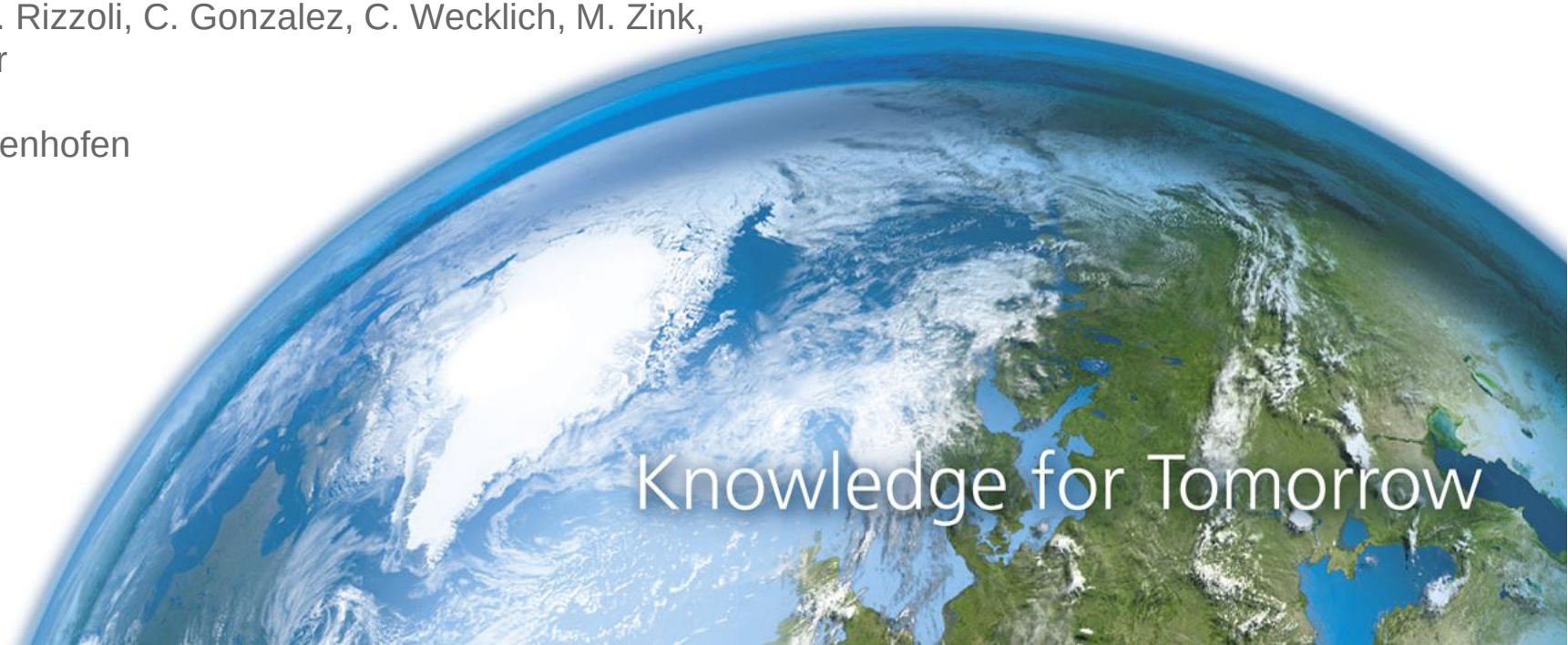
A Decade of TerraSAR-X and TanDEM-X Operation: A Retrospective on the Performance of the SAR Systems and an Outlook to the Future

A. Bojarski, M. Bachmann, J. Böer, P. Rizzoli, C. Gonzalez, C. Wecklich, M. Zink,
S. Buckreuss, M. Martone, G. Krieger

German Aerospace Center Oberpfaffenhofen
Microwave and Radar Institute

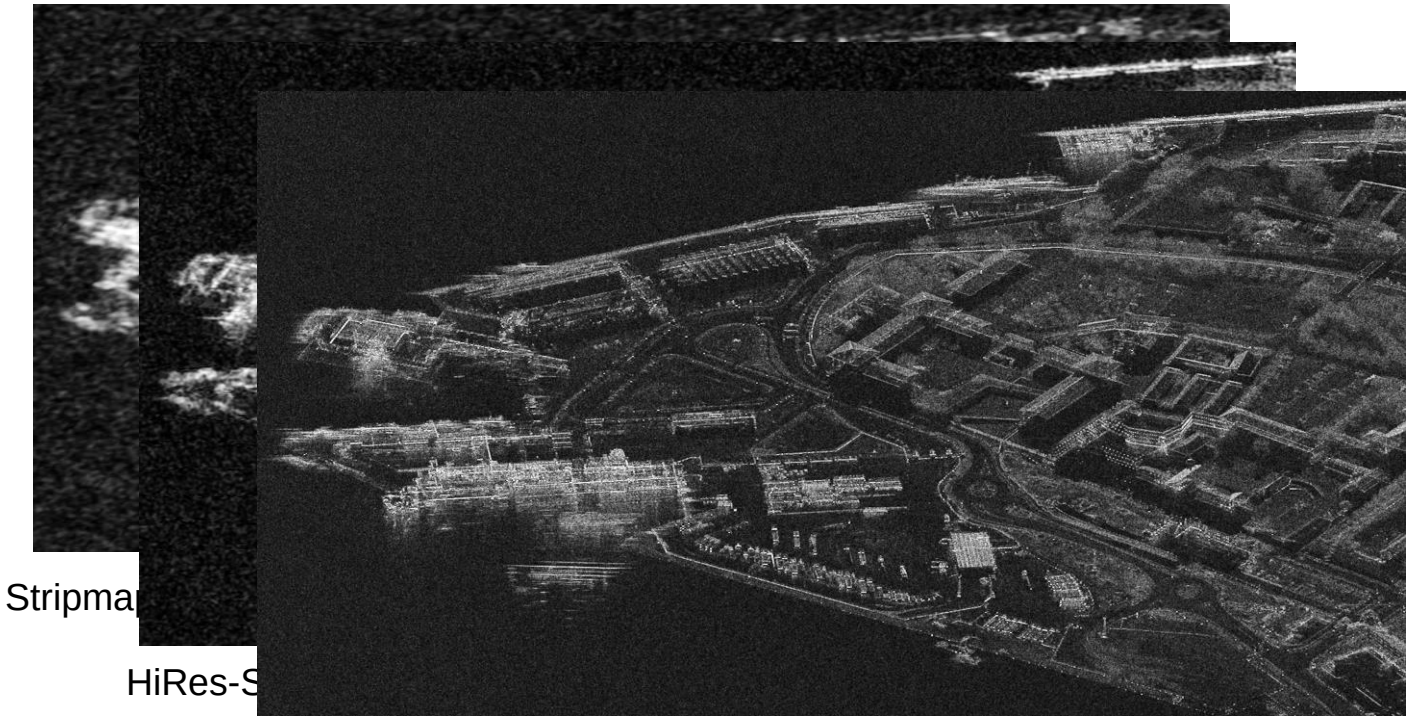


Outline

1. TerraSAR-X mission
    a. TSX/TDX introduction
    b. System monitoring
    c. Radiometric stability
2. TanDEM-X mission
    a. Global DEM quality
    b. Change DEM
3. Future missions
    a. Tandem-L
    b. HRWS

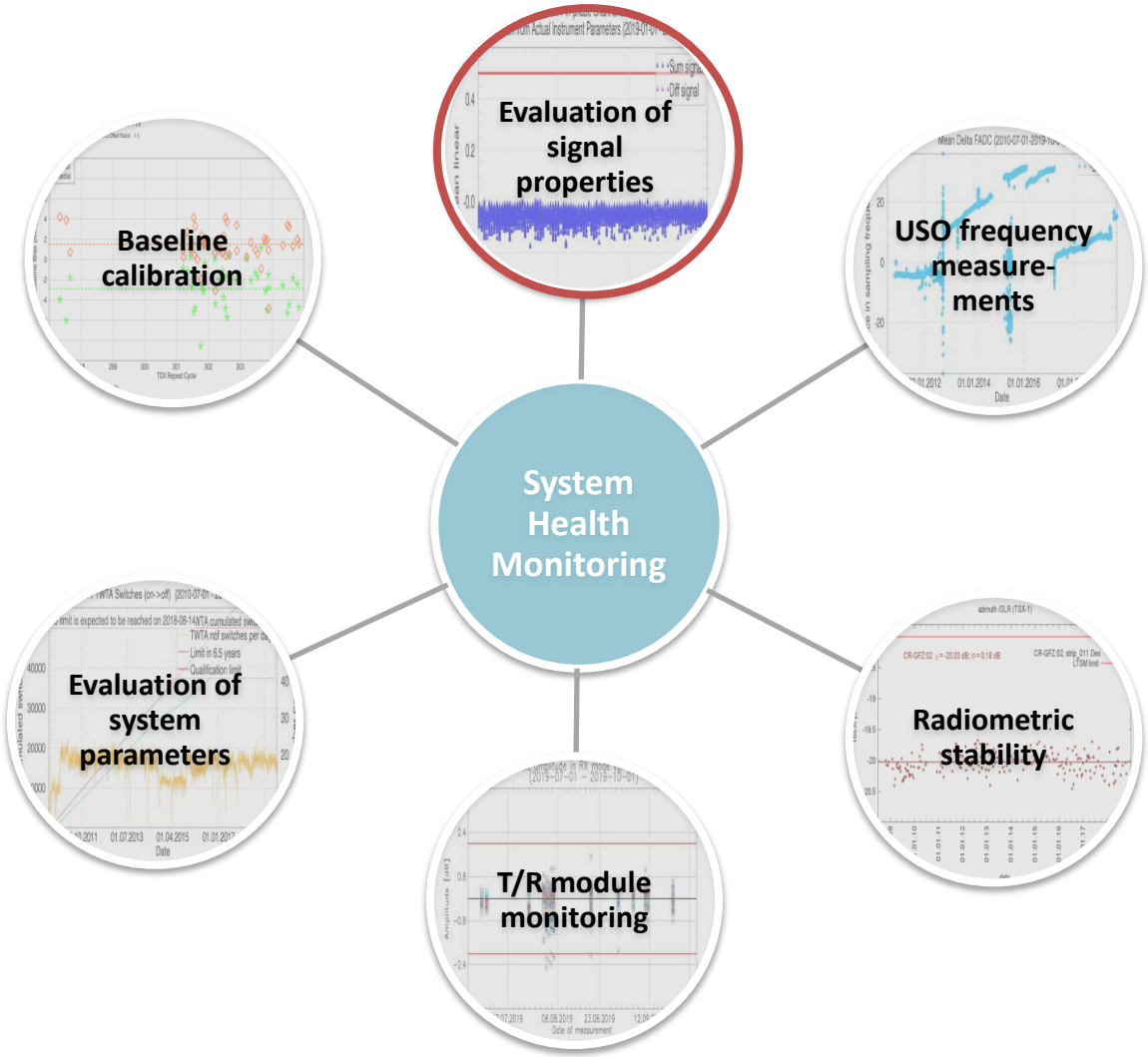
TerraSAR-X Mission

- Mono-static imaging of the Earth's surface
- Multi-mode highly flexible operation (Stripmap, ScanSAR, Spotlight)
- Various applications (ATI, DInSAR, PolInSAR)

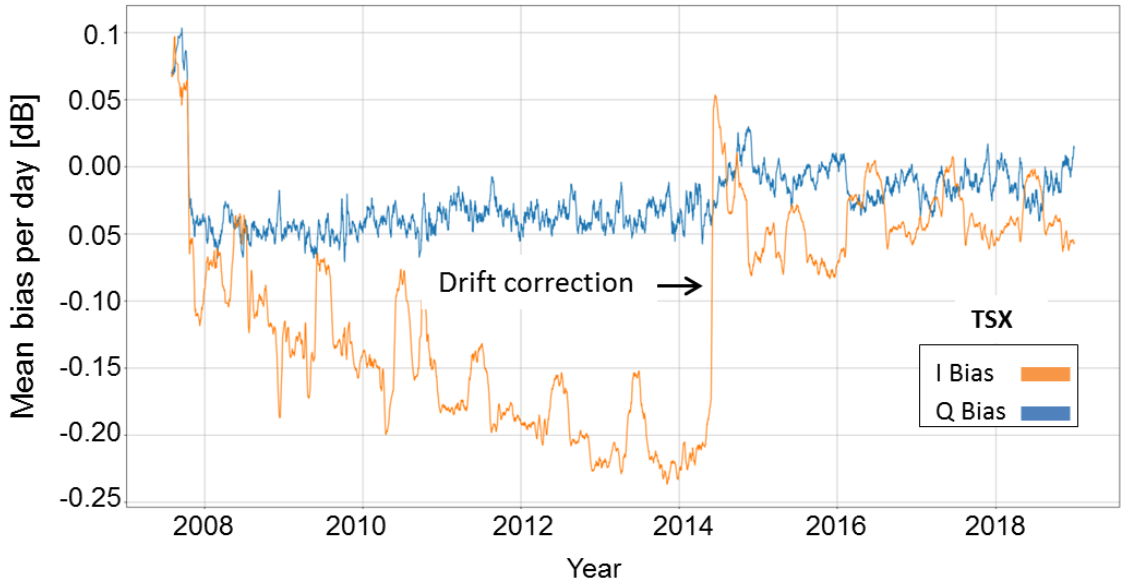


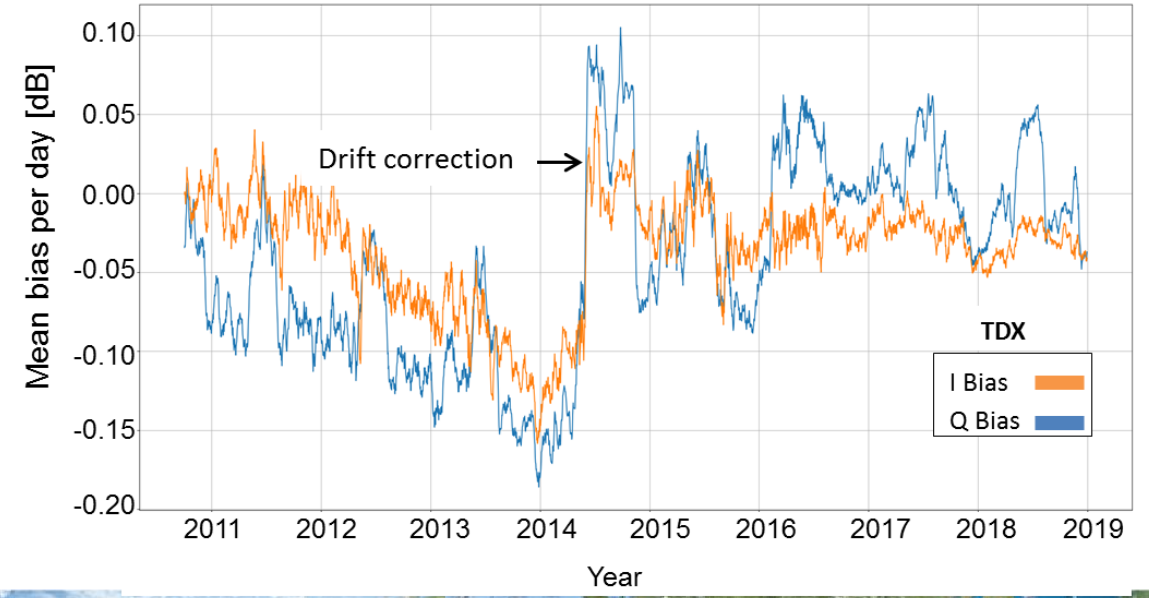
Staring-Spotlight-Mode

System Health Monitoring

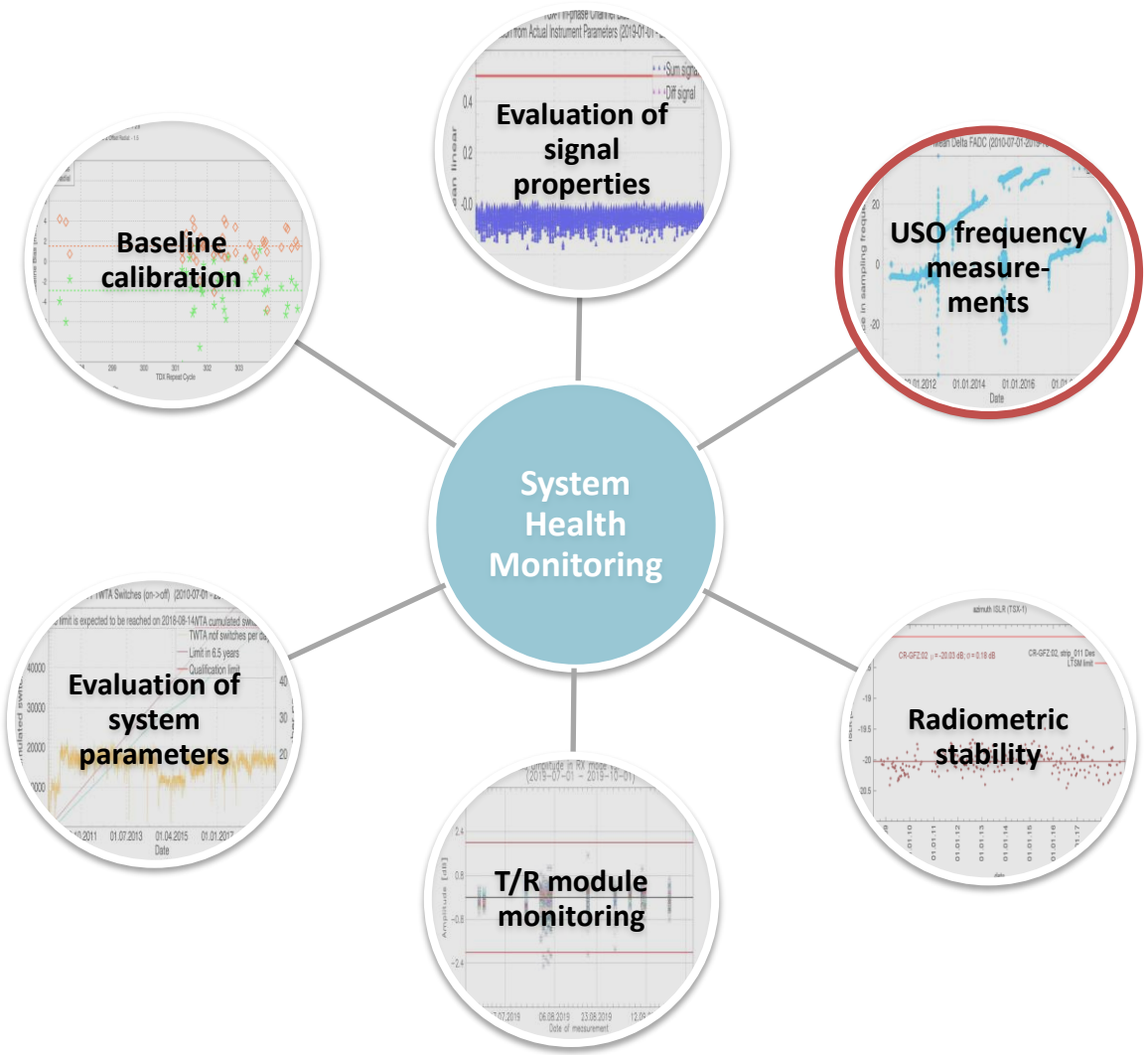


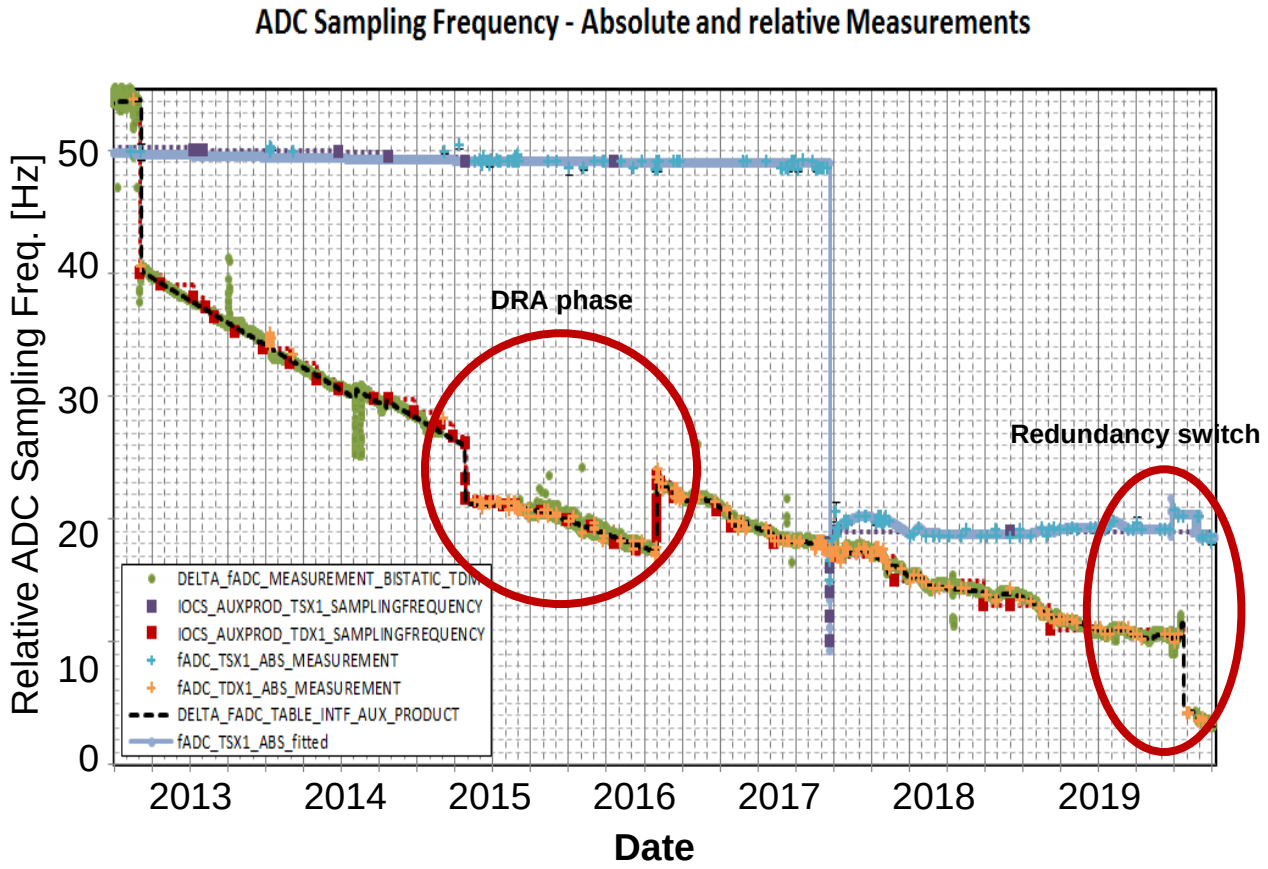
In-phase/quadrature bias



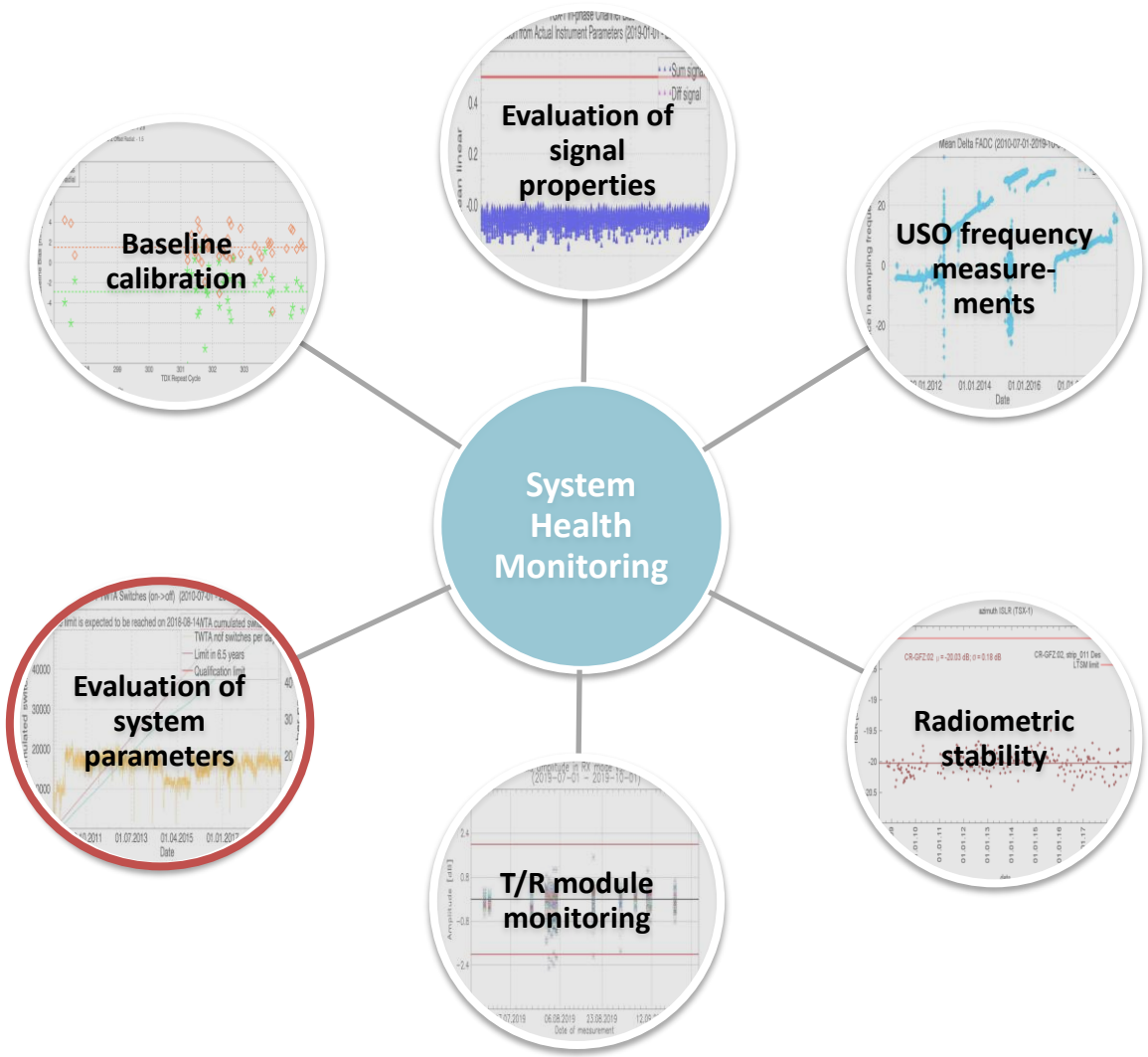


System Health Monitoring

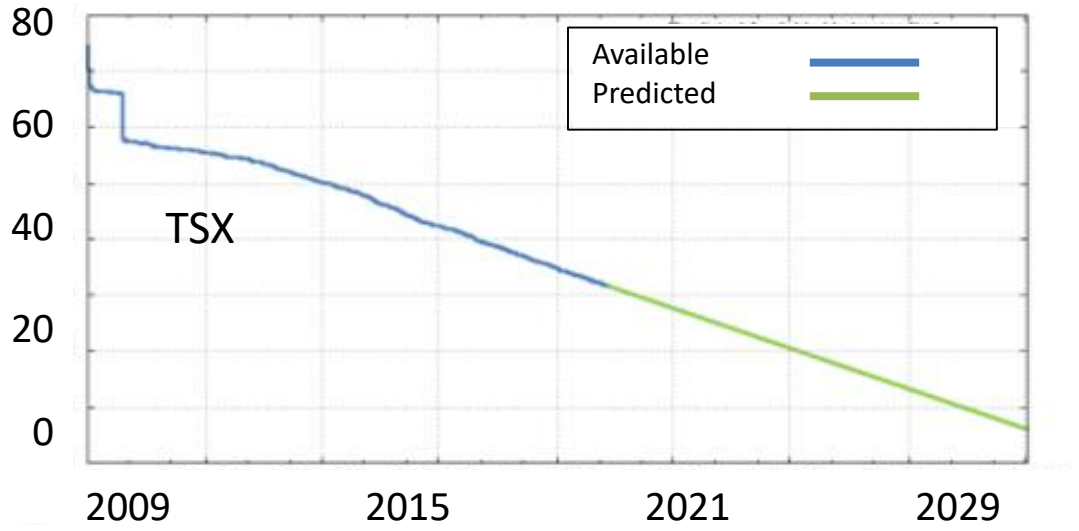




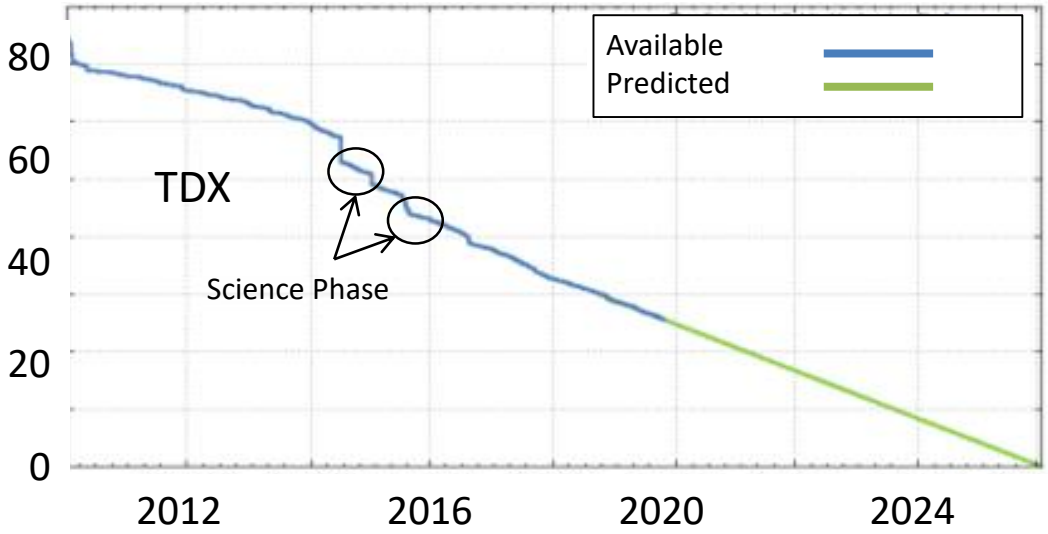
System Health Monitoring



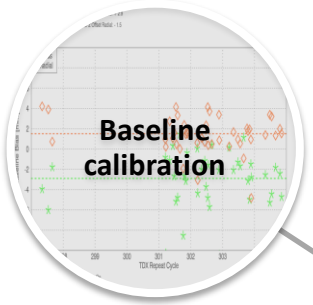
Hydrazine mass [kg]

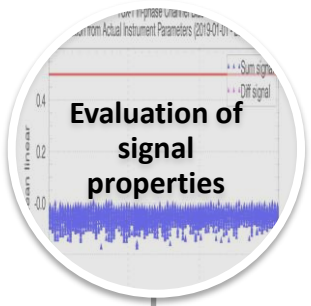


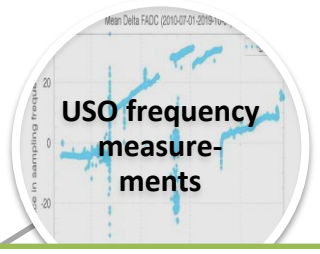
Hydrazine mass [kg]

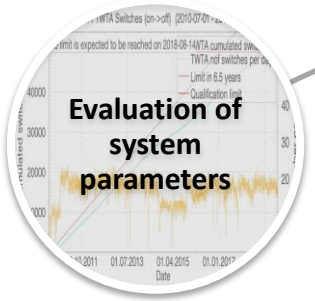


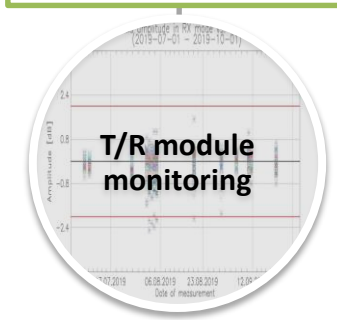
System Health Monitoring

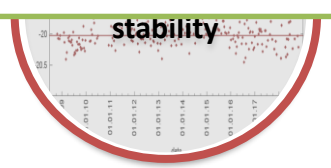

Baseline calibration


Evaluation of signal properties


USO frequency measure-ments

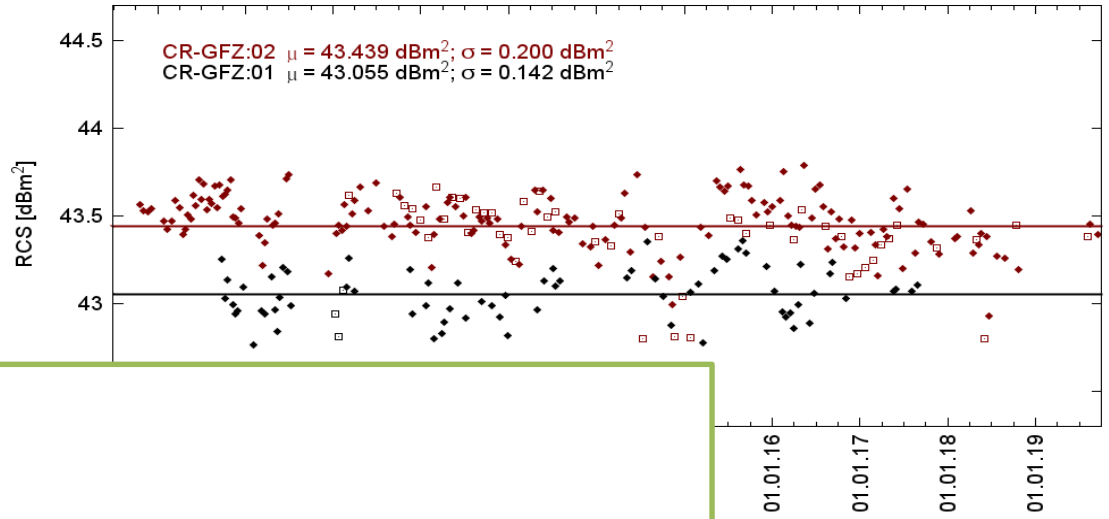

Evaluation of system parameters


T/R module monitoring

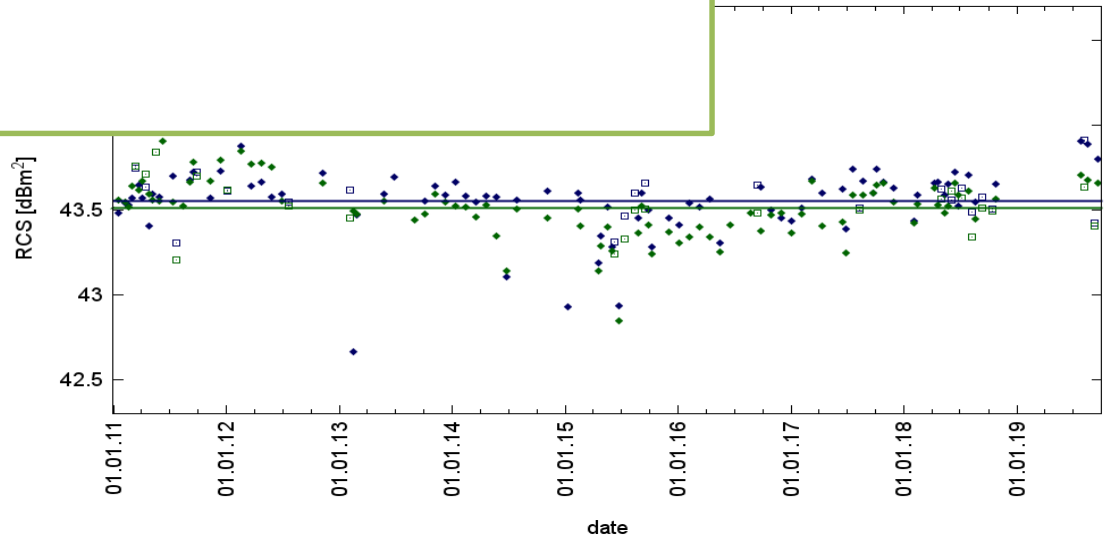

stability

Stable SAR product quality since launch

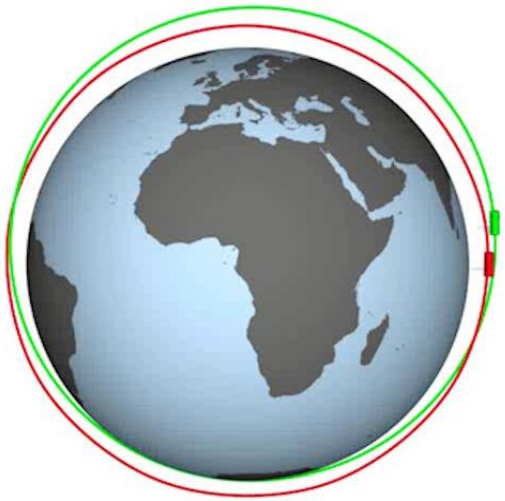
Radar cross section (TSX)



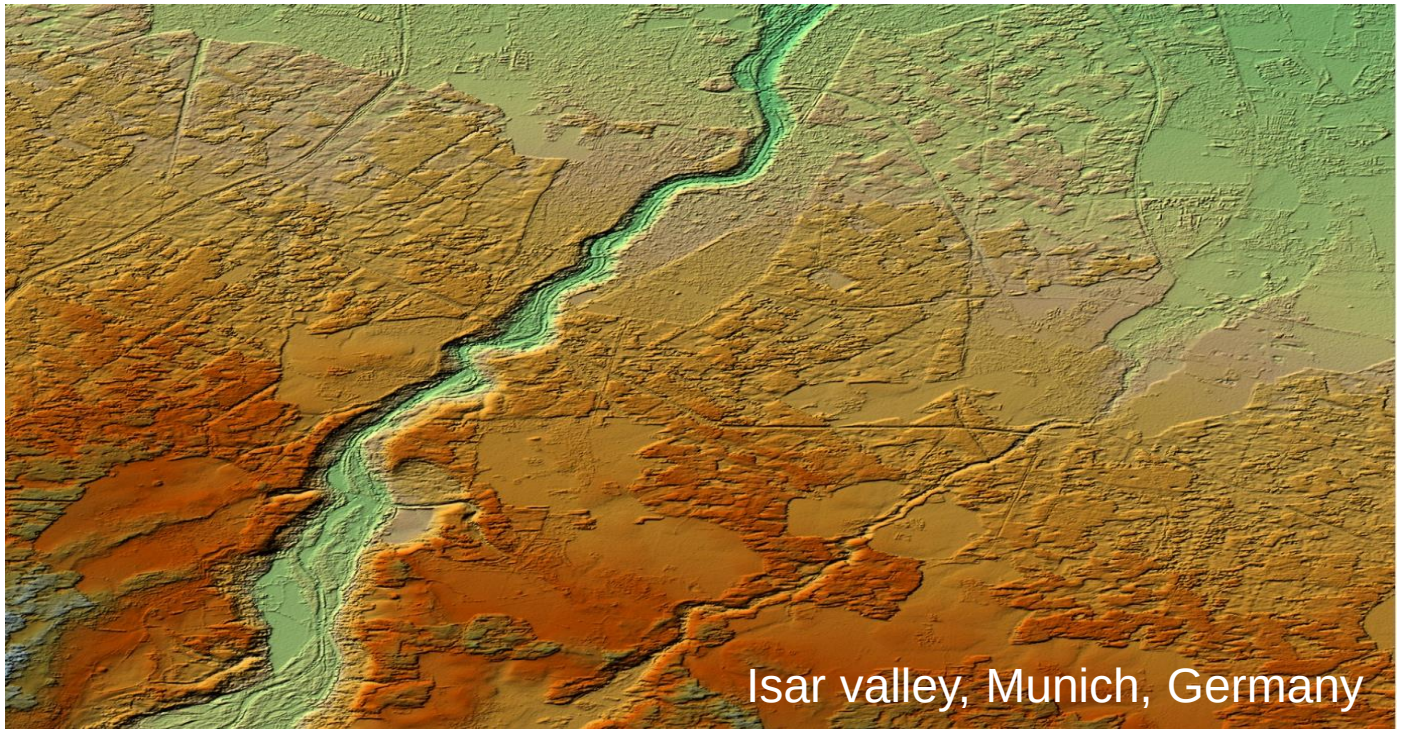
(TDX)

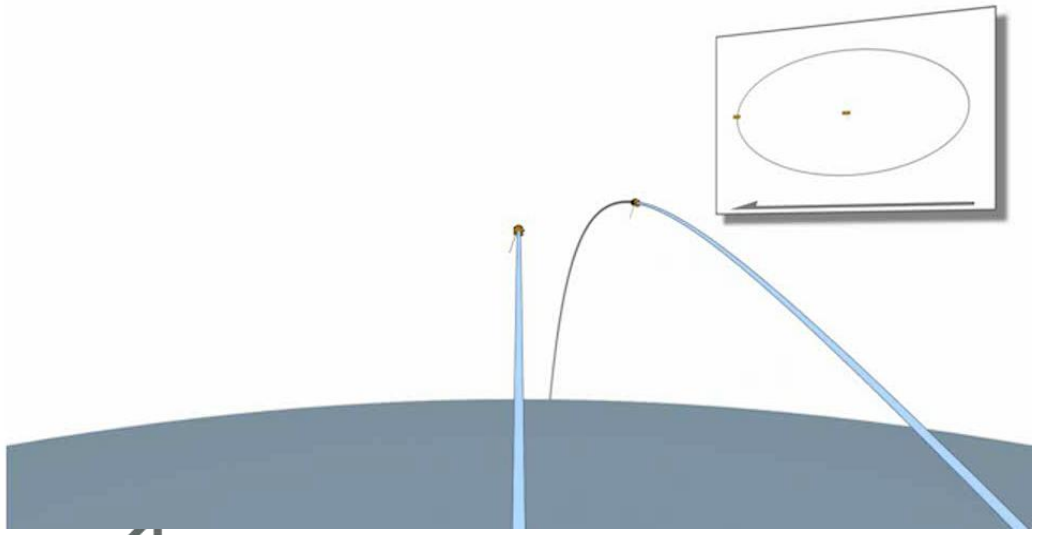


TanDEM-X Mission



- Formation flight → bi-static acquisitions
- Generation of Digital Elevation Models





Global DEM

1st Global Coverage

- Small baseline (~280 m)
- HoA* ~ 50 m

2nd Global Coverage

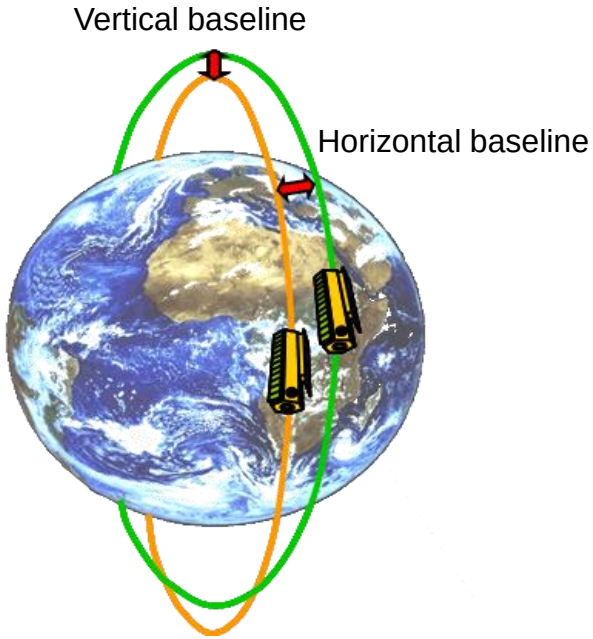
- Increased baseline (~350 m)
- HoA* ~ 35 m

Combination:

- Dual Baseline Phase Unwrapping
- Improved Height Accuracy

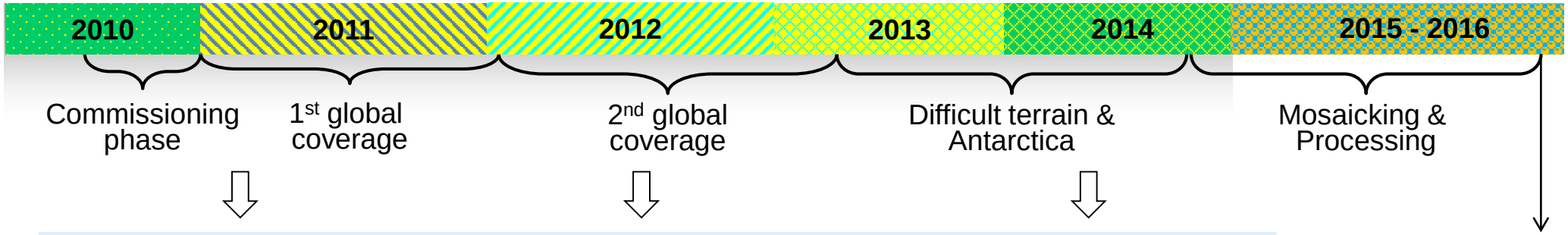
3rd- 4th Year Acquisitions

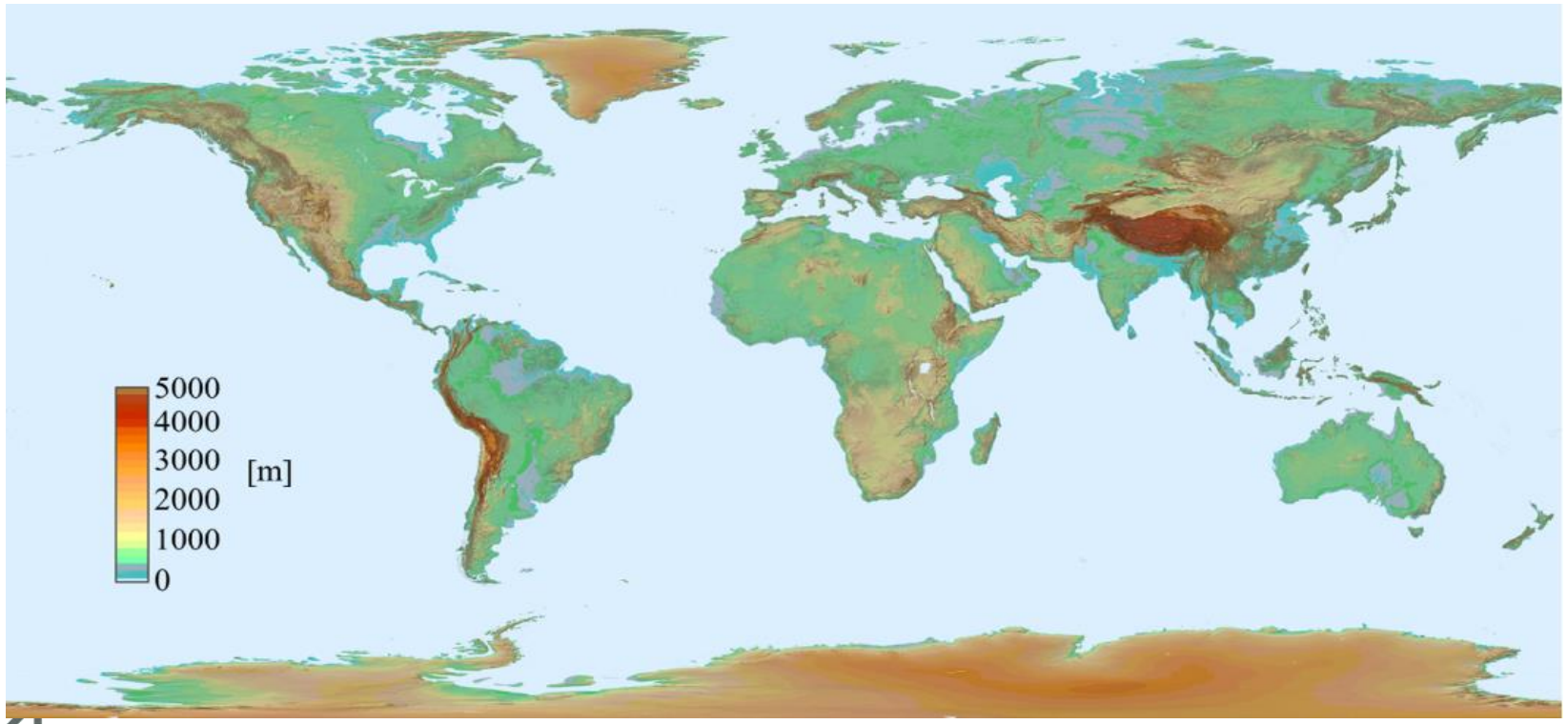
- Antarctica in left looking
- Difficult terrain to account for shadow & layover
  => Deserts, mountains
  => Different viewing geometry



*HoA: Height of Ambiguity ↔ 2π Interferometric Phase

Global DEM





September 2016 completion of the final global DEM product
→ ~ 20,000 tiles (1° x 1°) with 12 m posting at equator
tandemx-science.dlr.de

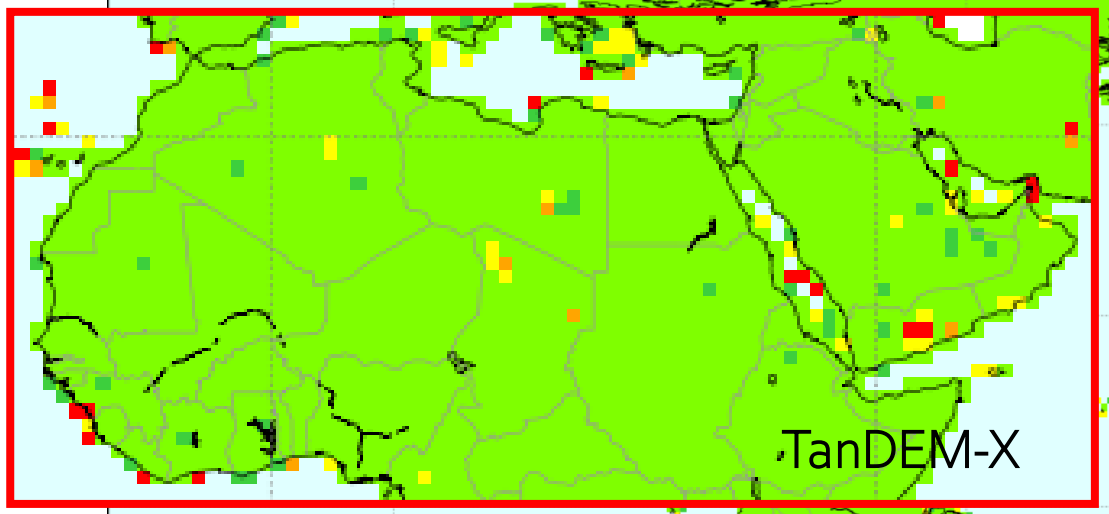
September 2018 release of a free of charge version with 90 m posting
→ 3 million tiles downloaded
geoservice.dlr.de

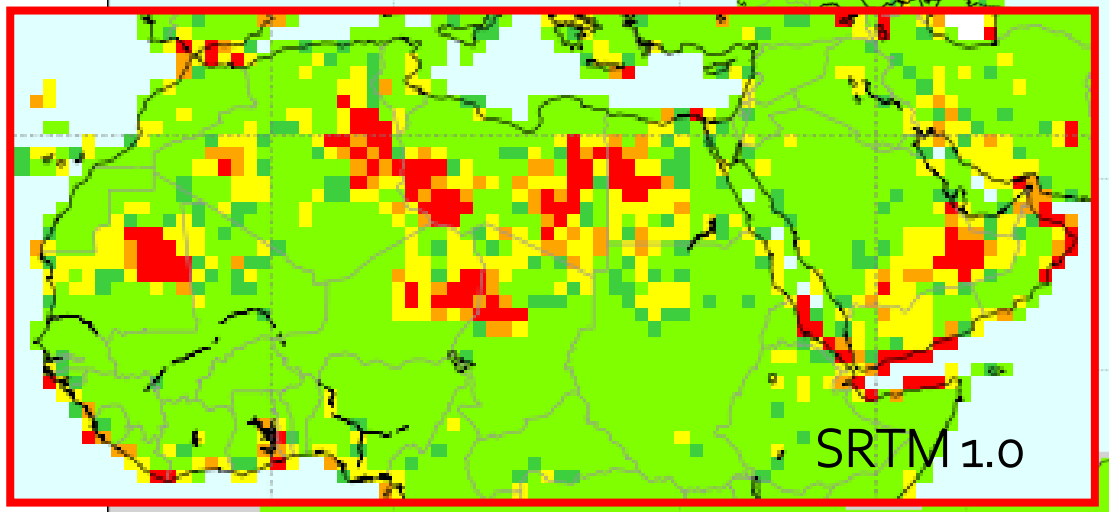
Absolute Height Accuracy

TanDEM-X DEM – ICESat (specification: < 10 m global, 90% confidence level)

Statistics	All Tiles	Ice Only	Forest Only	No Forest / No Ice	No Ice
Landmass [Mio. Km²]	144.2	14.3	33.2	96.76	129.9
Mean Height Deviation [m]	-0.37	-2.83	0.57	0.04	0.15
Absolute Height Accuracy of 10 m [%]	99.5	98.4	99.2	99.8	99.7
Absolute Height Accuracy 90% Linear Error (m)	3.5	6.4	2.3	0.9	1.1

TanDEM-X Data Coverage – Global Voids Performance

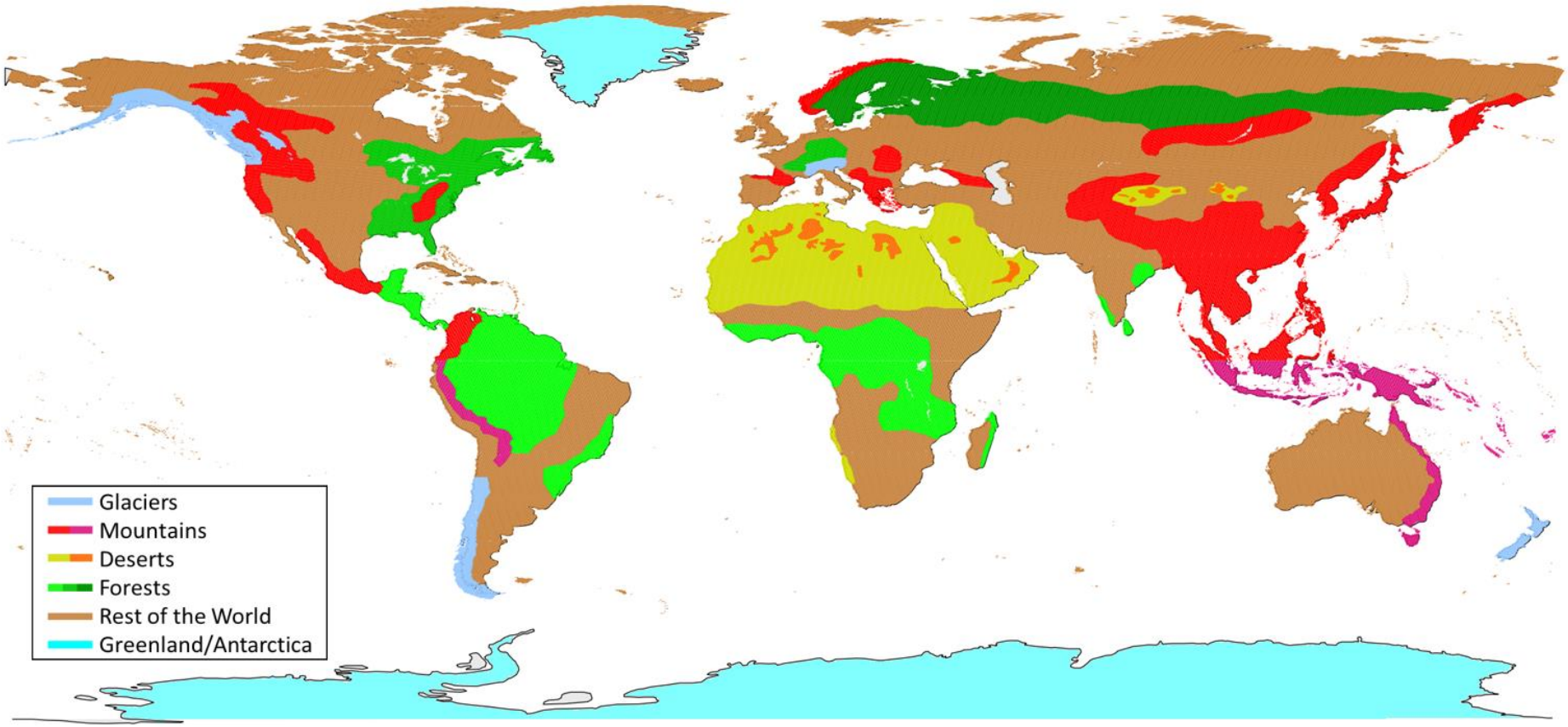




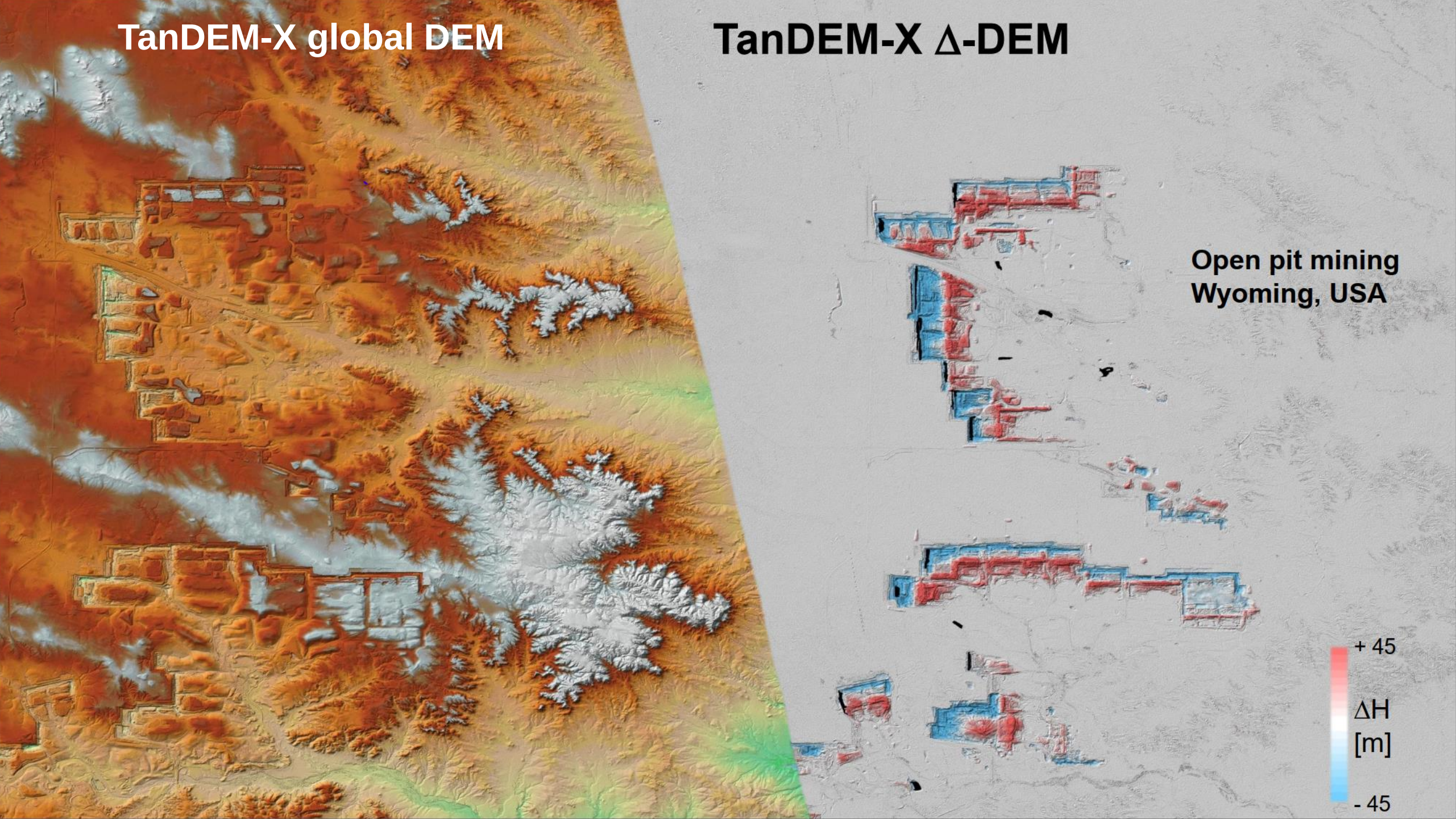
Parameter	Value
Valid Land	144.05 Mio km²
Total Land	144.21 Mio km²
Invalid Land	0.154 Mio km²
Percent Valid	99.89 %
Percent Invalid	0.11%

Change DEM

Region	Coverages	Season	Height of Ambiguity	Inc. Angle Range
Mountains with Forest	2	Local summer	55 - 75 m (1st) 45 - 53 m (2nd)	27 - 49 deg
Glaciers	2	Local winter	55 - 75 m (1st) 45 - 53 m (2nd)	29 - 47 deg
Tropical forest	1	Year round	50 - 60 m	27 - 49 deg
Temperate & boreal forest	1	Local summer	50 - 55 m	27 - 49 deg
Deserts with Mountains	2	Year round	55 - 75 m (1st) 45 - 55 m (2nd)	27 - 49 deg
Deserts	1	Year round	23 - 45 m	14 - 38 deg
Permafrost area	1	Local winter	35 - 45 m	29 - 47 deg
Rest of the world	1	Year round	35 - 45 m	27 - 49 deg

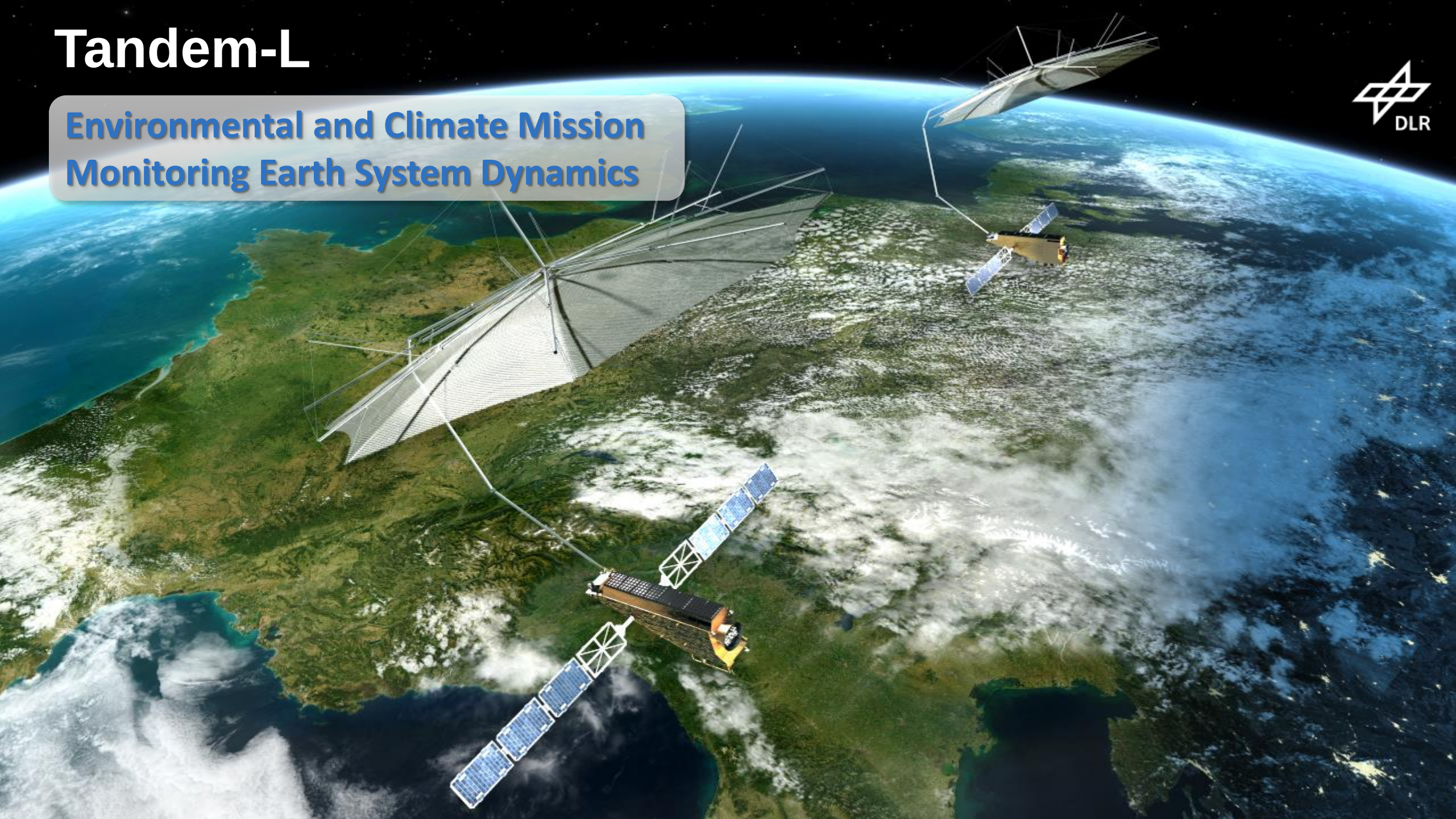


- Division of landmasses according to terrain type
- Acquisition plan adapted to seasonal and baseline requirements
- Improved processing methods → global DEM accuracy with fewer acquisitions


TanDEM-X global DEM
TanDEM-X Δ-DEM
Open pit mining
Wyoming, USA
+ 45
ΔH
[m]
- 45

Tandem-L

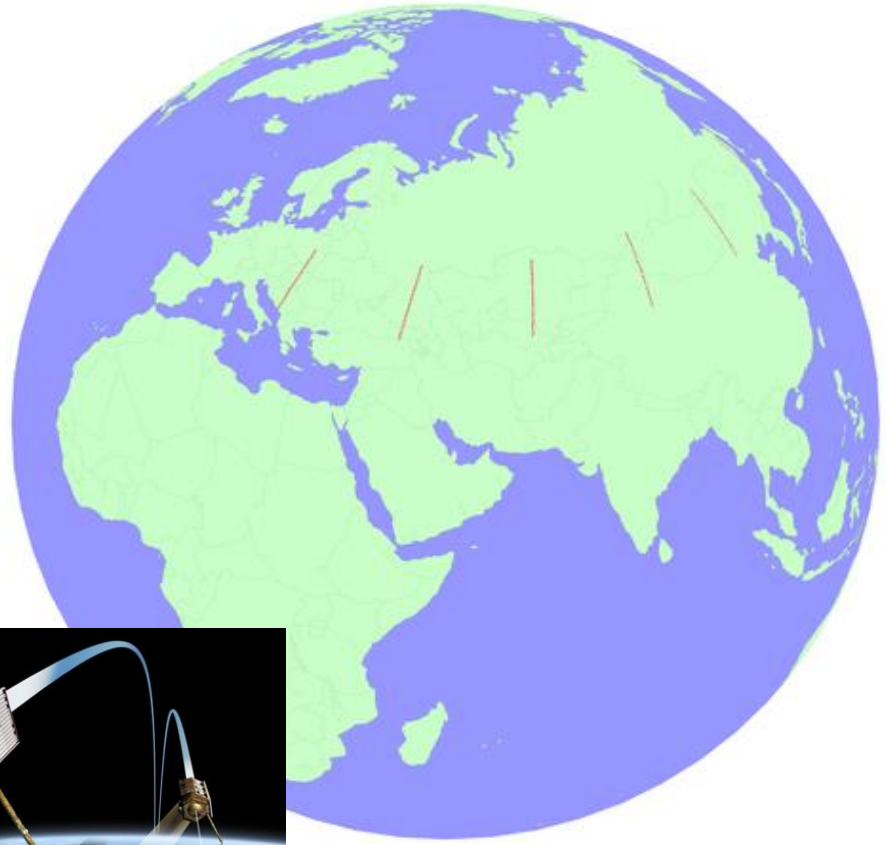
Environmental and Climate Mission
Monitoring Earth System Dynamics

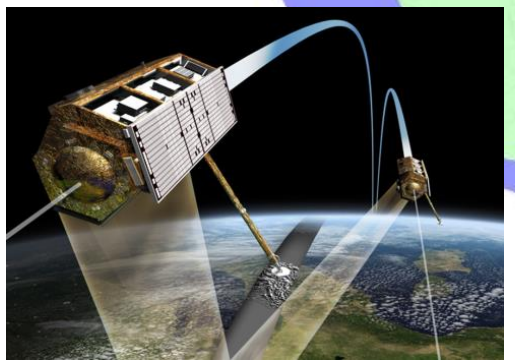


Imaging capabilities

TerraSAR-X/TanDEM-X

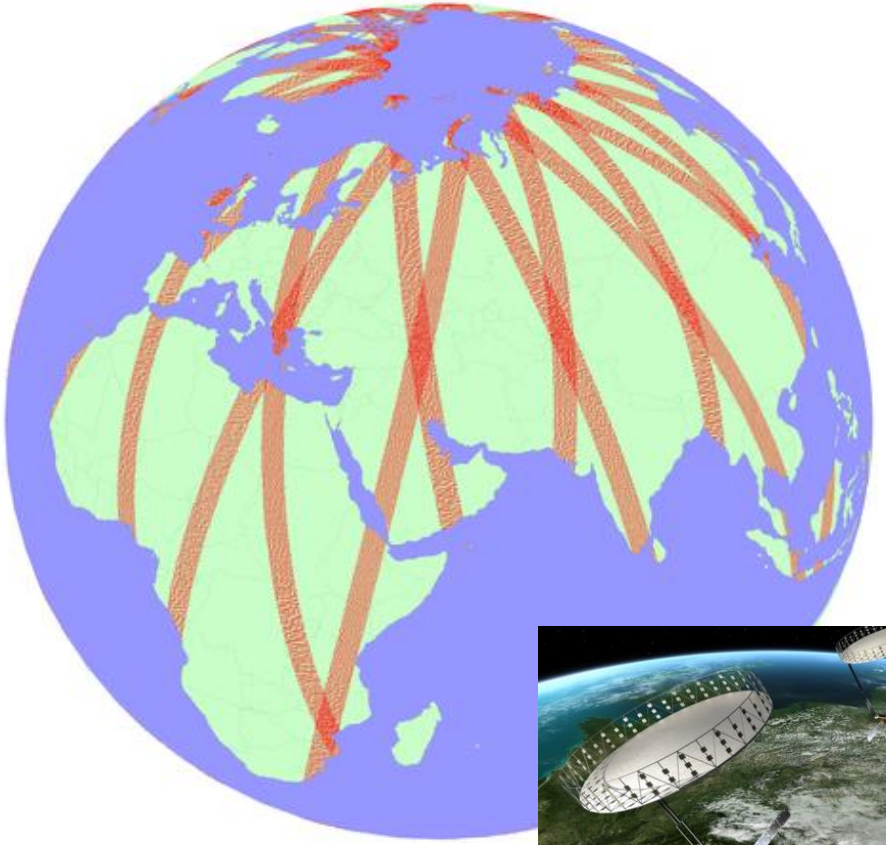
1 global coverage / year





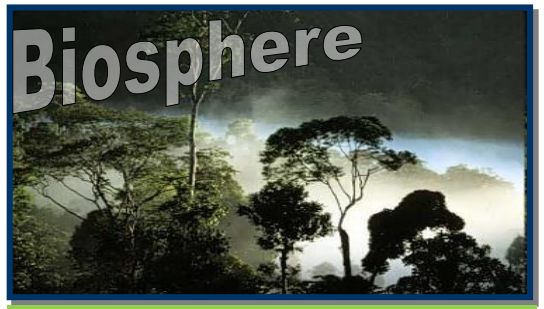
Tandem-L

2 global coverages / 8 days

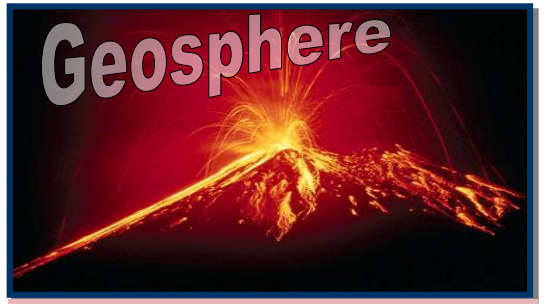


1

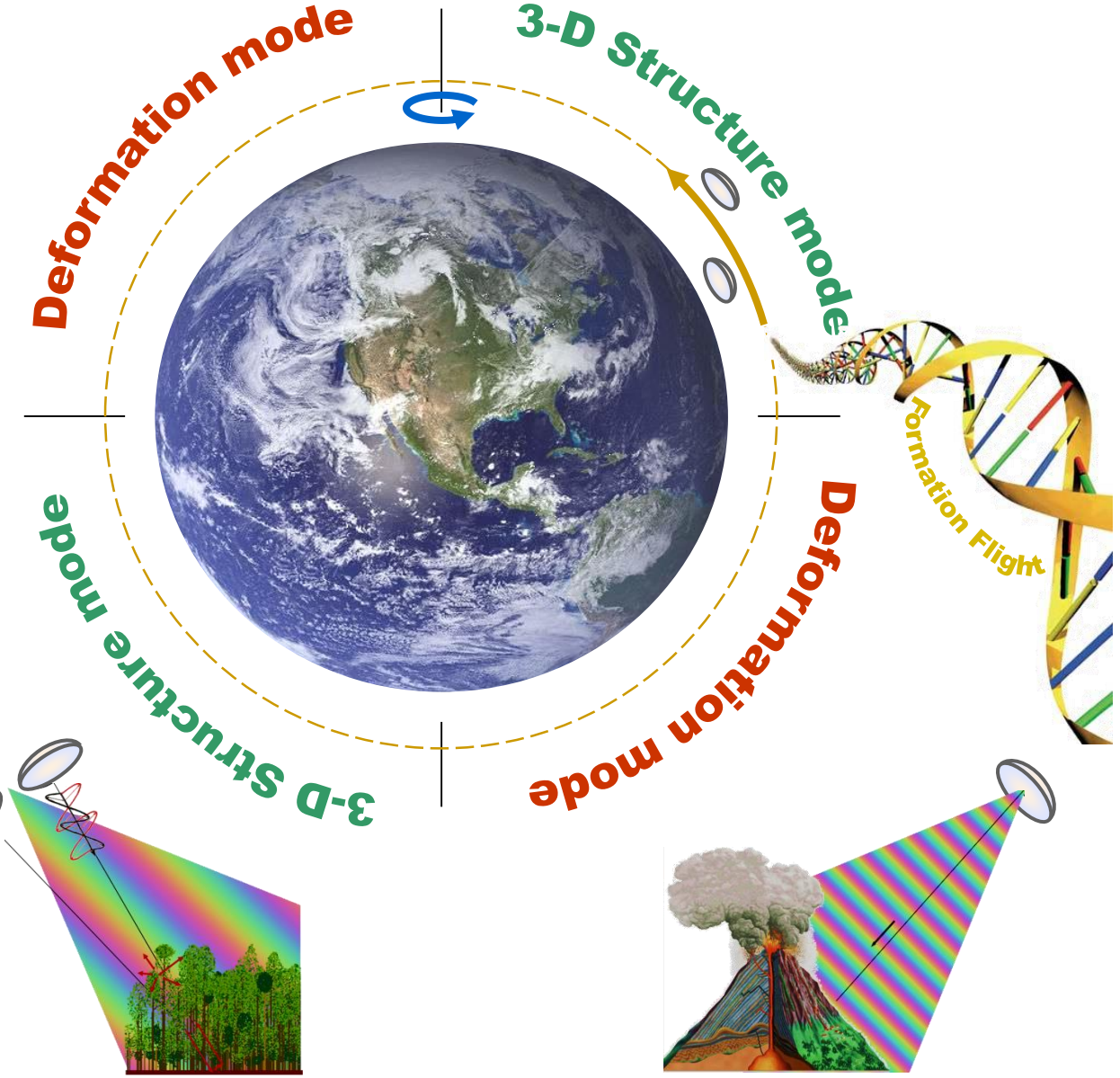
Days



- 3-D forest structure
- Forest height and biomass
- Tomography



- Earthquakes
- Volcanoes and tectonics
- Subsidence



- Soil moisture
- Flooding
- Ocean currents

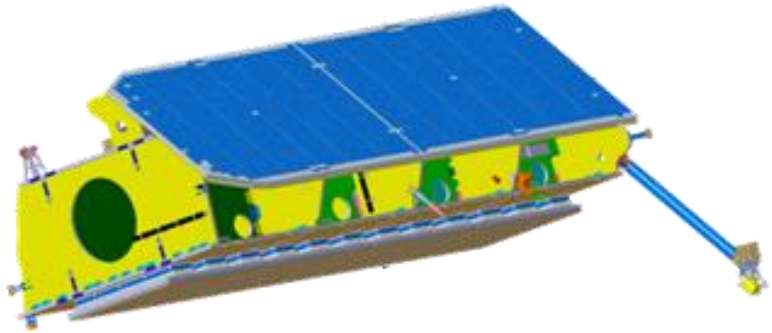
- Permafrost
- Sea ice extent
- Glaciers and ice cap dynamics

DLR

HRWS – High Resolution Wide Swath

Mono-static applications:

- High resolution infrastructure monitoring
- Large area maritime surveillance
- Target recognition
- Improved NRT capabilities



	Resolution [m²] (Rg x Az)	Scene Size [km²] (W x L)	Polarization
Staring SL „Theatre“	0.25 x 0.25	10 x 10	Single
Sliding SL	0.25 x 0.25	20 x 20	Single
Sliding SL	0.25 x 0.25	15 x 15	Quad
Sliding SL	0.5 x 0.5	30 x 30	Single
Strip-Map	1 x 1	50	Single
Strip-Map	2 x 2	30	Quad
Strip-Map	3 x 3	80	Single
Scan-SAR	2 x 8	120	Quad
Scan-SAR	2 x 16	540	Single

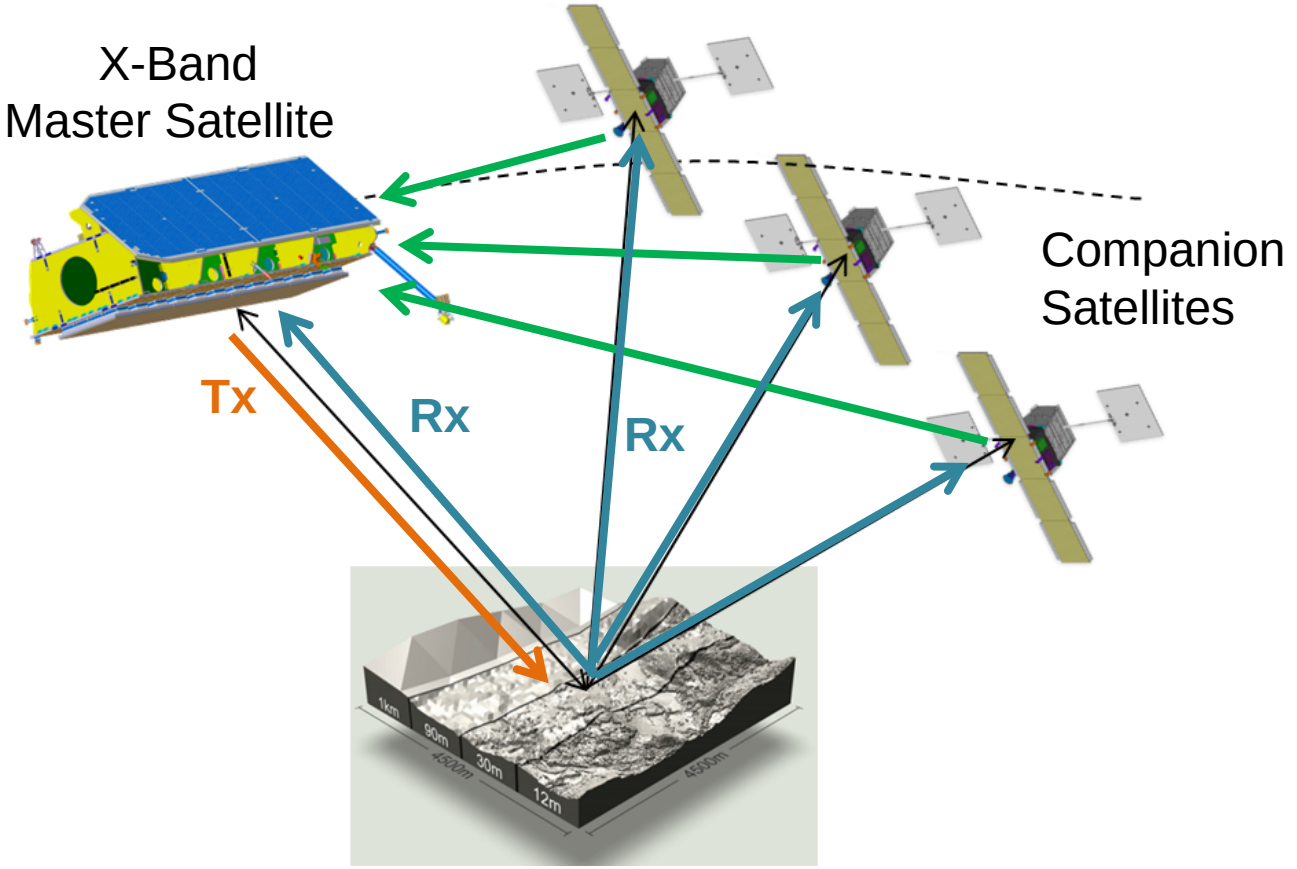
HRWS – High Resolution Wide Swath

Mono-static applications :

- High resolution infrastructure monitoring
- Large area maritime surveillance
- Target recognition
- Improved NRT capabilities

Multi-static applications :

- On-demand regional DEMs
- 3D reconstruction using SAR Tomography
- 3D/4D change detection
- Sea ice topography
- Ground Moving Target Indication (GMTI)



Thank you very much for your attention
Makgadikgadi Pans National Park, Botswana