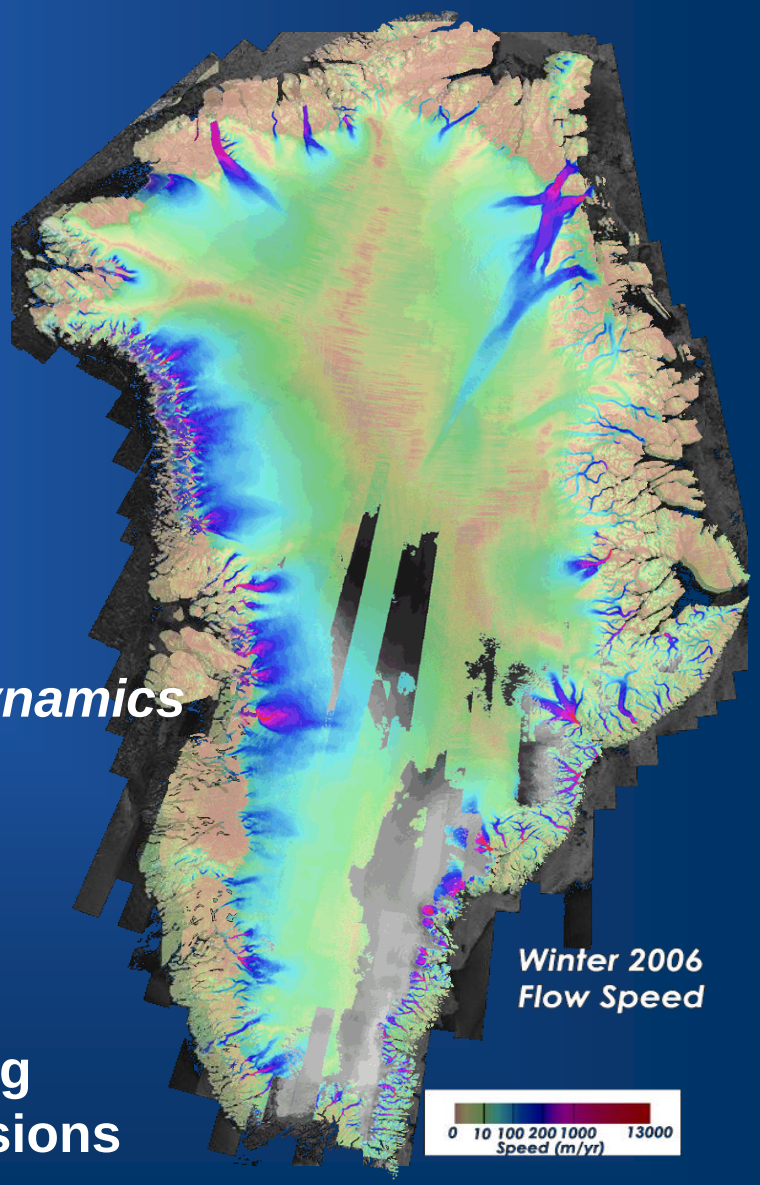


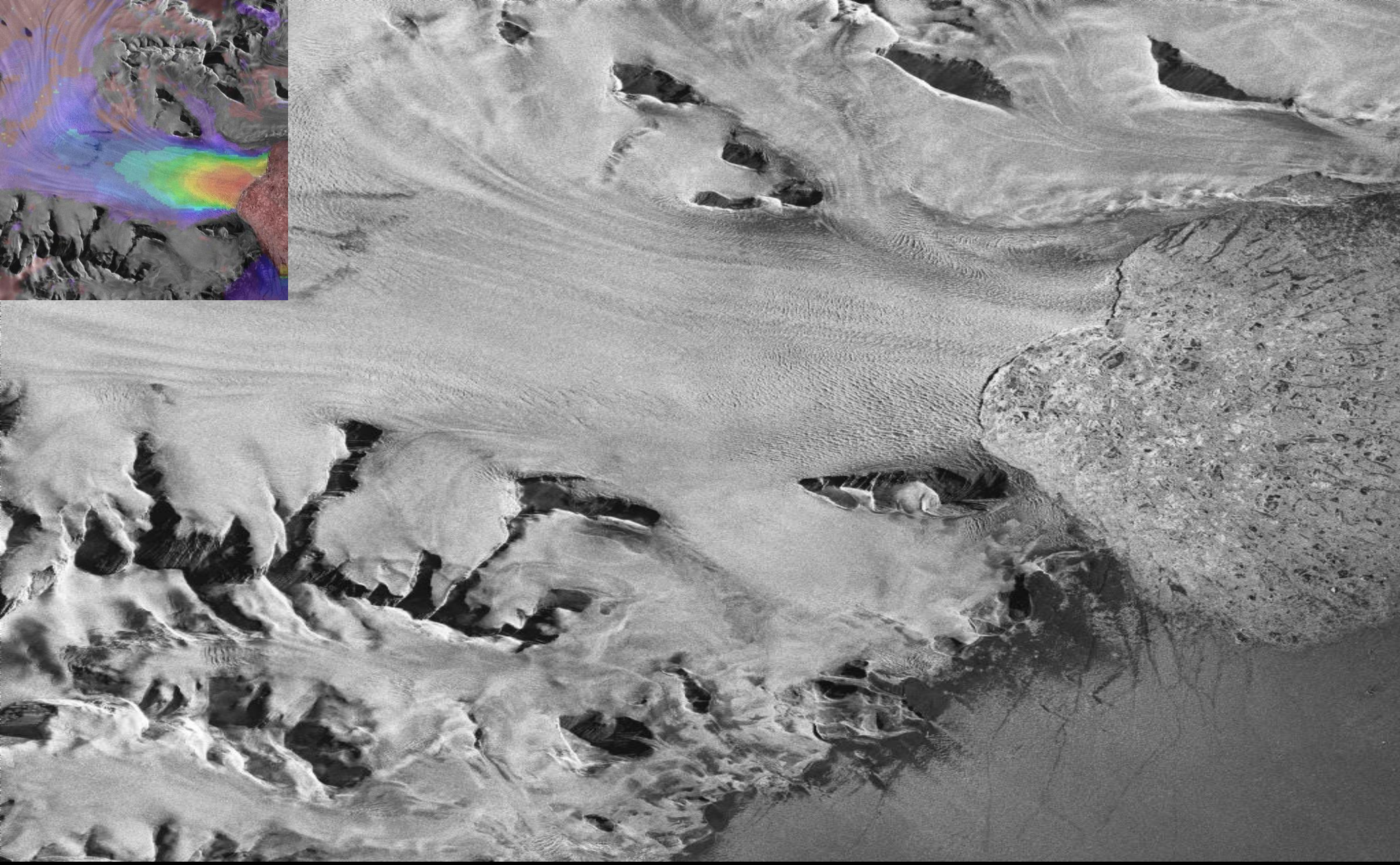


Tandem-L provides unique information:

- *glacier flow in 3-D*
- *3-D ice structure and its dynamics*
- *DEMs mit high spatial and temporal resolution*
- *thaw and freeze cycles*
- *sea ice classification*

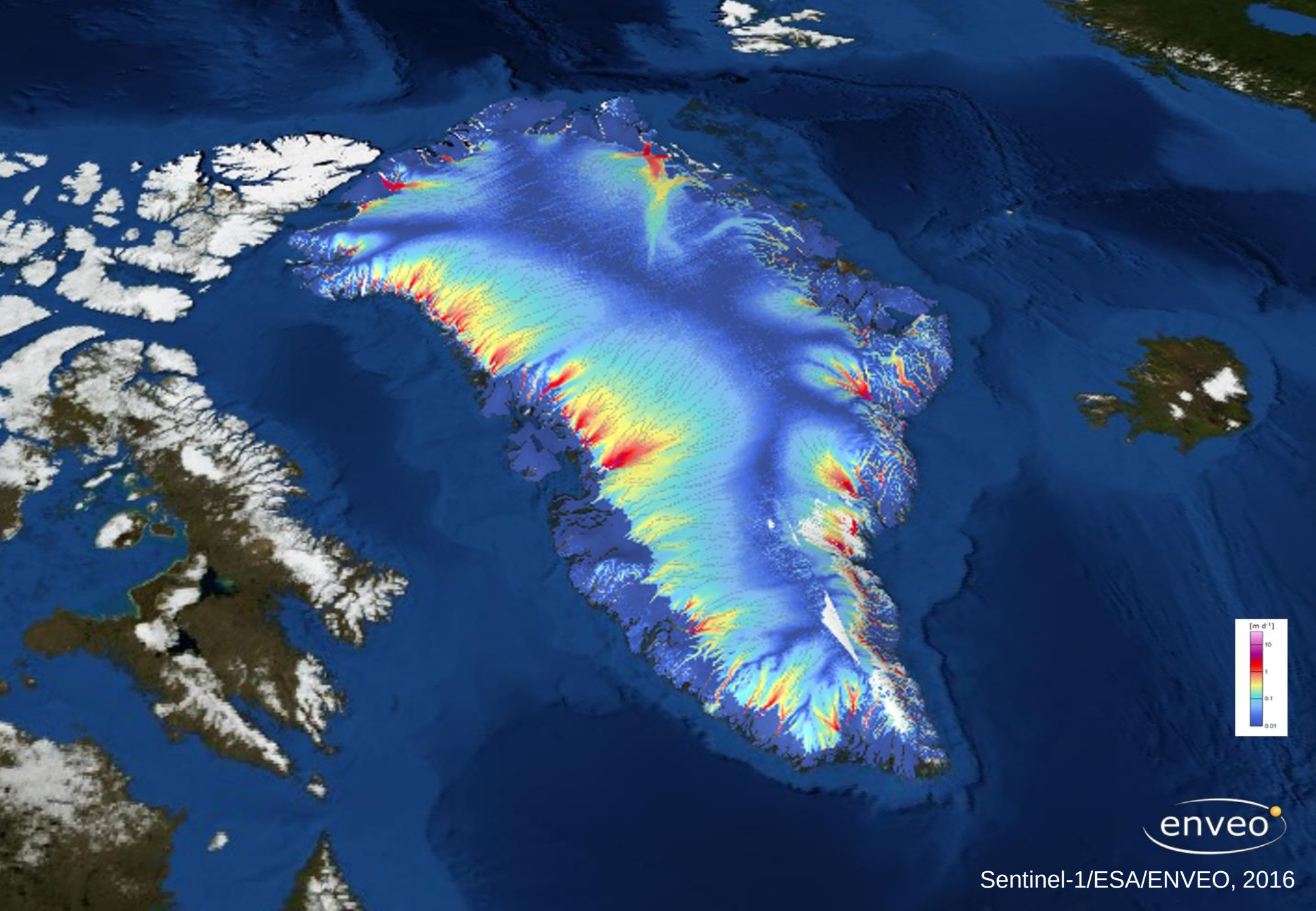
→ **ideal complement to existing or planned cryosphere missions**





Drygalski Glacier, Oct 2007 – July 2008

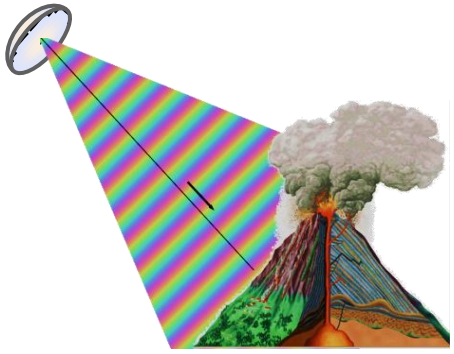
TERRA SAR X

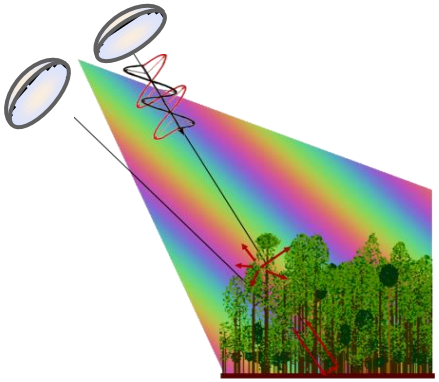


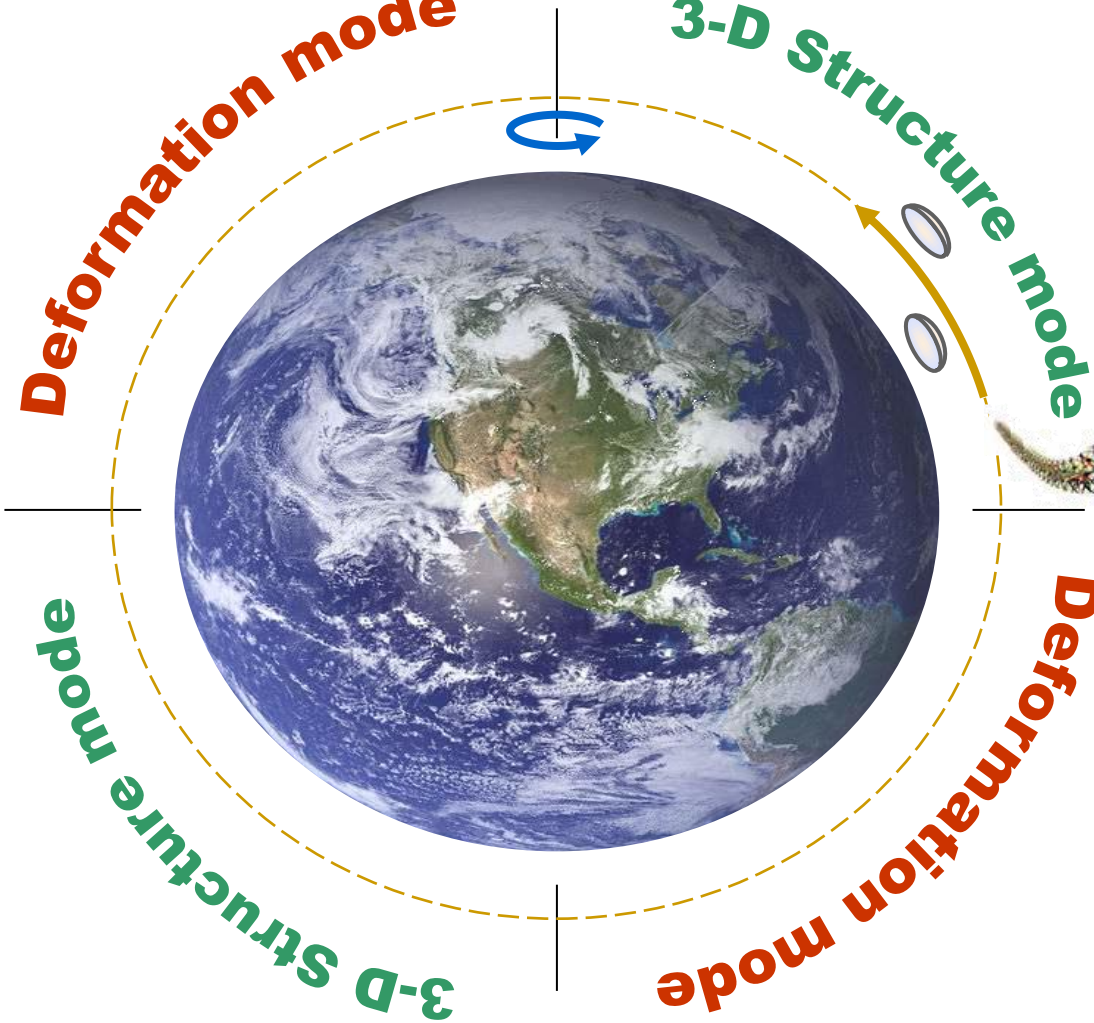
Sentinel-1/ESA/ENVEO, 2016

Tandem-L: Radar Mission Concept

Mission Concept



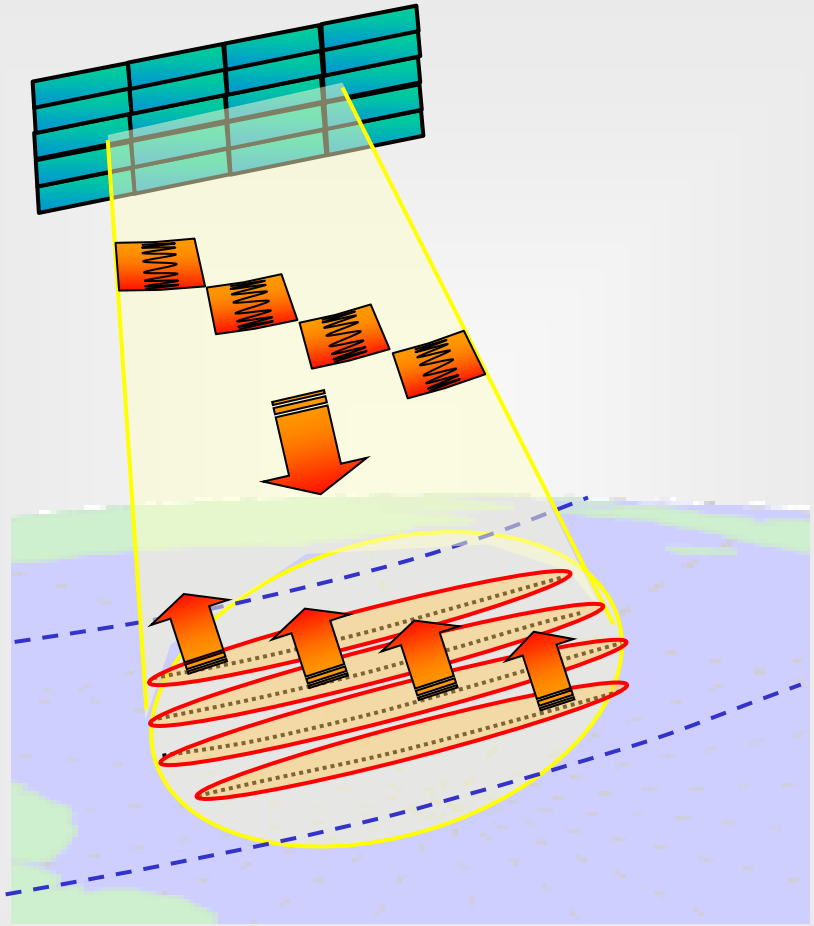




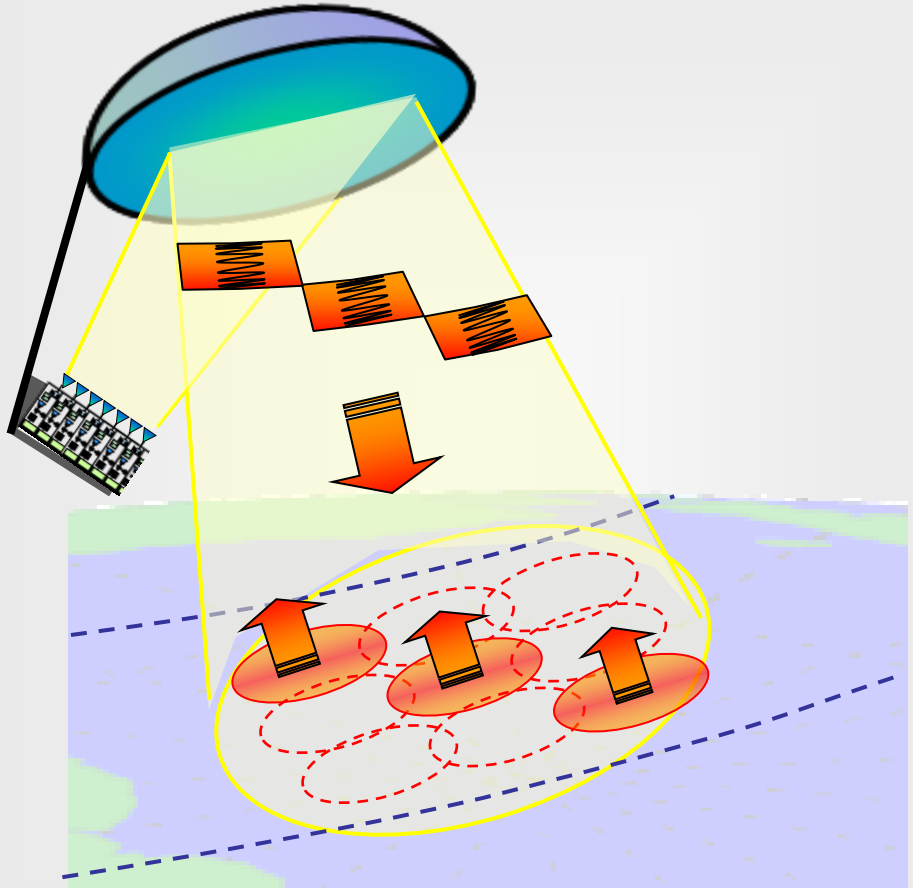
DLR

Digital Beamforming

Direct Radiating Arrays

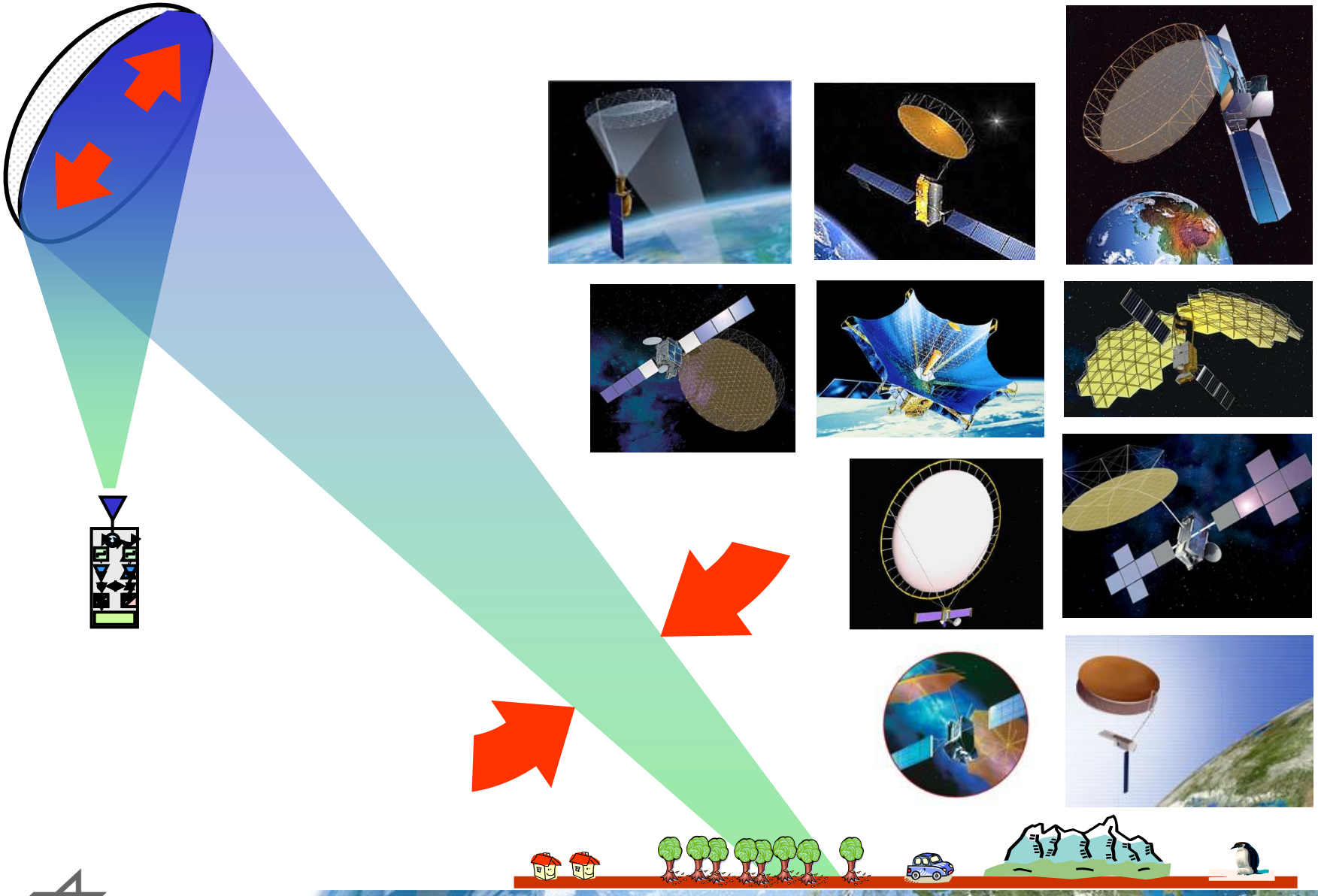


Reflectors with Digital Feed Array

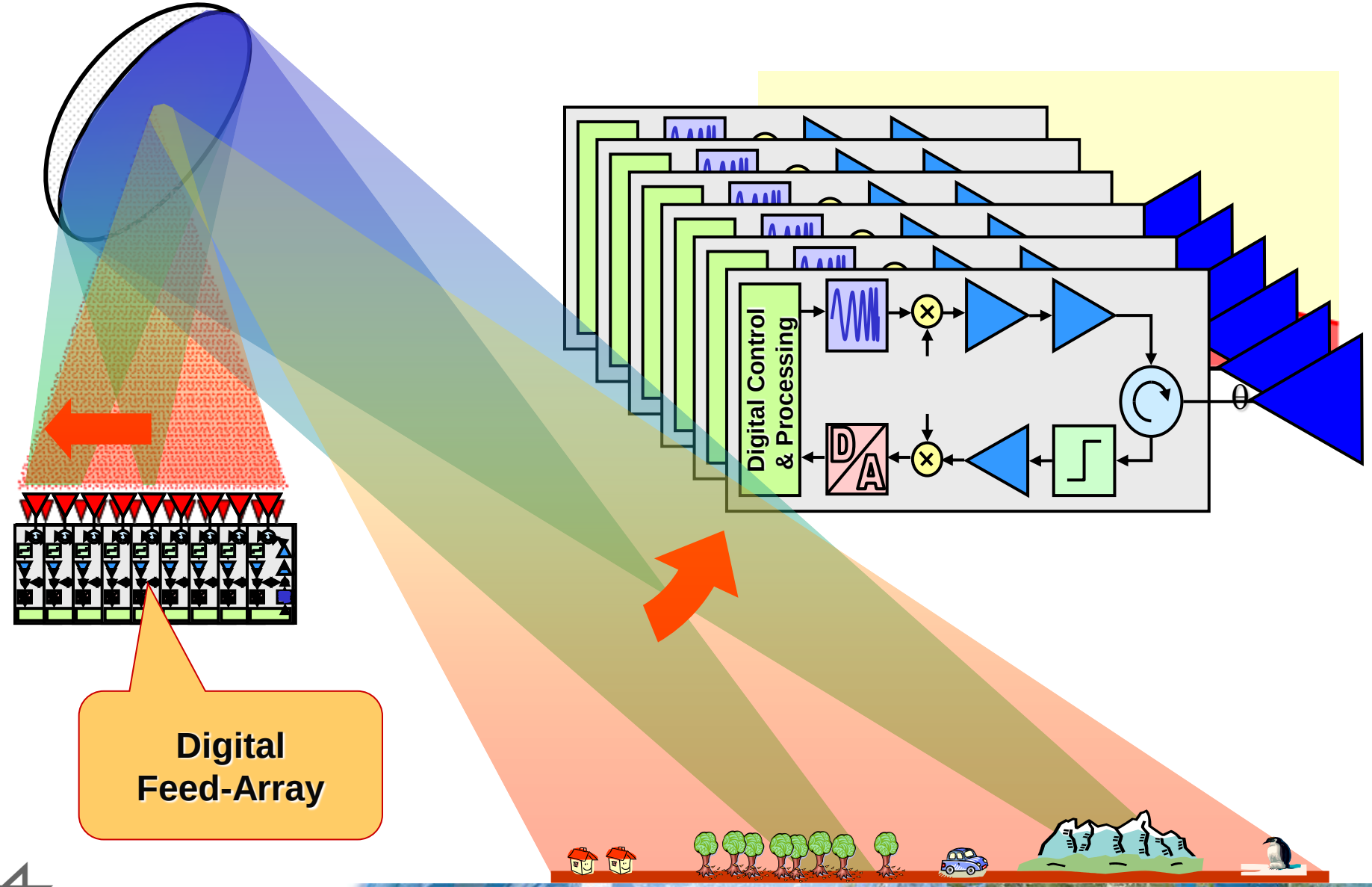


DLR

Digital Beamforming with Large Reflector Antenna



Digital Beamforming with Large Reflector Antenna



DLR

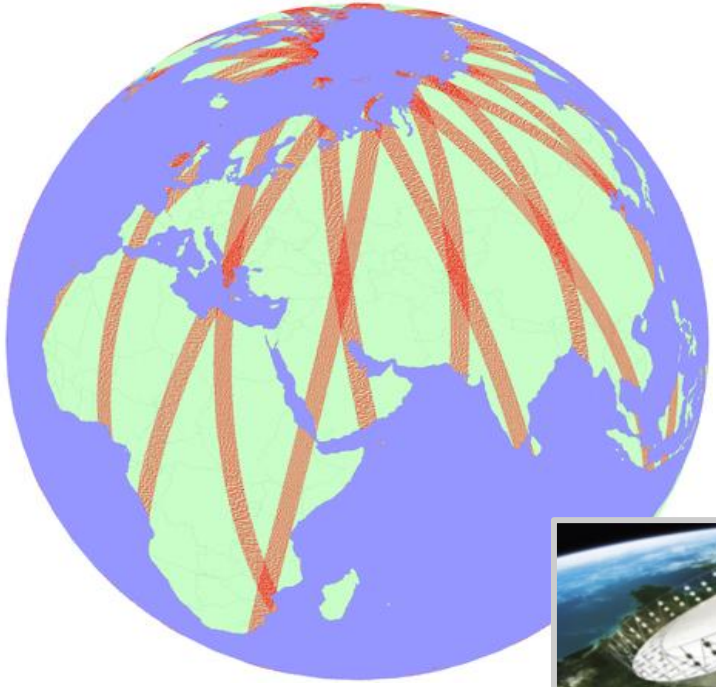
Comparison of Imaging Capacity

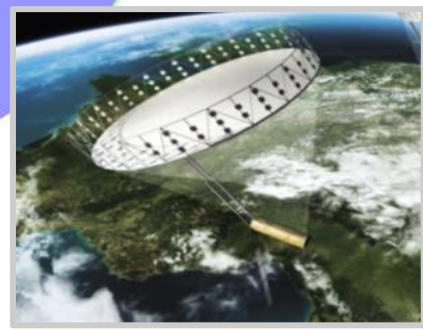
TerraSAR-X/TanDEM-X

1 global coverage / year

Digital Beamforming

2 global coverages / week



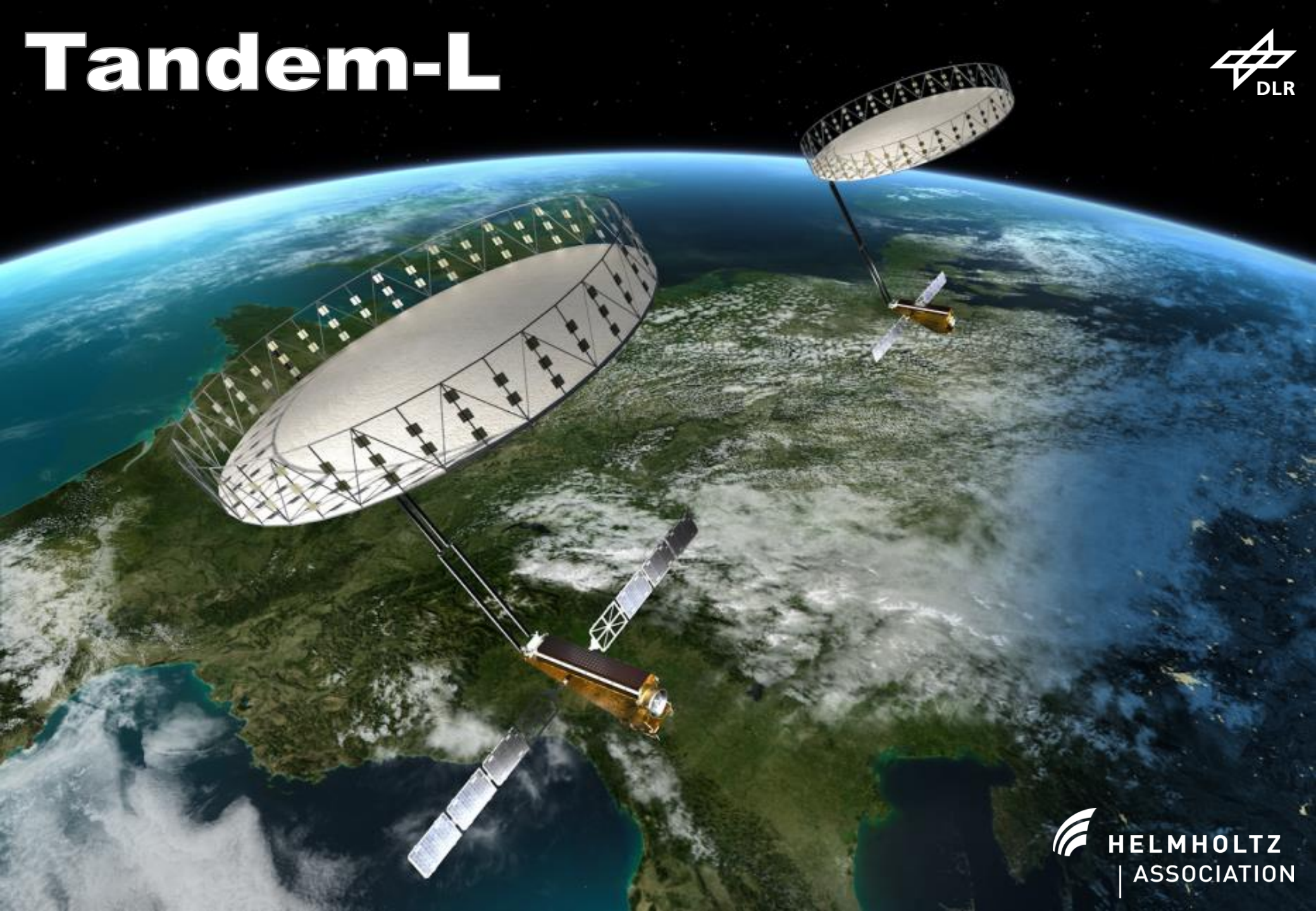


1

Days

DLR

Tandem-L



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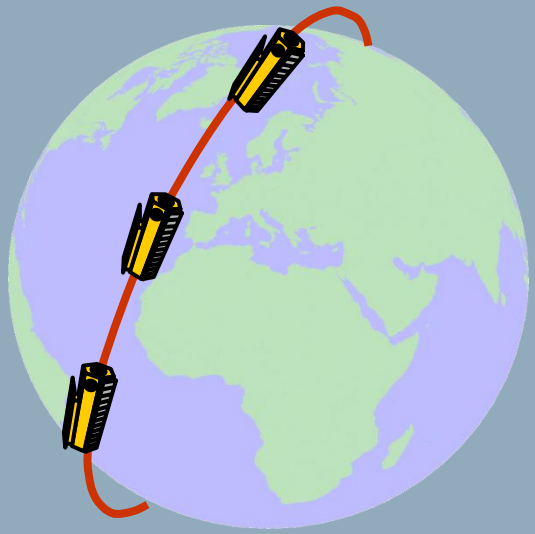
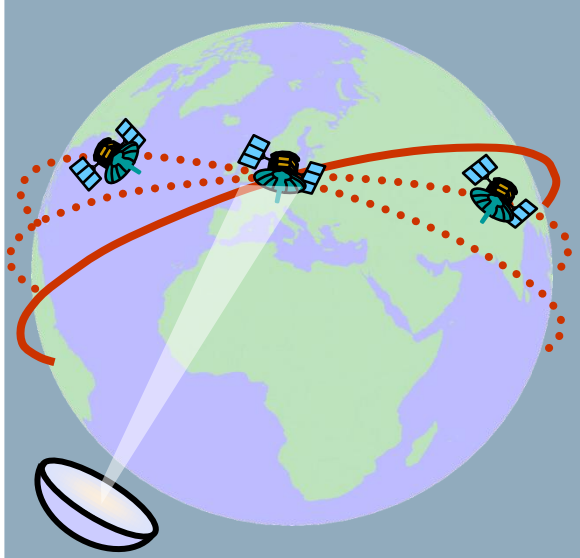
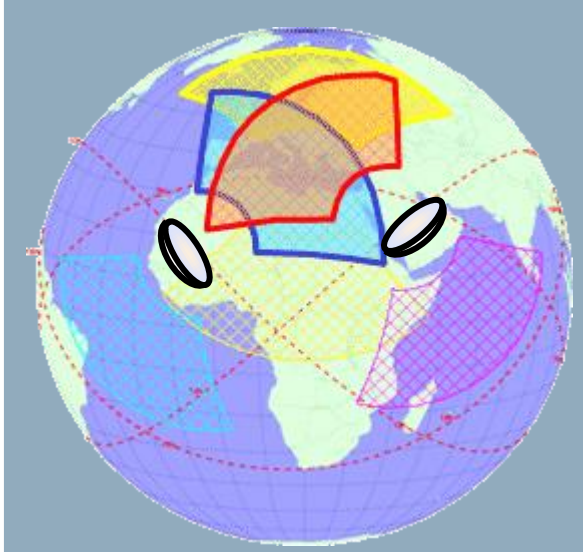
HELMHOLTZ
ASSOCIATION

Future Spaceborne Radar System Concepts

Low Earth Orbit (LEO) Satellites	Geostationary Illuminator (GEO) and LEO Receivers	Medium Earth Orbit (MEO) Satellites
		

Vision of a Websensor for Climate and Environment

DLR

The Golden Age for Spaceborne Radar!