

# 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



Knowledge for Tomorrow



# Outline

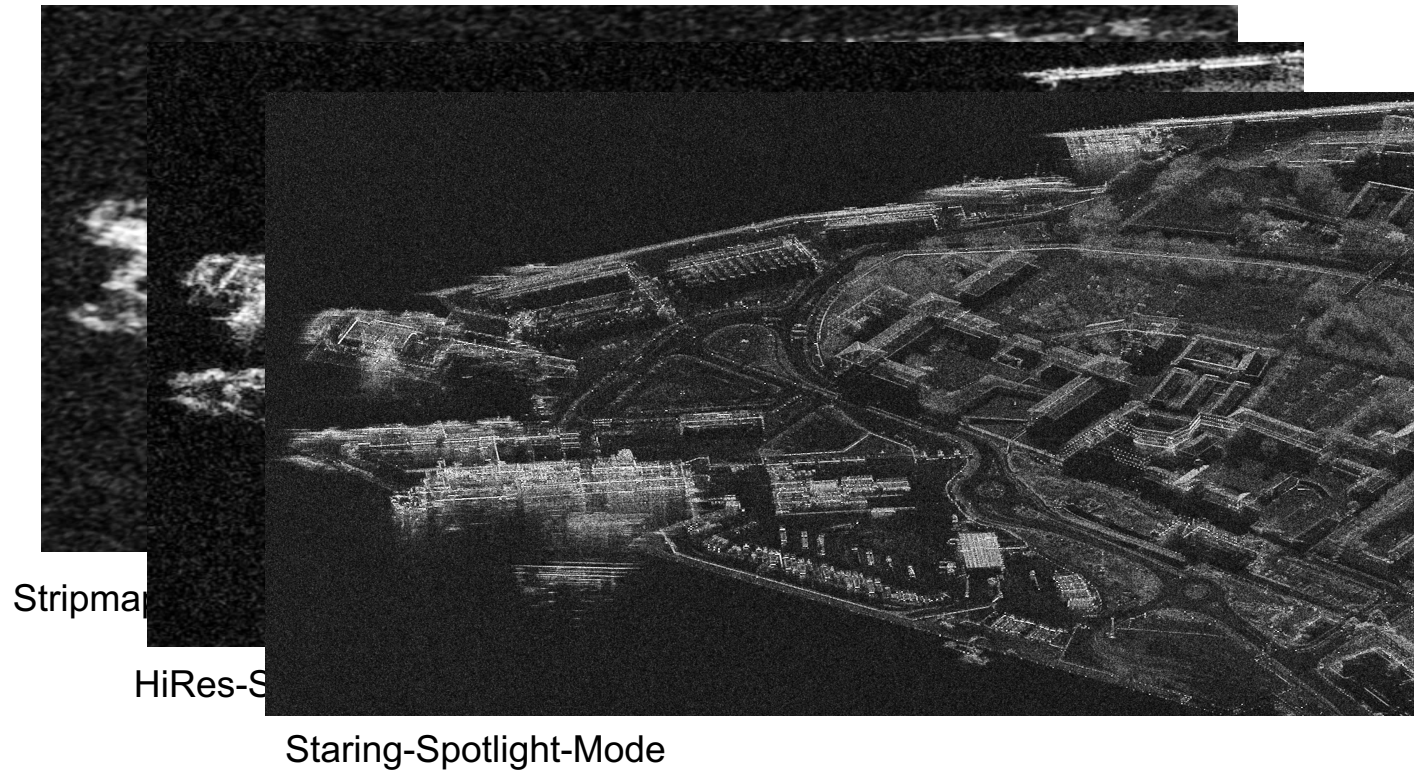
1. TerraSAR-X mission
  - a. TSX/TDX introduction
  - b. System monitoring
  - c. Radiometric stability
2. TanDEM-X mission
  - a. Global DEM quality
  - b. Change DEM
3. Future missions
  - a. Tandem-L
  - b. HRWS



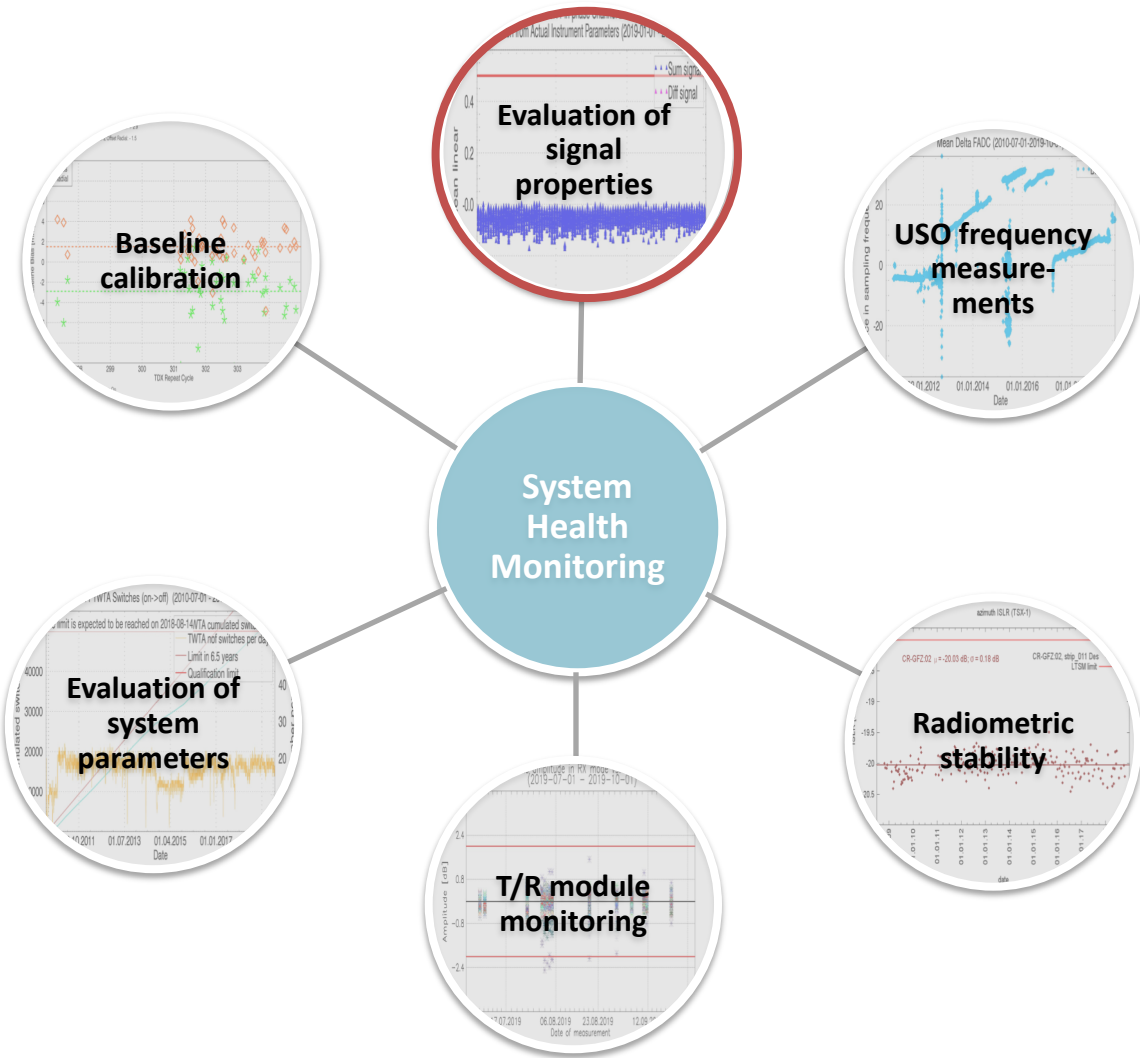
# TerraSAR-X Mission



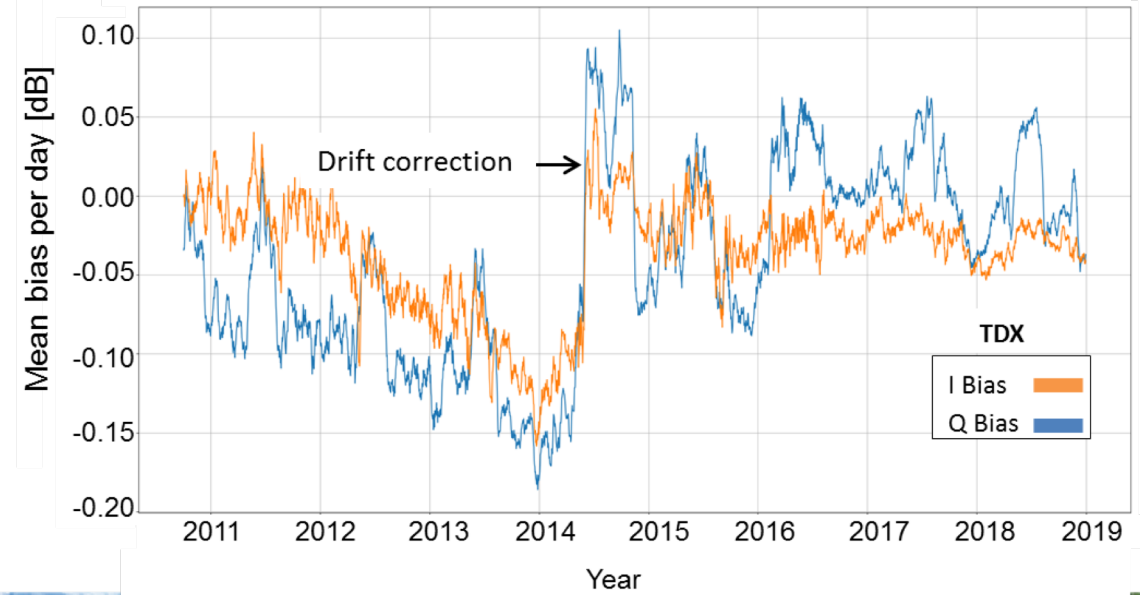
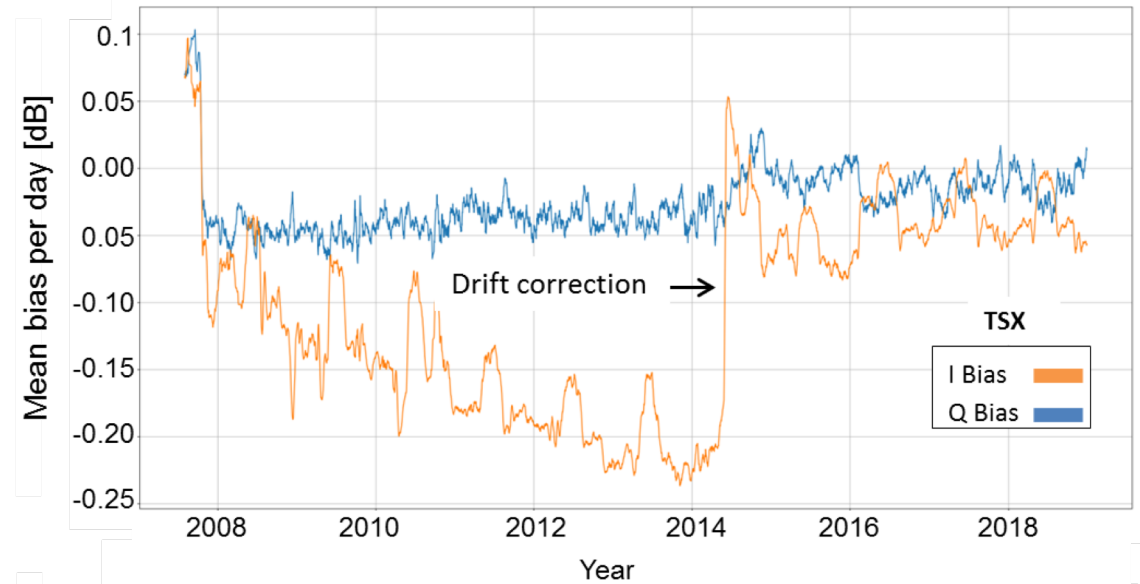
- Mono-static imaging of the Earth's surface
- Multi-mode highly flexible operation (Stripmap, ScanSAR, Spotlight)
- Various applications (ATI, DInSAR, PolInSAR)



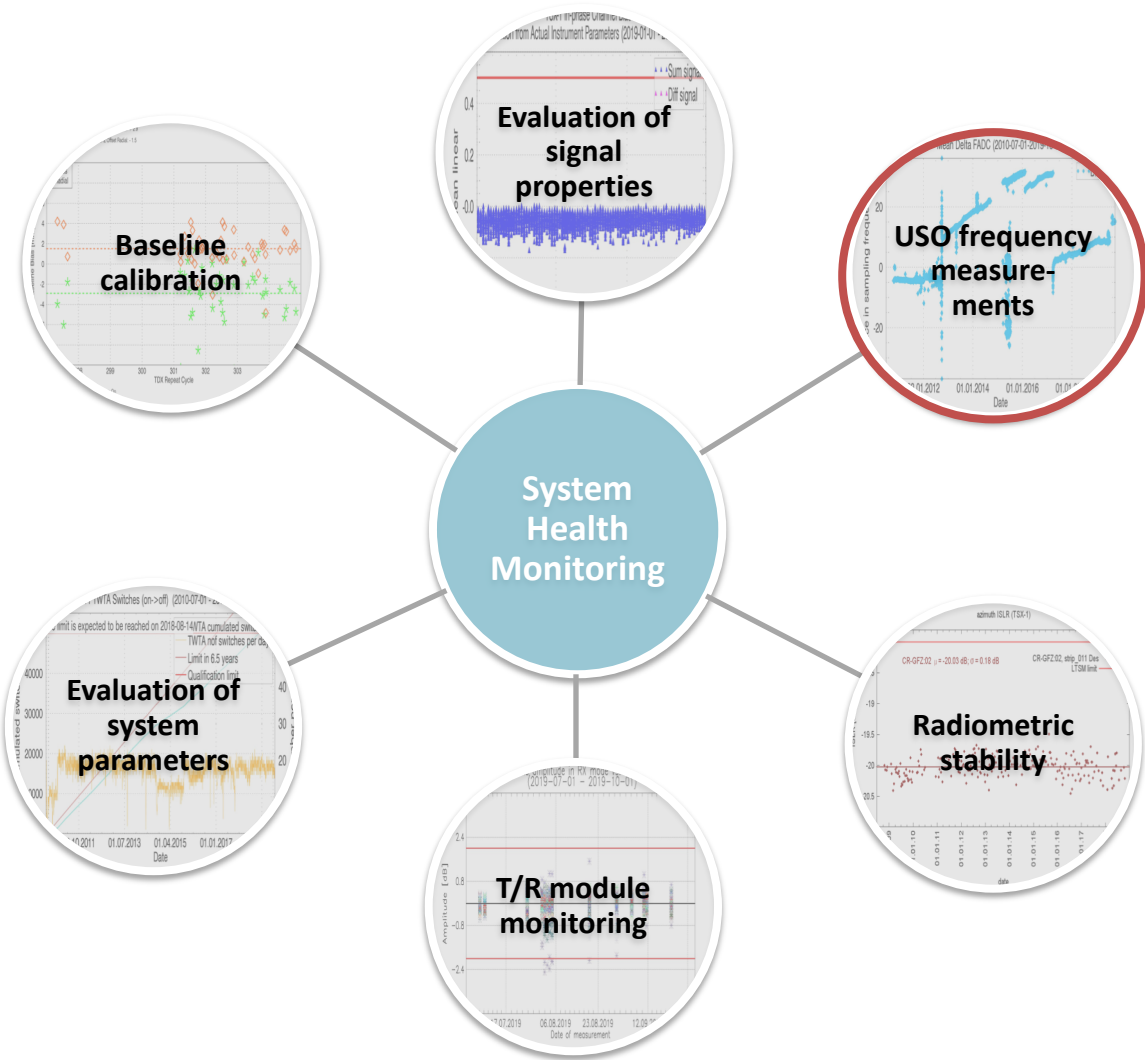
# System Health Monitoring



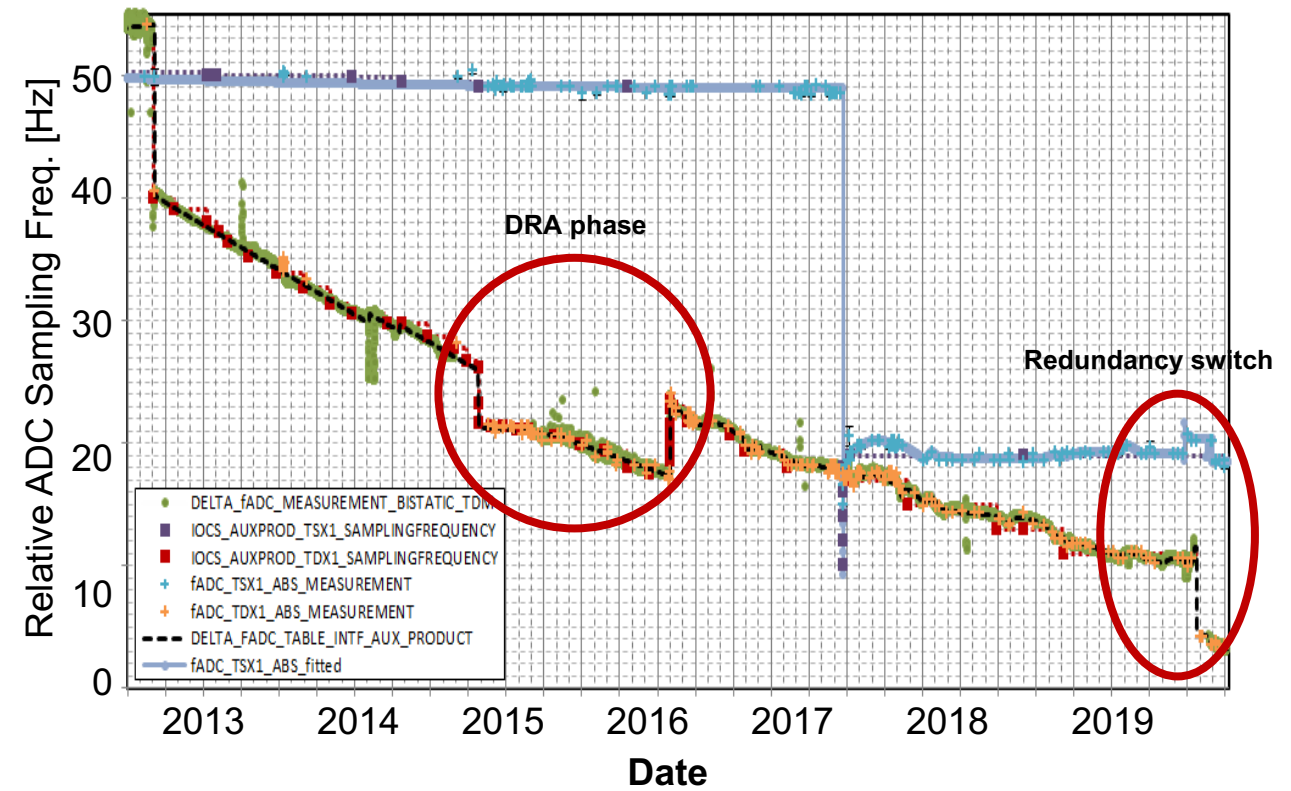
In-phase/quadrature bias



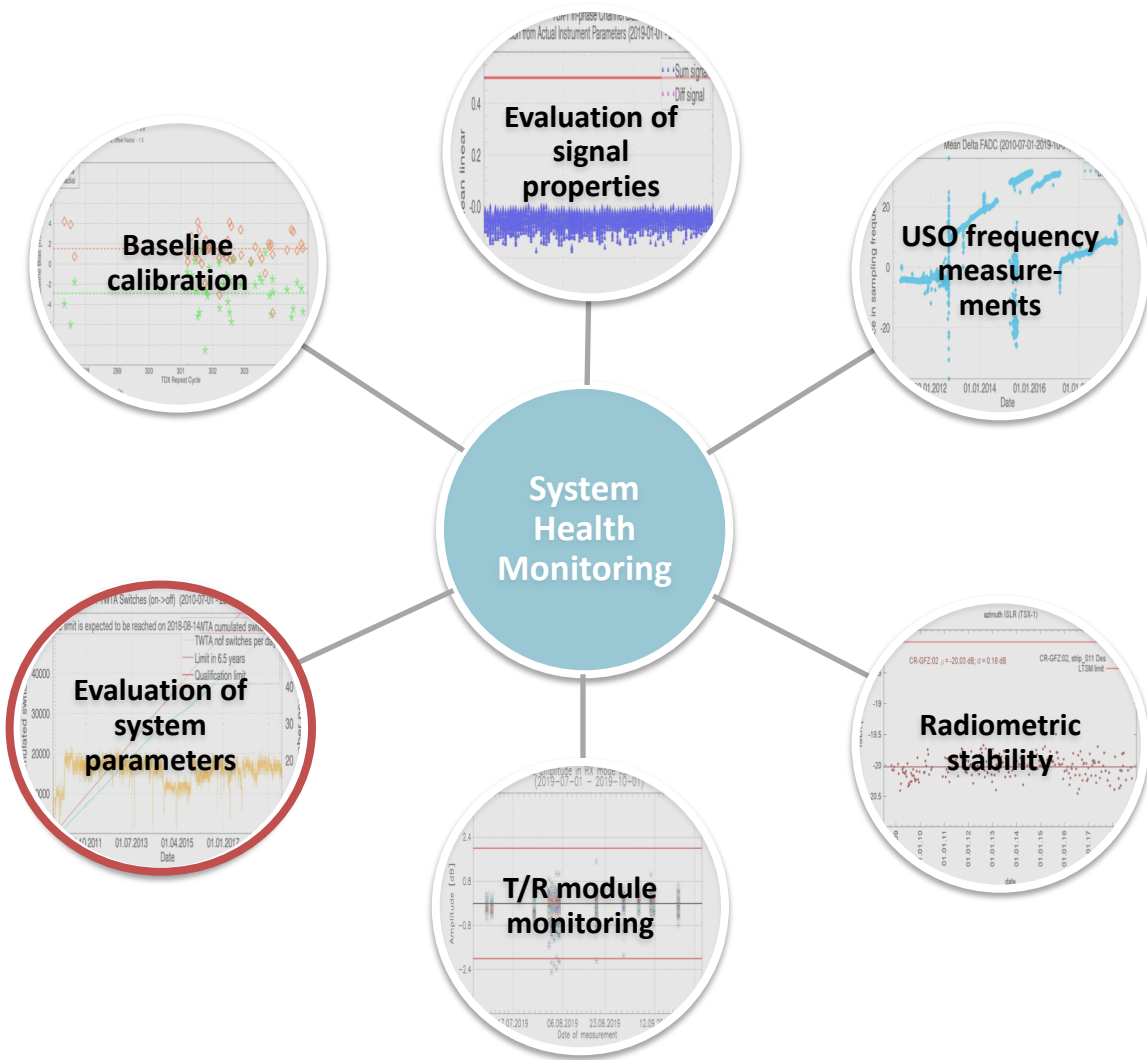
# System Health Monitoring



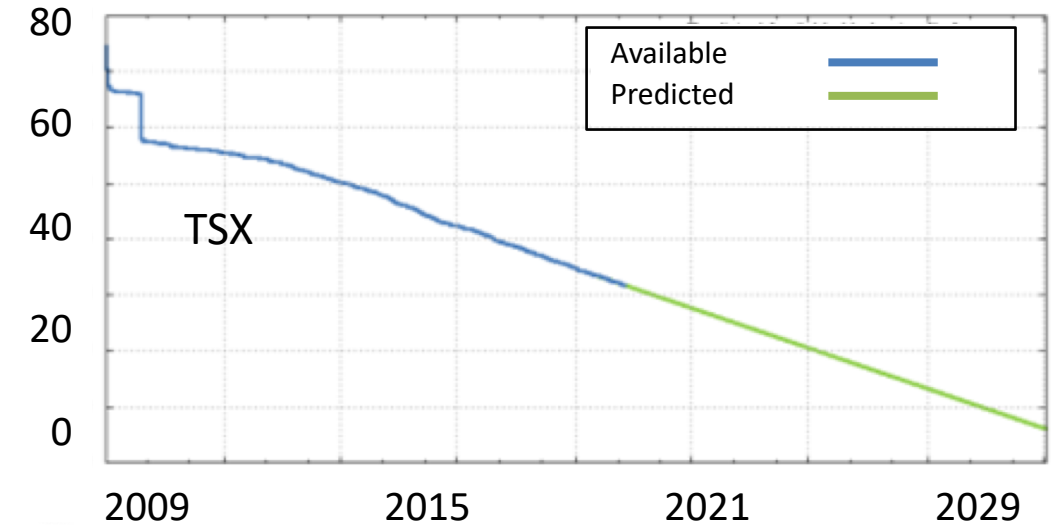
ADC Sampling Frequency - Absolute and relative Measurements



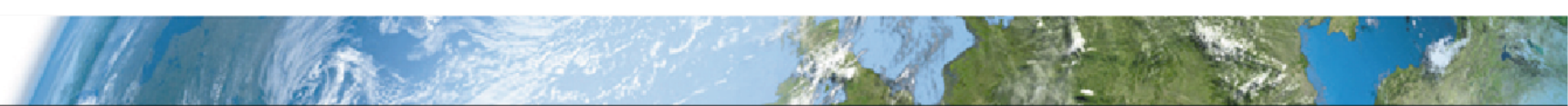
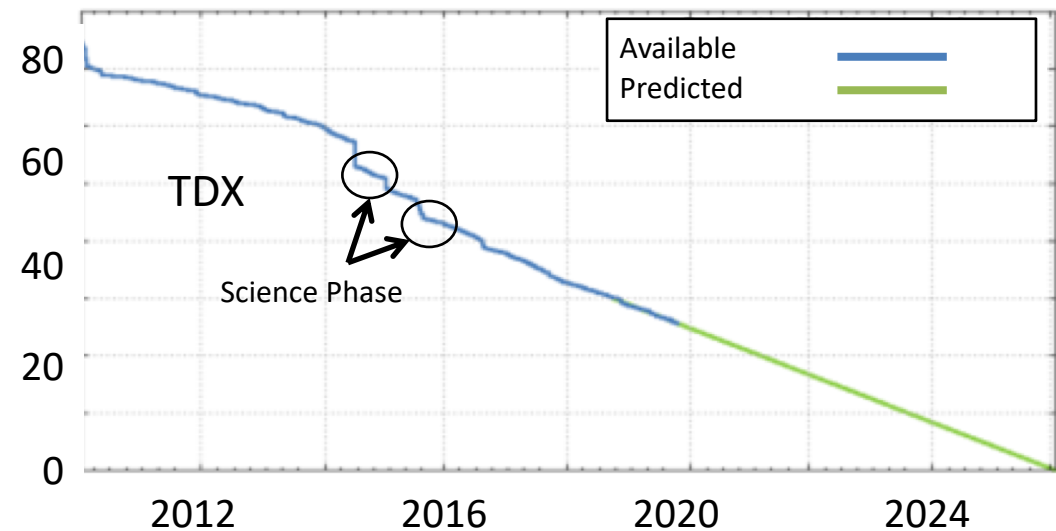
# System Health Monitoring



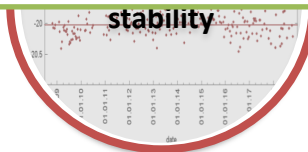
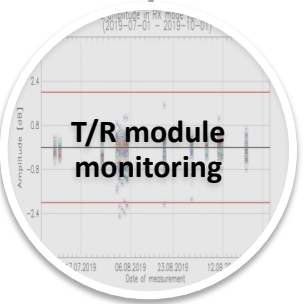
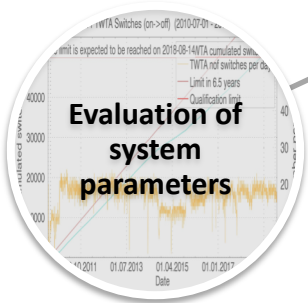
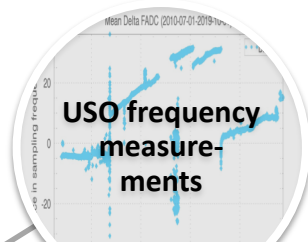
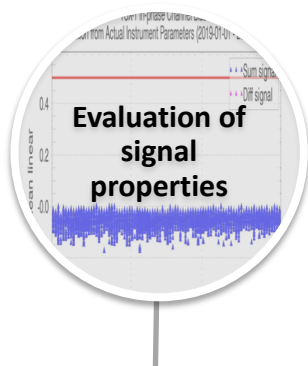
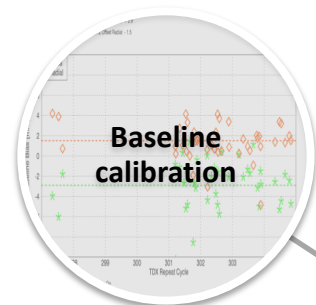
Hydrazine mass [kg]



Hydrazine mass [kg]

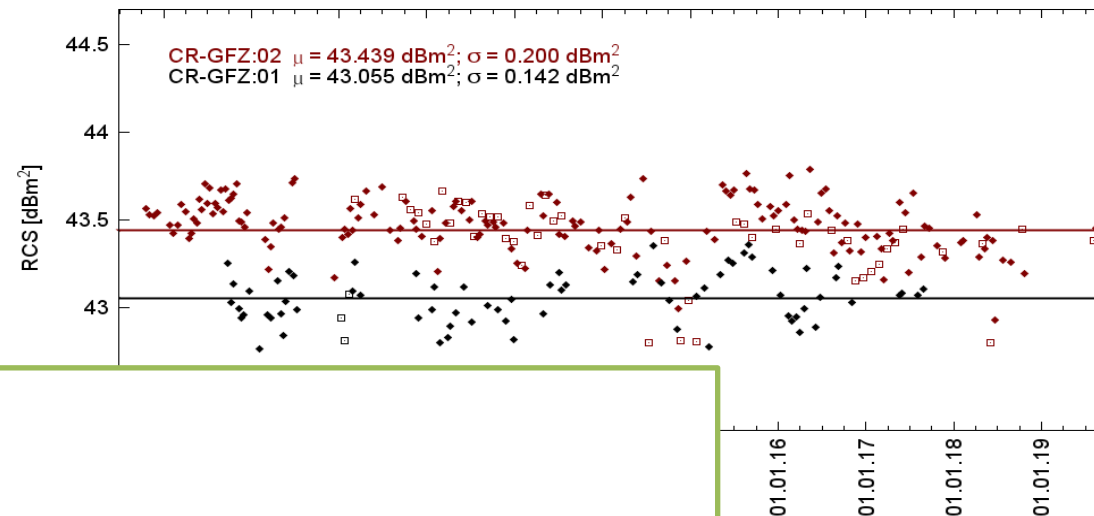


# System Health Monitoring

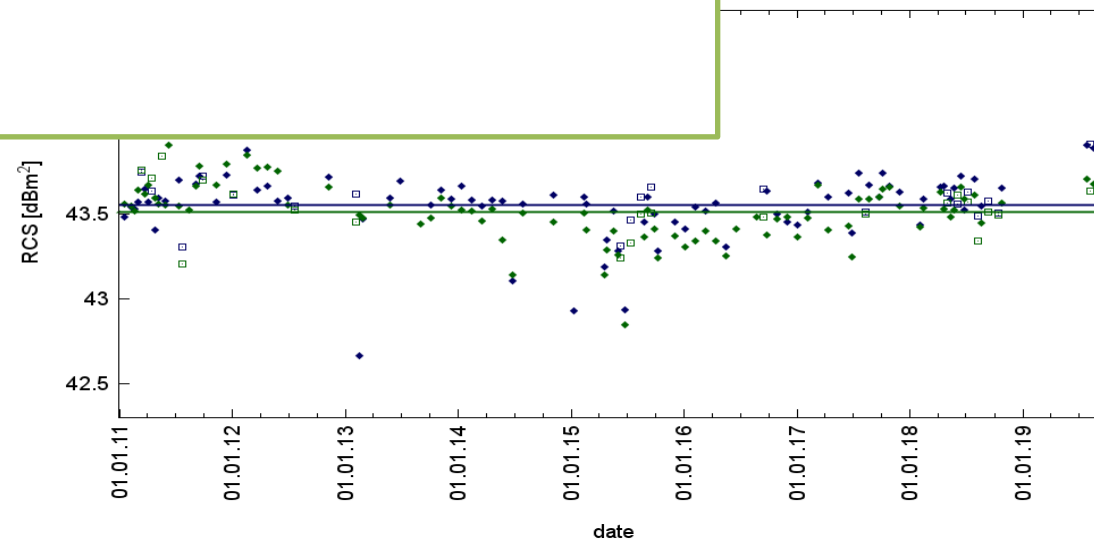


**Stable SAR product quality since launch**

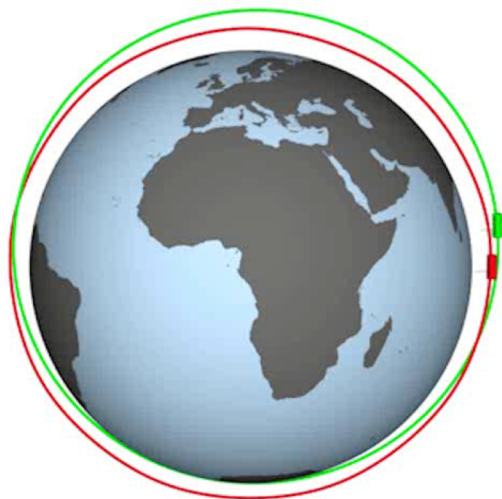
Radar cross section (TSX)



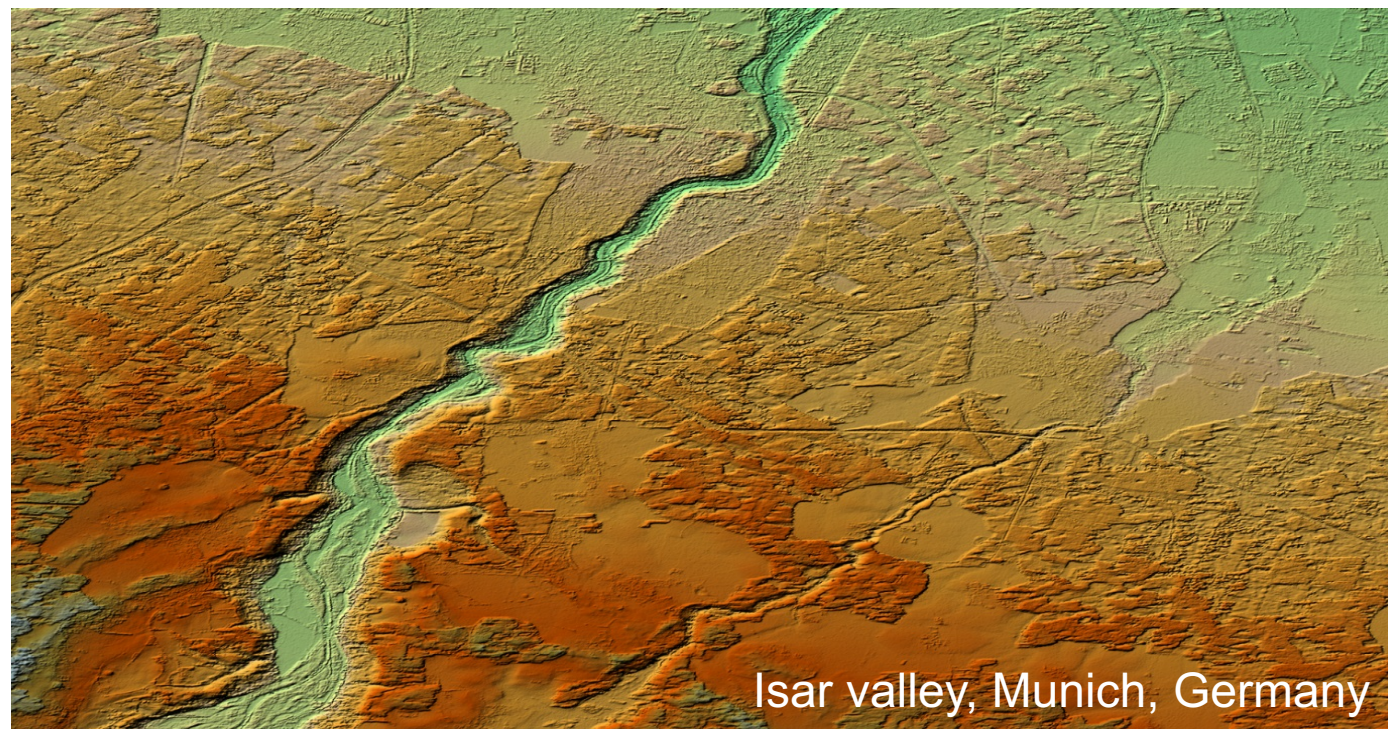
(TDX)



# 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

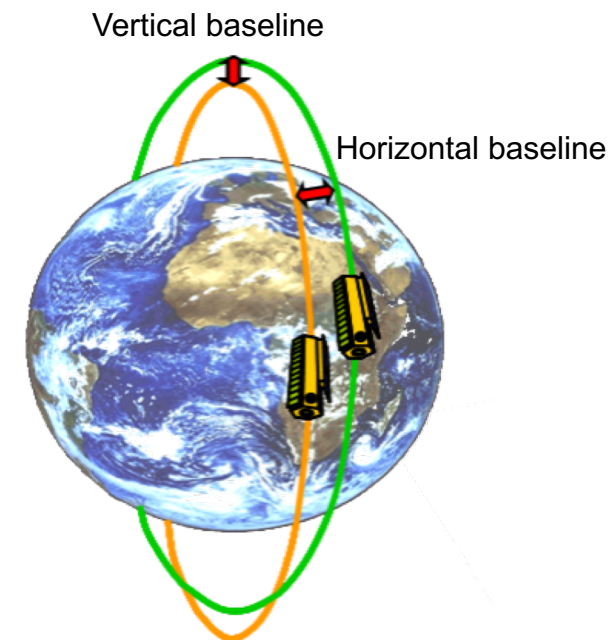
- Increased baseline (~350 m)
- HoA\* ~ 35 m

Combination:

- Dual Baseline Phase Unwrapping
- Improved Height Accuracy

## 3rd- 4th Year Acquisitions

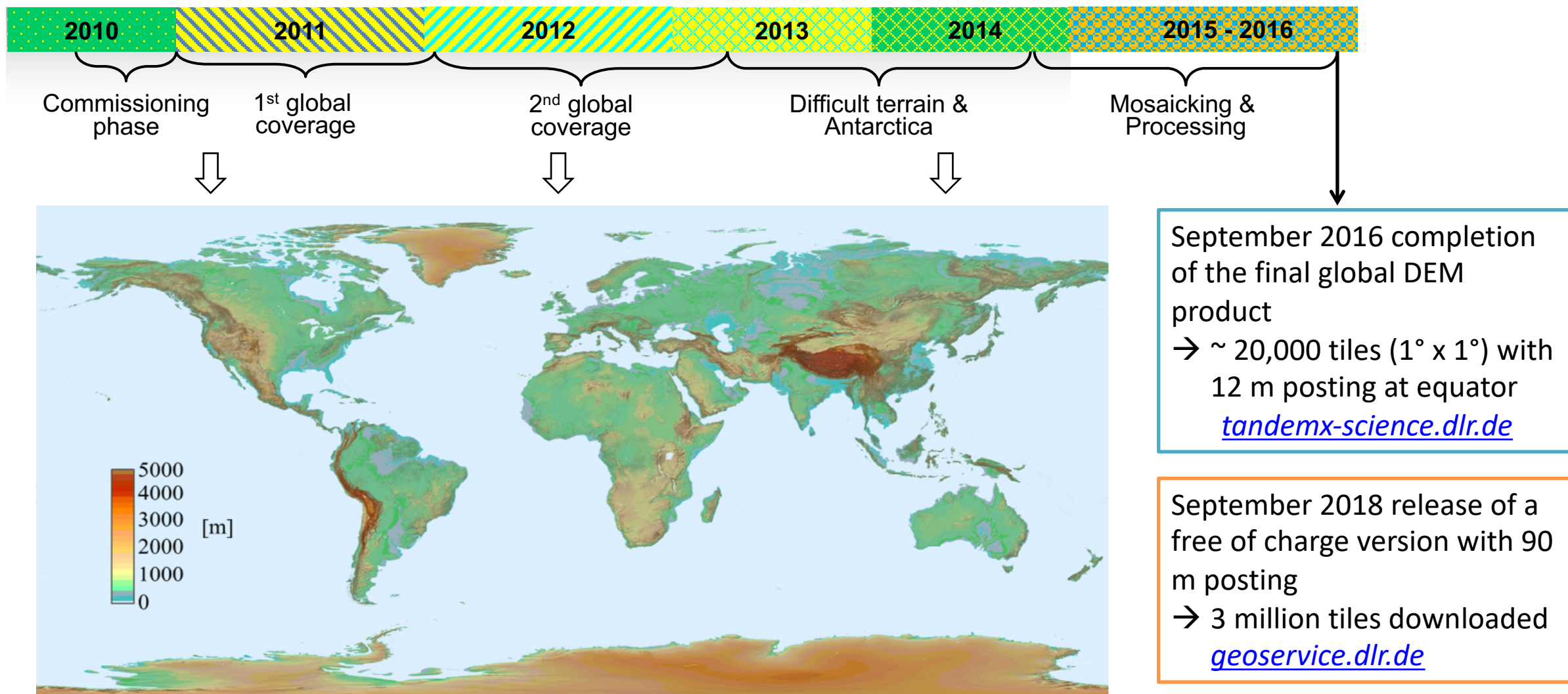
- Antarctica in left looking
- Difficult terrain to account for shadow & layover  
=> Deserts, mountains  
=> Different viewing geometry



\*HoA: Height of Ambiguity  $\leftrightarrow 2\pi$  Interferometric Phase



# Global DEM



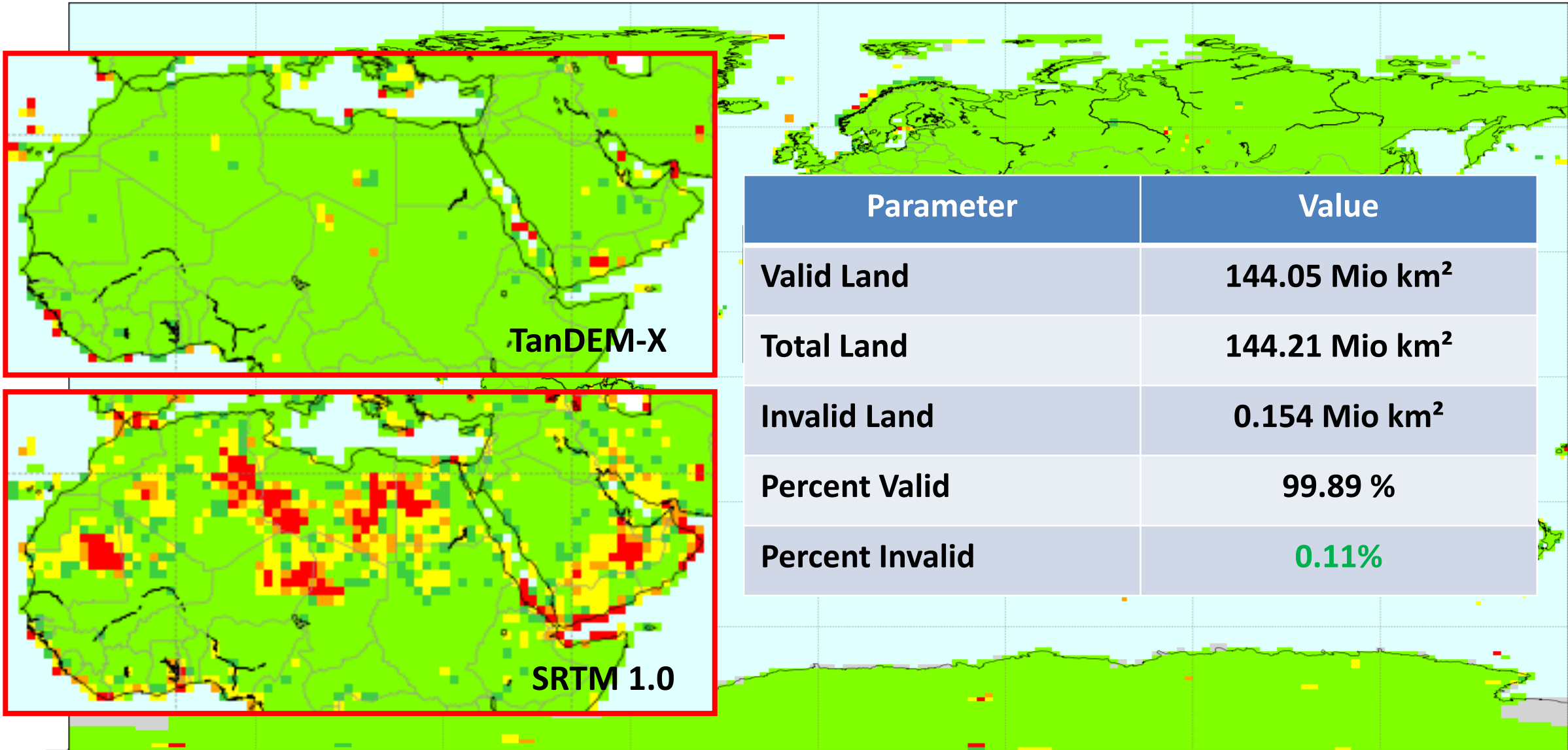
# Absolute Height Accuracy

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. Km <sup>2</sup> ]	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

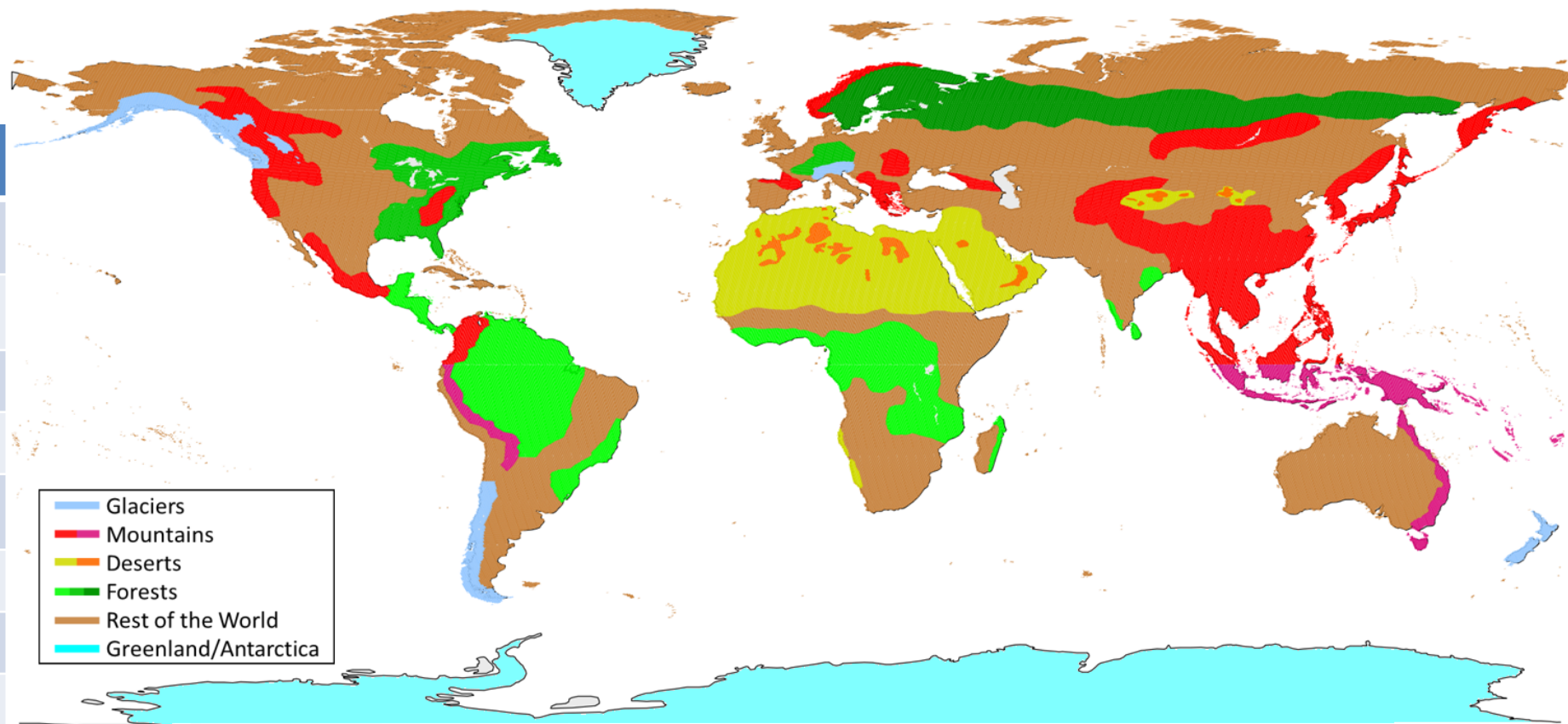
# TanDEM-X Data Coverage – Global Voids Performance



Parameter	Value
Valid Land	144.05 Mio km <sup>2</sup>
Total Land	144.21 Mio km <sup>2</sup>
Invalid Land	0.154 Mio km <sup>2</sup>
Percent Valid	99.89 %
Percent Invalid	0.11%

# Change DEM

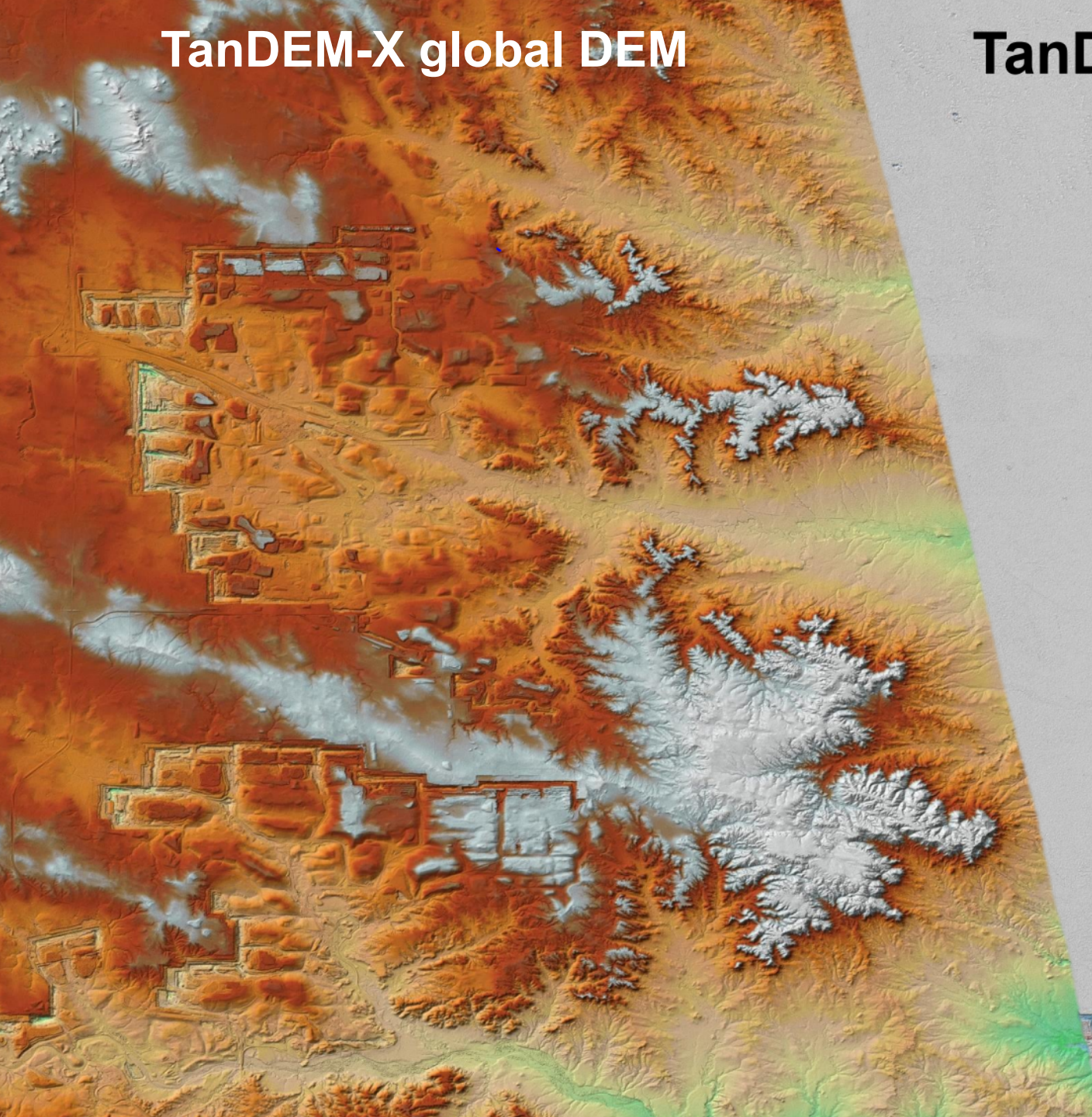
Region	Coverages	Season	Height of Ambiguity	Inc. Angle Range
Mountains with Forest	2	Local summer	55 - 75 m (1 <sup>st</sup> ) 45 - 53 m (2 <sup>nd</sup> )	27 - 49 deg
Glaciers	2	Local winter	55 - 75 m (1 <sup>st</sup> ) 45 - 53 m (2 <sup>nd</sup> )	29 - 47 deg
Tropical forest	1	Year round	50 - 60 m	27 - 49 deg
Temperate & boreal forest	1	Local summer	50 - 55 m	27 - 49 deg
Deserts with Mountains	2	Year round	55 - 75 m (1 <sup>st</sup> ) 45 - 55 m (2 <sup>nd</sup> )	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



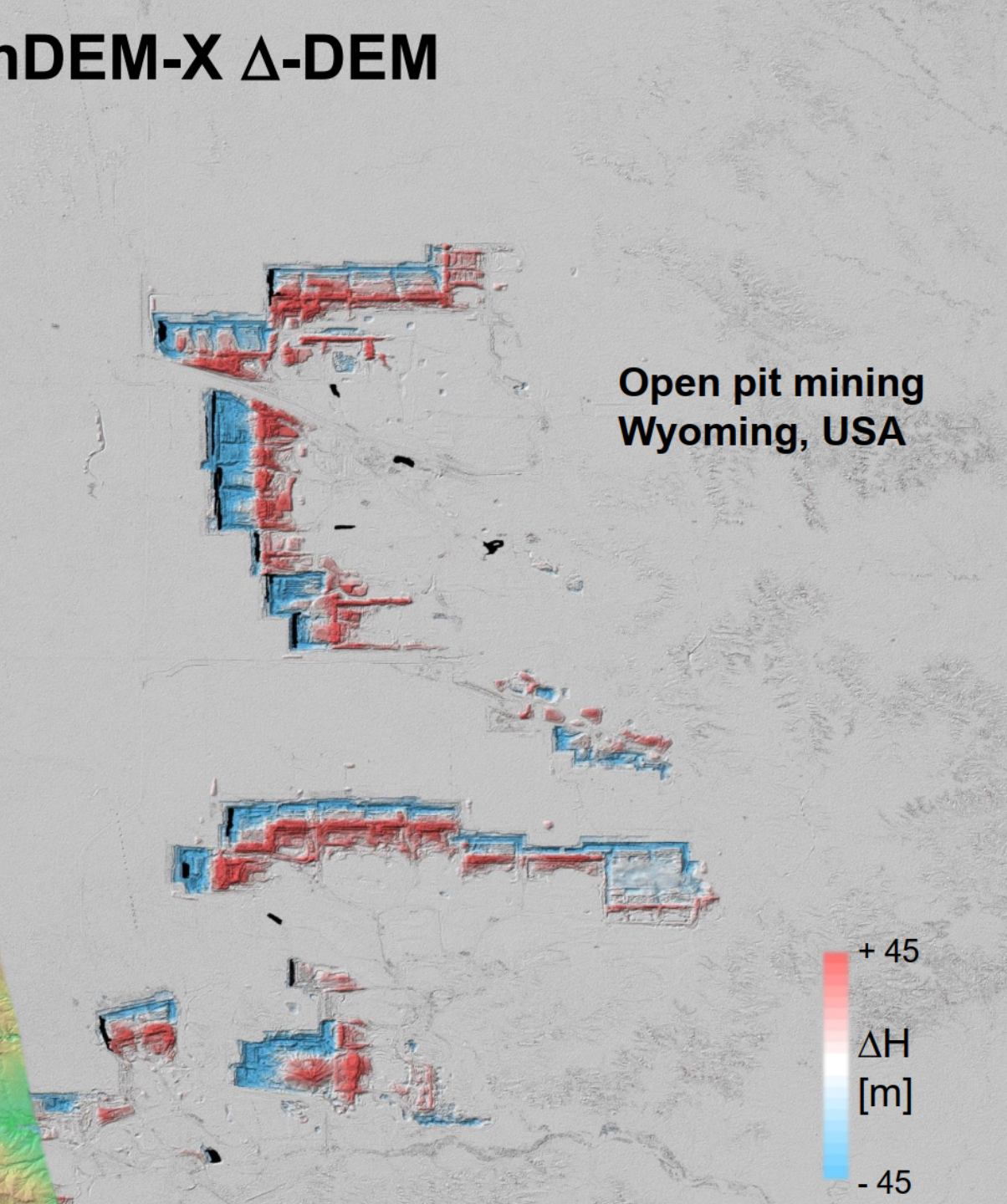
- Division of landmasses according to terrain type
- Acquisition plan adapted to seasonal and baseline requirements
- Improved processing methods → global DEM accuracy with fewer acquisitions



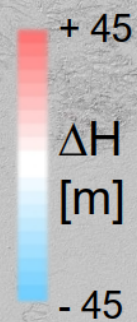
TanDEM-X global DEM



TanDEM-X  $\Delta$ -DEM

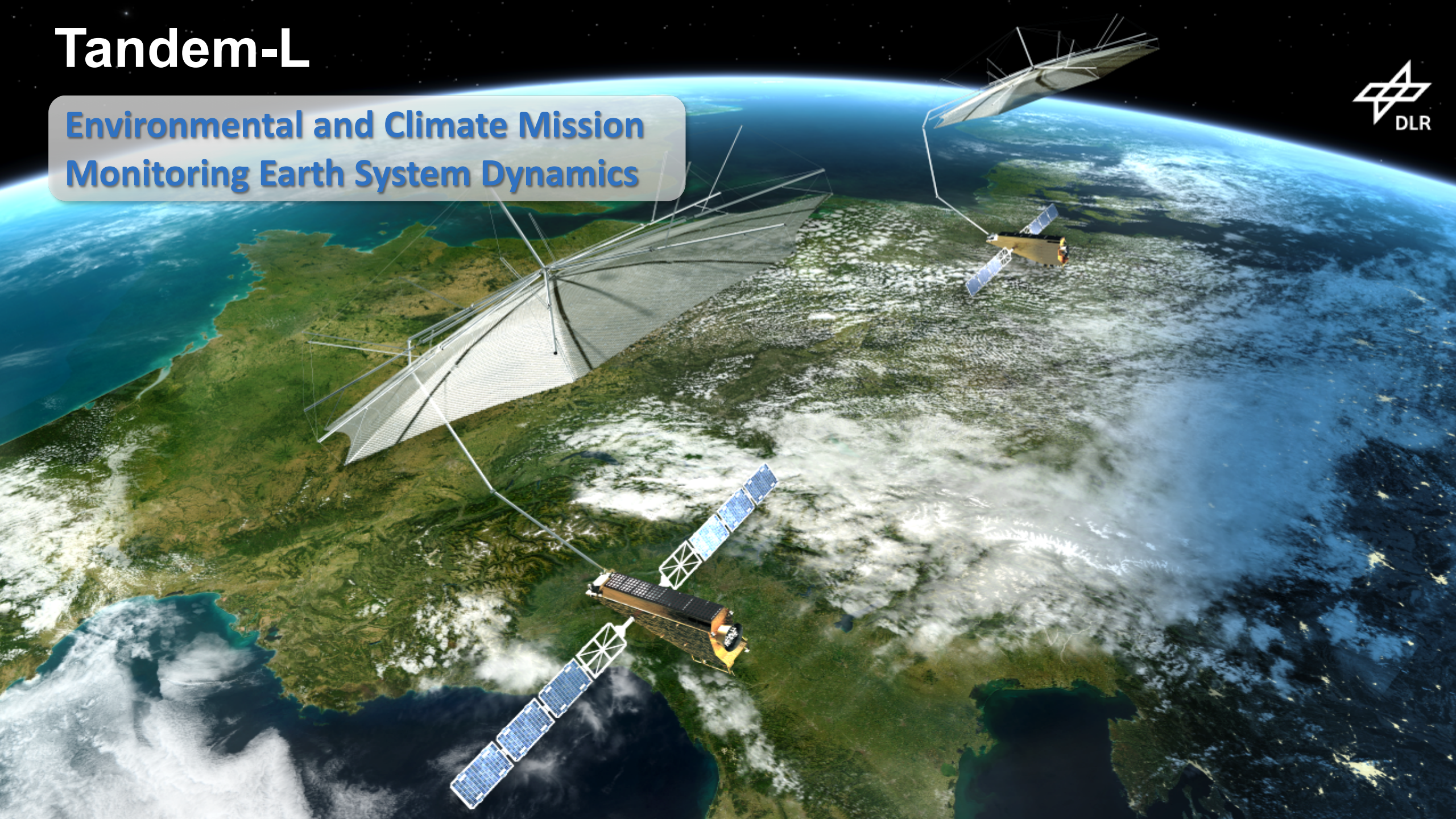


Open pit mining  
Wyoming, USA



# Tandem-L

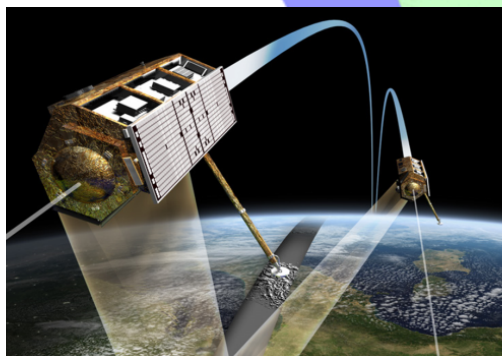
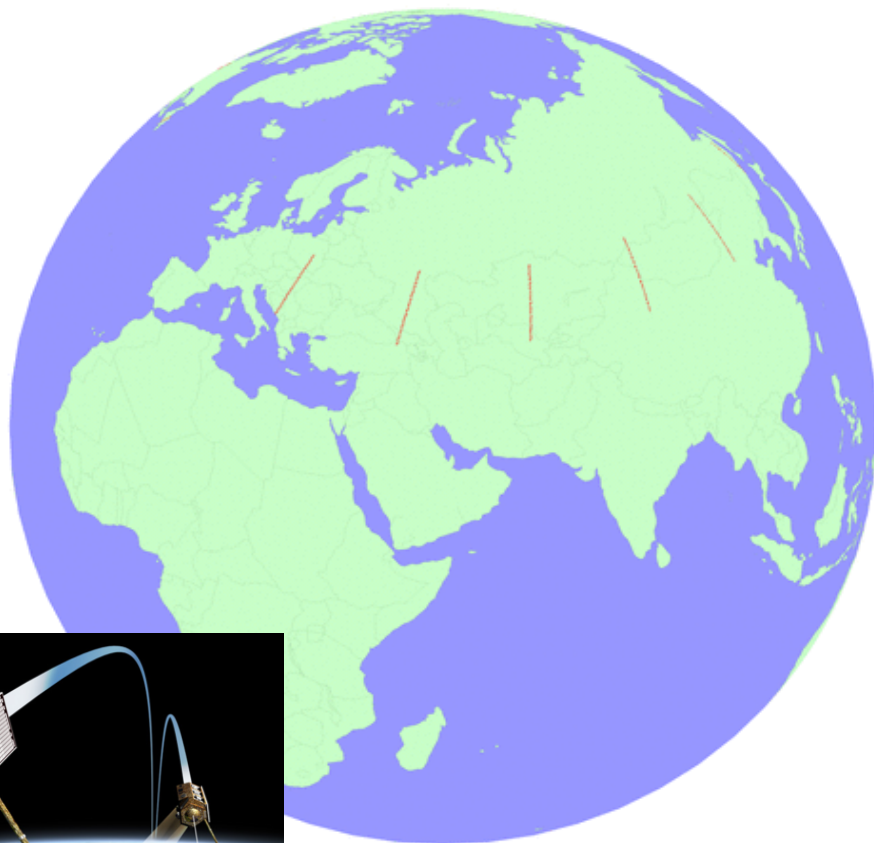
Environmental and Climate Mission  
Monitoring Earth System Dynamics



# Imaging capabilities

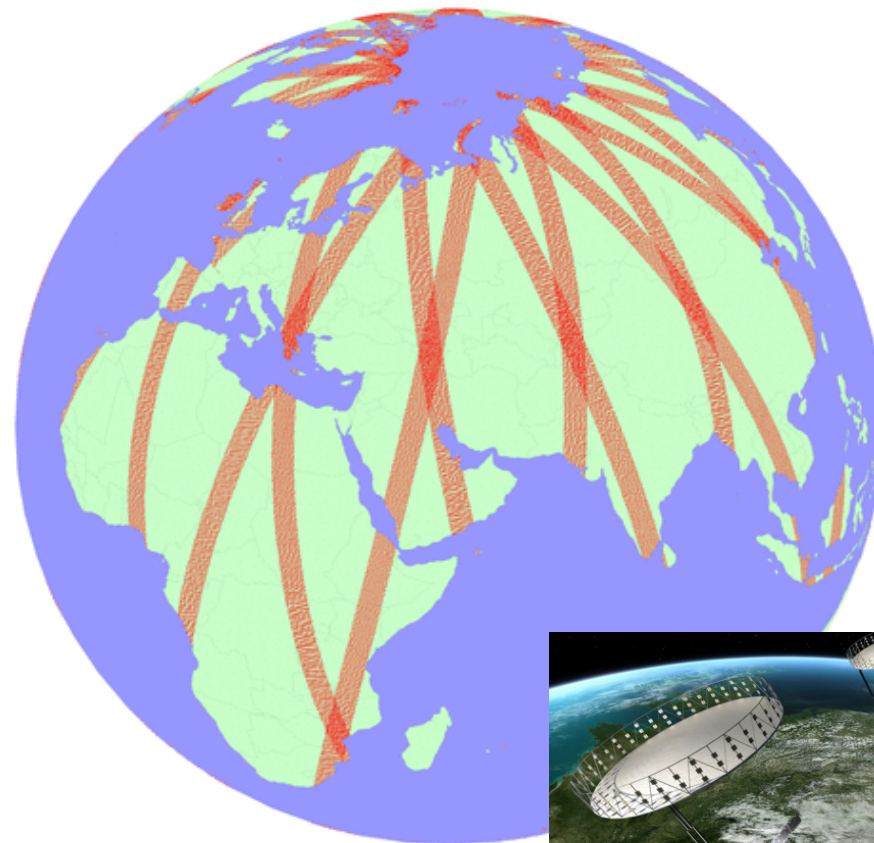
**TerraSAR-X/TanDEM-X**

**1 global coverage / year**



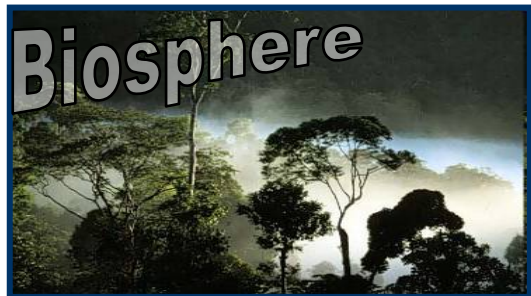
**Tandem-L**

**2 global coverages / 8 days**

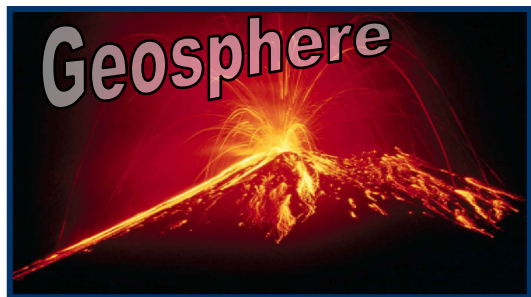


**1**  
**Days**

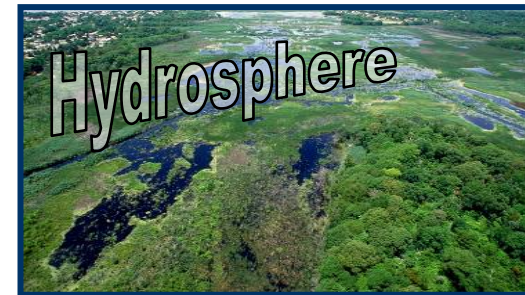
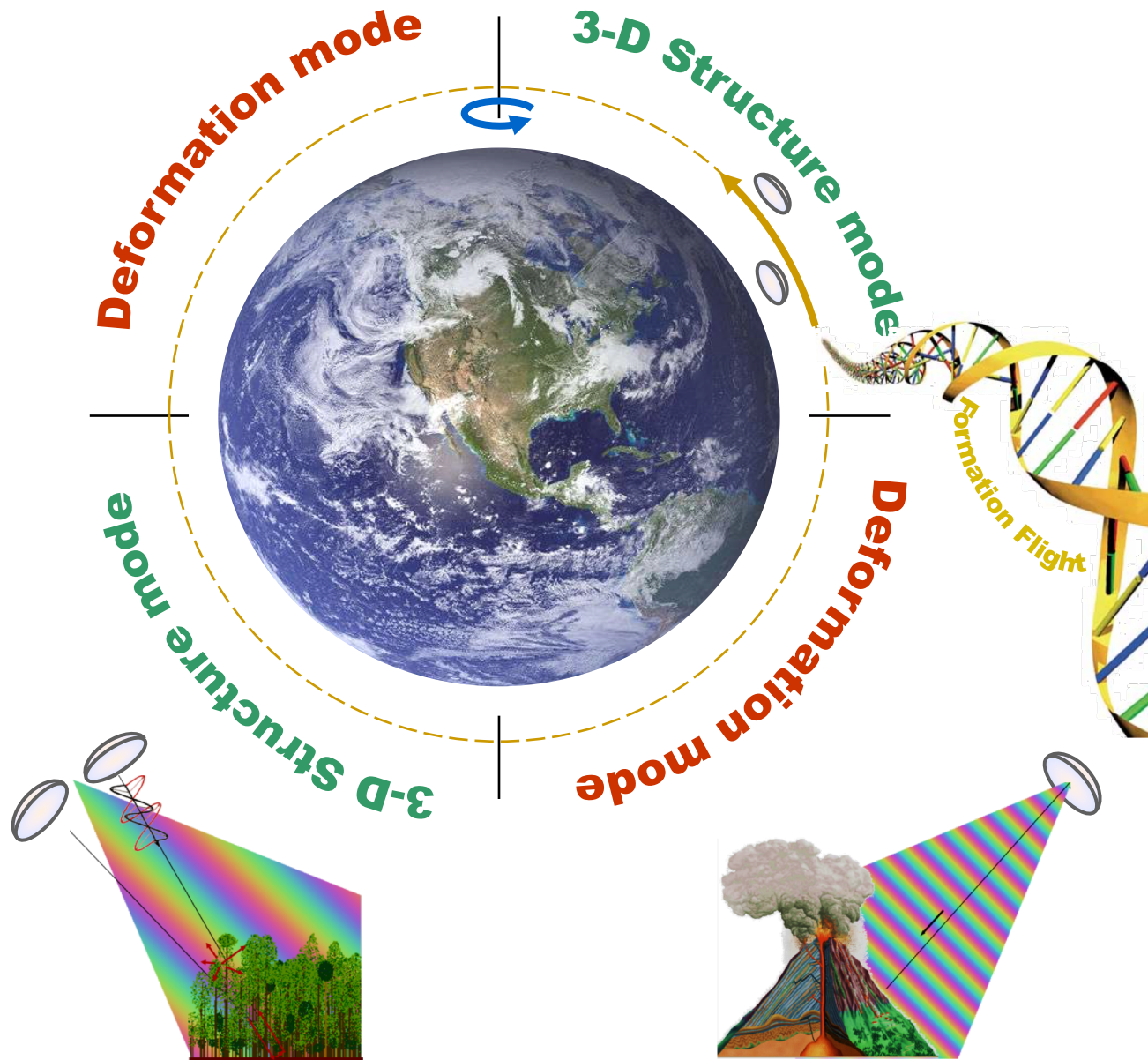




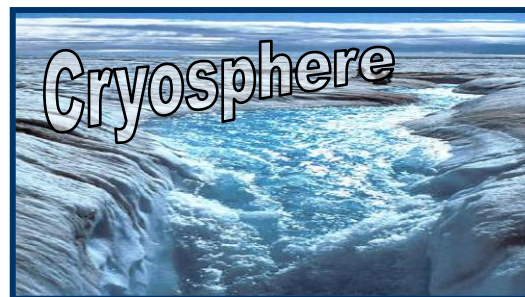
- 3-D forest structure
- Forest height and biomass
- Tomography



- Earthquakes
- Volcanoes and tectonics
- Subsidence



- Soil moisture
- Flooding
- Ocean currents



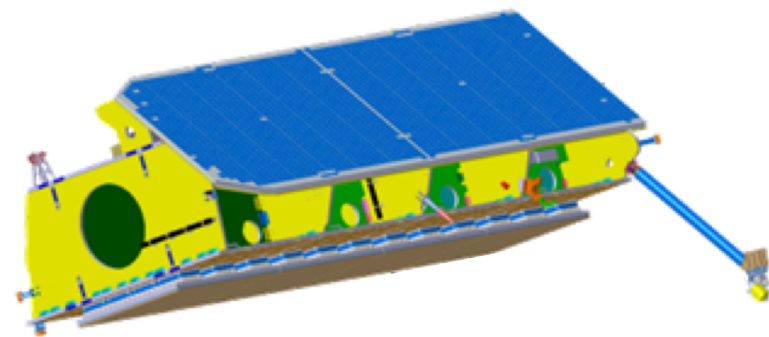
- Permafrost
- Sea ice extent
- Glaciers and ice cap dynamics



# HRWS – High Resolution Wide Swath

## Mono-static applications:

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



	Resolution [m <sup>2</sup> ] (Rg x Az)	Scene Size [km <sup>2</sup> ] (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



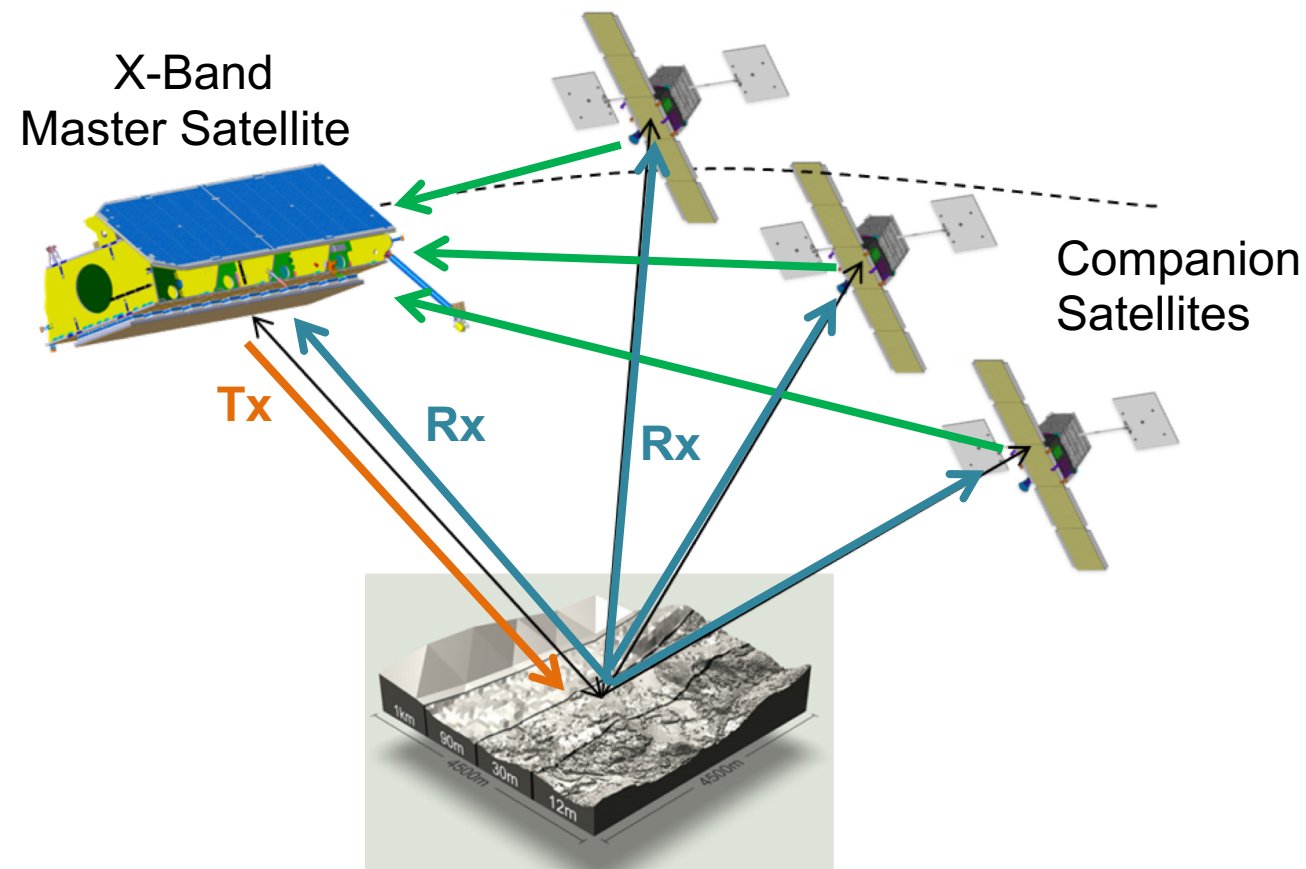
# HRWS – High Resolution Wide Swath

## 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