Quality of the TanDEM-X DEM

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CEOS SAR 2016

07-09 September 2016

Tokyo Denki University, Japan

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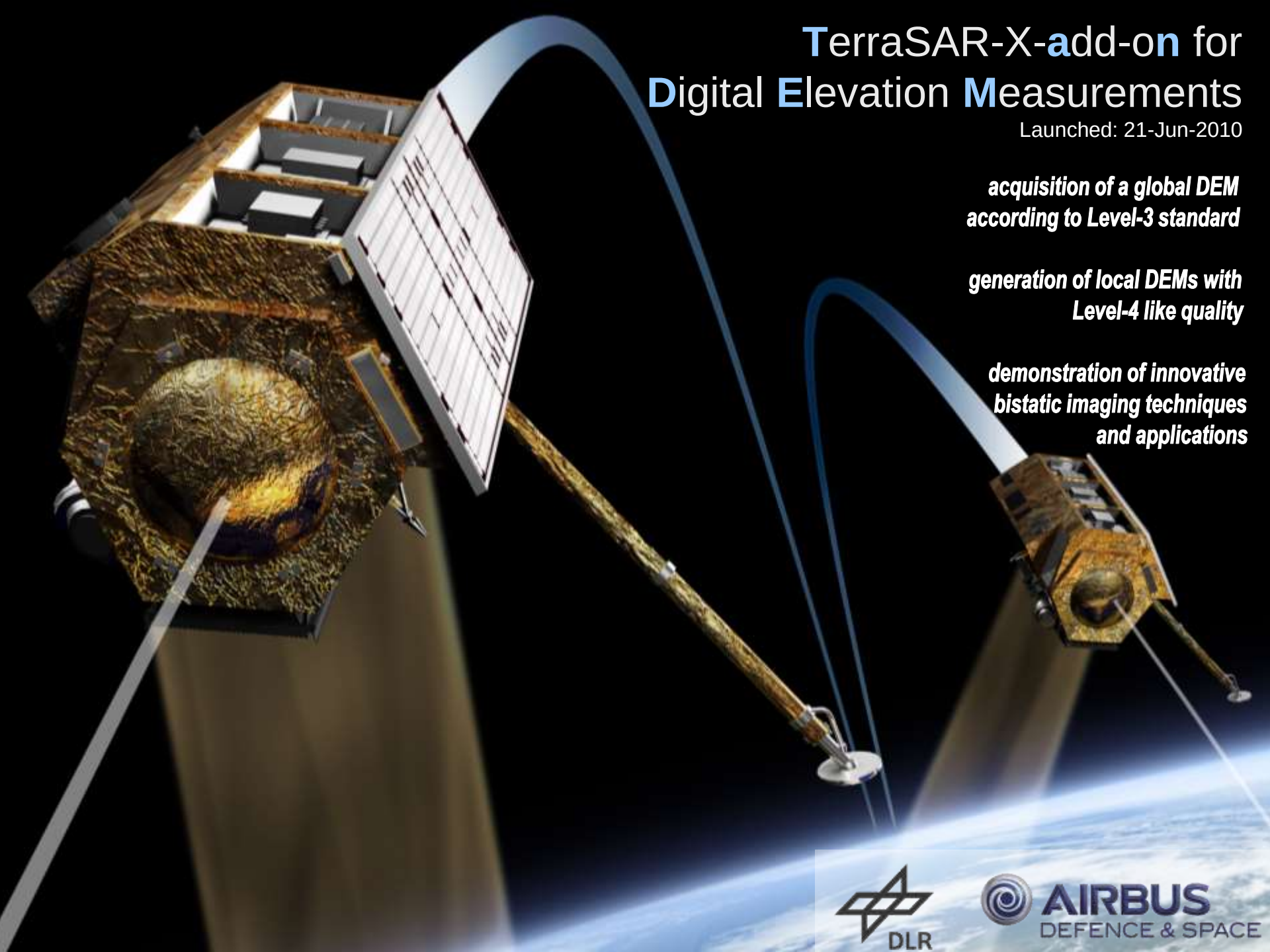

TerraSAR-X-add-on for Digital Elevation Measurements

Launched: 21-Jun-2010

acquisition of a global DEM according to Level-3 standard

generation of local DEMs with Level-4 like quality

demonstration of innovative bistatic imaging techniques and applications

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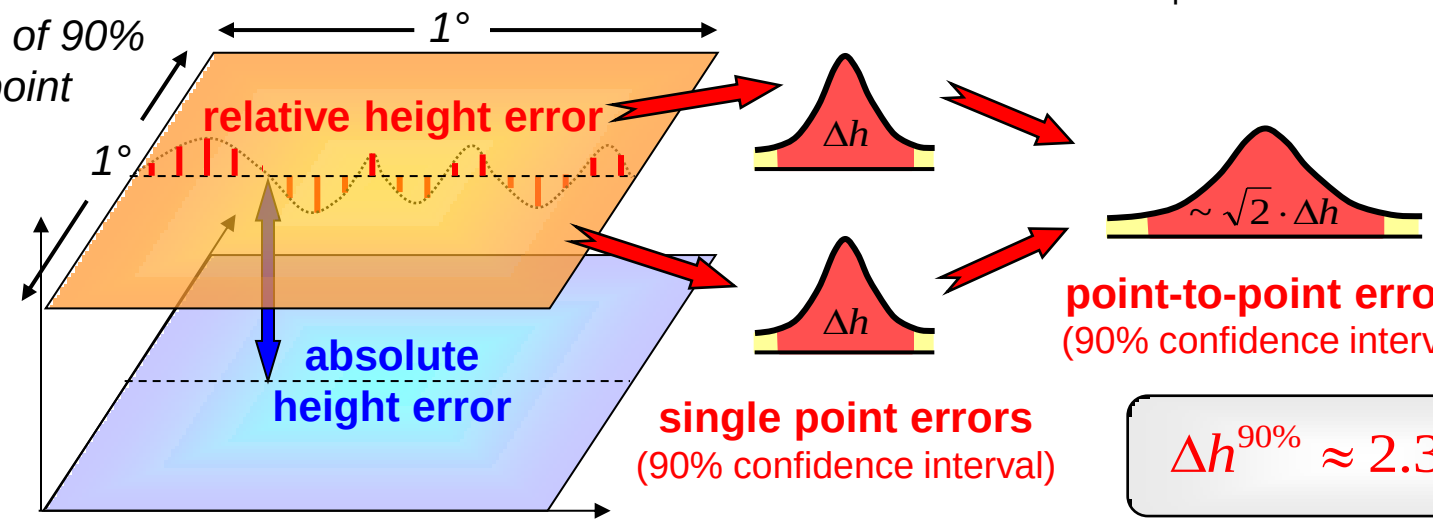
AIRBUS DEFENCE & SPACE

Standards for Digital Elevation Models

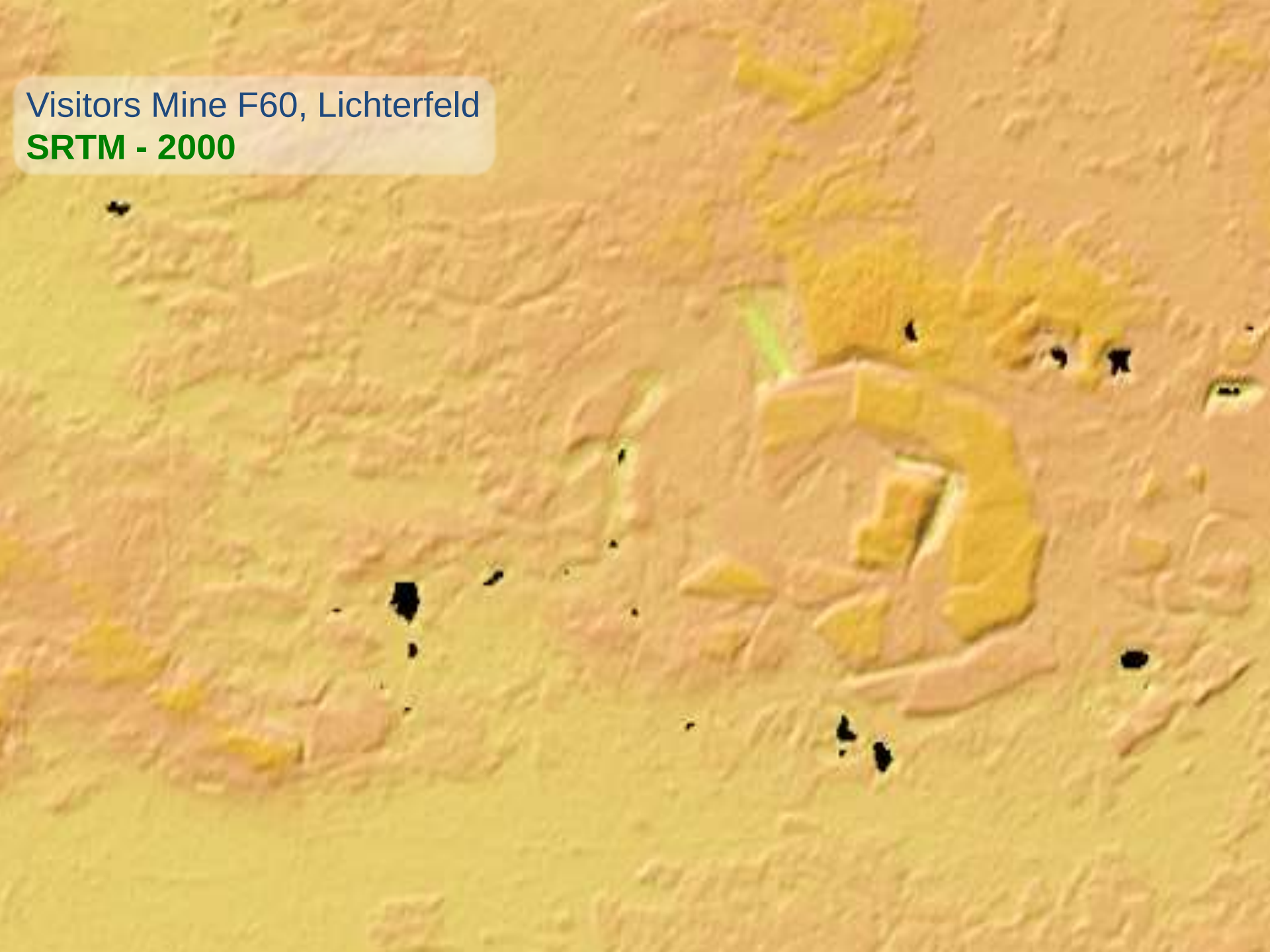
	Spatial Resolution	Absolute Vertical Accuracy (90%)	Relative Vertical Accuracy (point-to-point in 1° cell, 90%)
DTED-1	90 m x 90 m	< 30 m	< 20 m
DTED-2	30 m x 30 m	< 18 m	< 12 m
TanDEM-X	12 m x 12 m	< 10 m	< 2 m / 4 m *
Level-4	6 m x 6 m	< 5 m	< 0.8 m

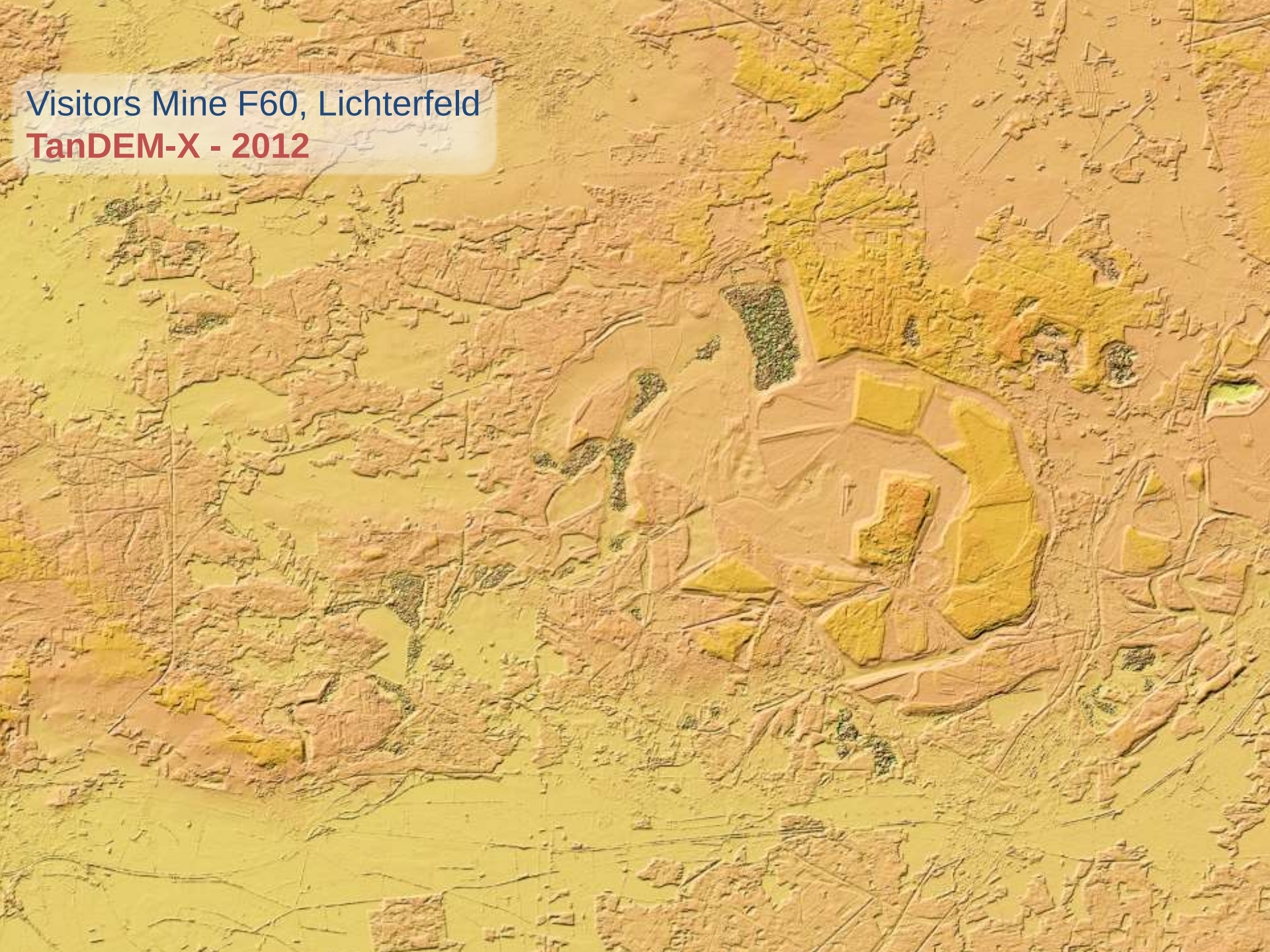
* slopes below/above 20%

Definition of 90% point-to-point errors:



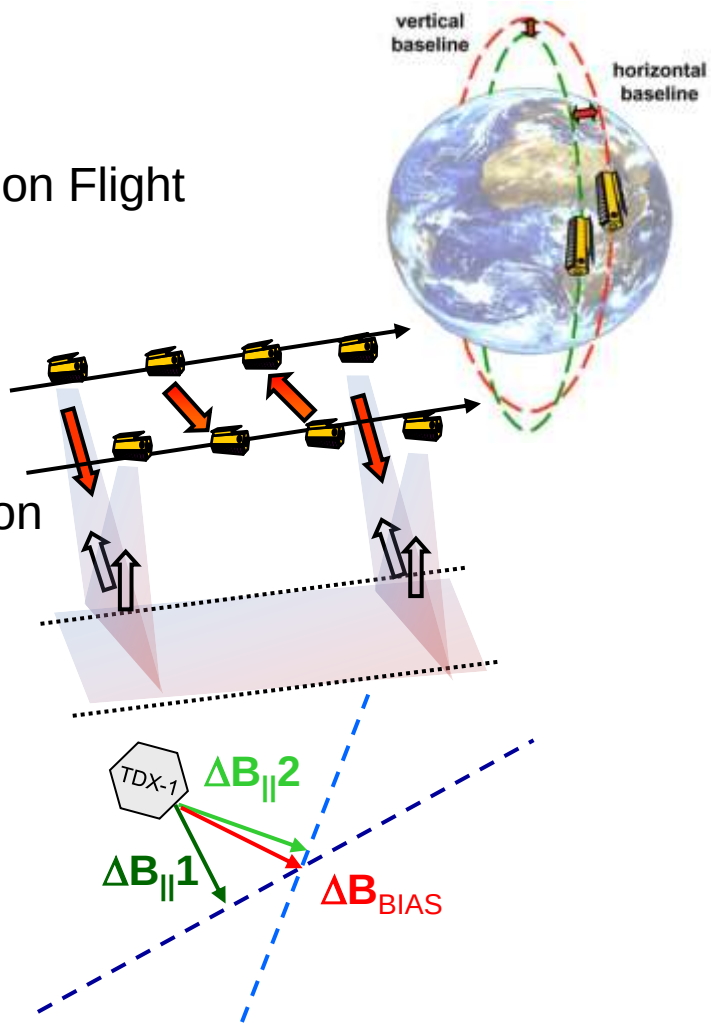
$$\Delta h^{90\%} \approx 2.33 \cdot \sigma_h$$


Visitors Mine F60, Lichterfeld
SRTM - 2000

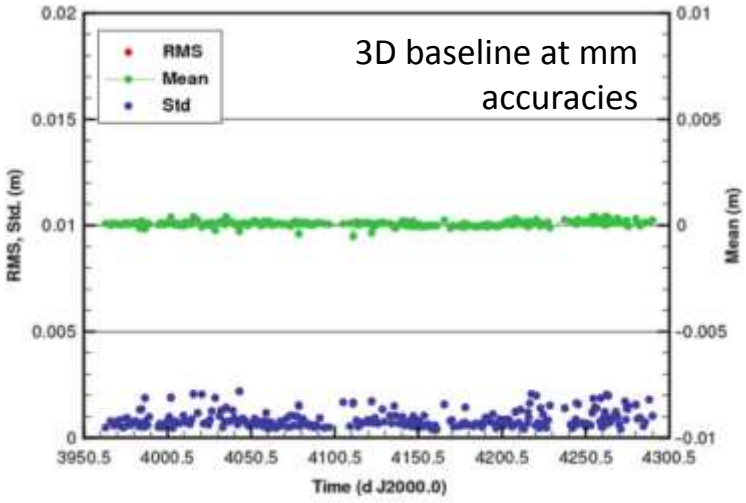

Visitors Mine F60, Lichterfeld
TanDEM-X - 2012

Key Capabilities of TanDEM-X

- Close Formation Flight
- Synchronisation
- Calibration



- Precise Baseline Determination



- Highly accurate and powerful processing chains

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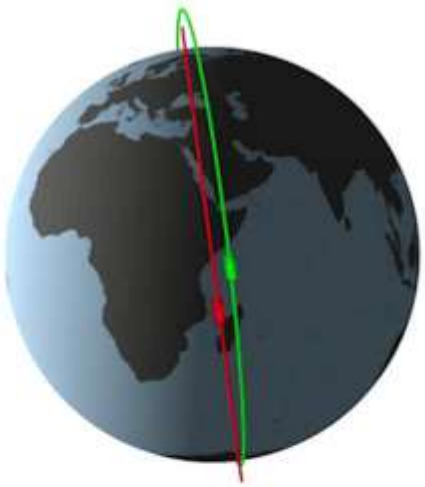
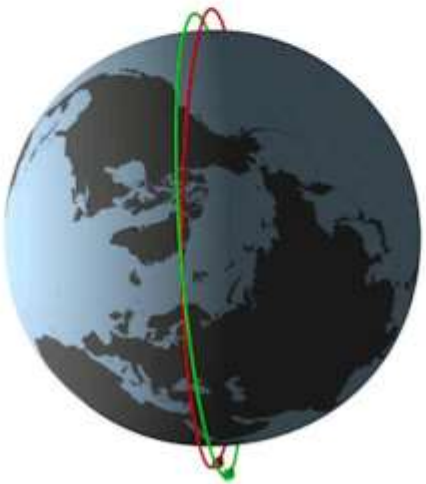
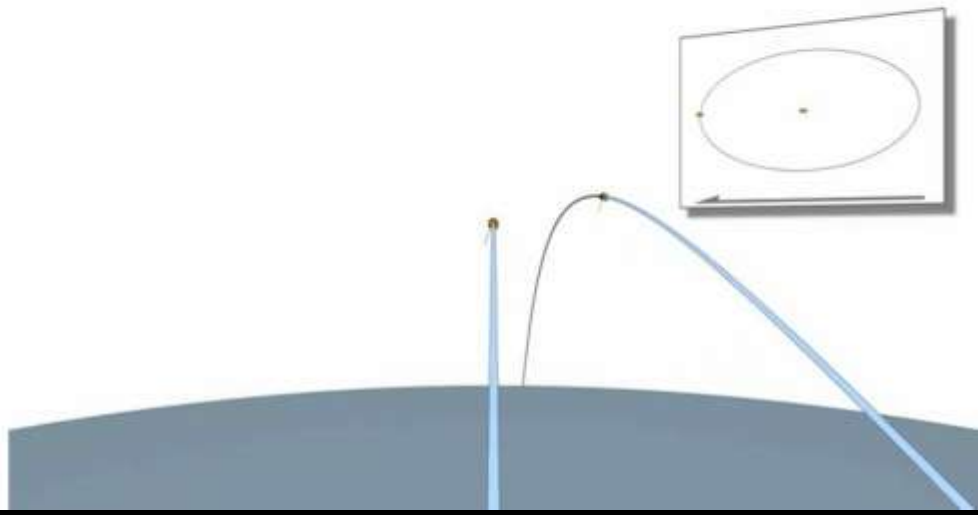
Helix Formation

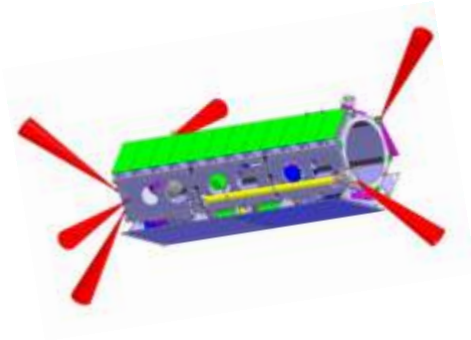


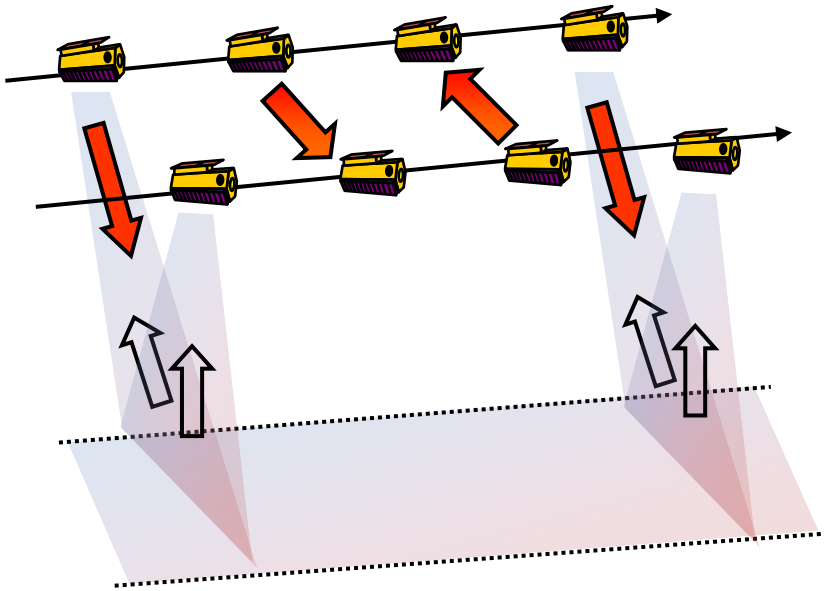




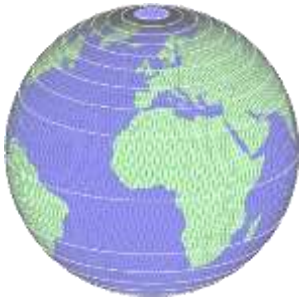
Bi-static Operation - Synchronisation

- Bi-static operation of TSX and TDX requires synchronisation of independent oscillators
- Phase referencing by exchange of pulses via synchronization link
- Leap PRIs compensate drift of Echo Window
- *Sync Warning for mutual health check*
- *Picosecond accuracies achieved*





TanDEM-X Global DEM Acquisition Plan



1st Global Coverage

- Small baseline (~200 m)
- Height of Ambiguity ~ 50 m

3rd Year

- Antarctica
- Difficult terrain to account for shadow & layover
  → Different viewing geometry
- Deserts

2nd Global Coverage

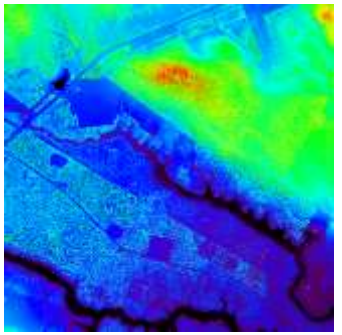
- Increased baseline (~300 m)
- Height of Ambiguity ~ 35 m

Combination:

- Dual Baseline Phase Unwrapping
- Improved relative height accuracy

4th Year & Beyond

- TanDEM-X Science Phase
- Local High-Resolution DEMs
- Global DEM improvement &
- Complementary products



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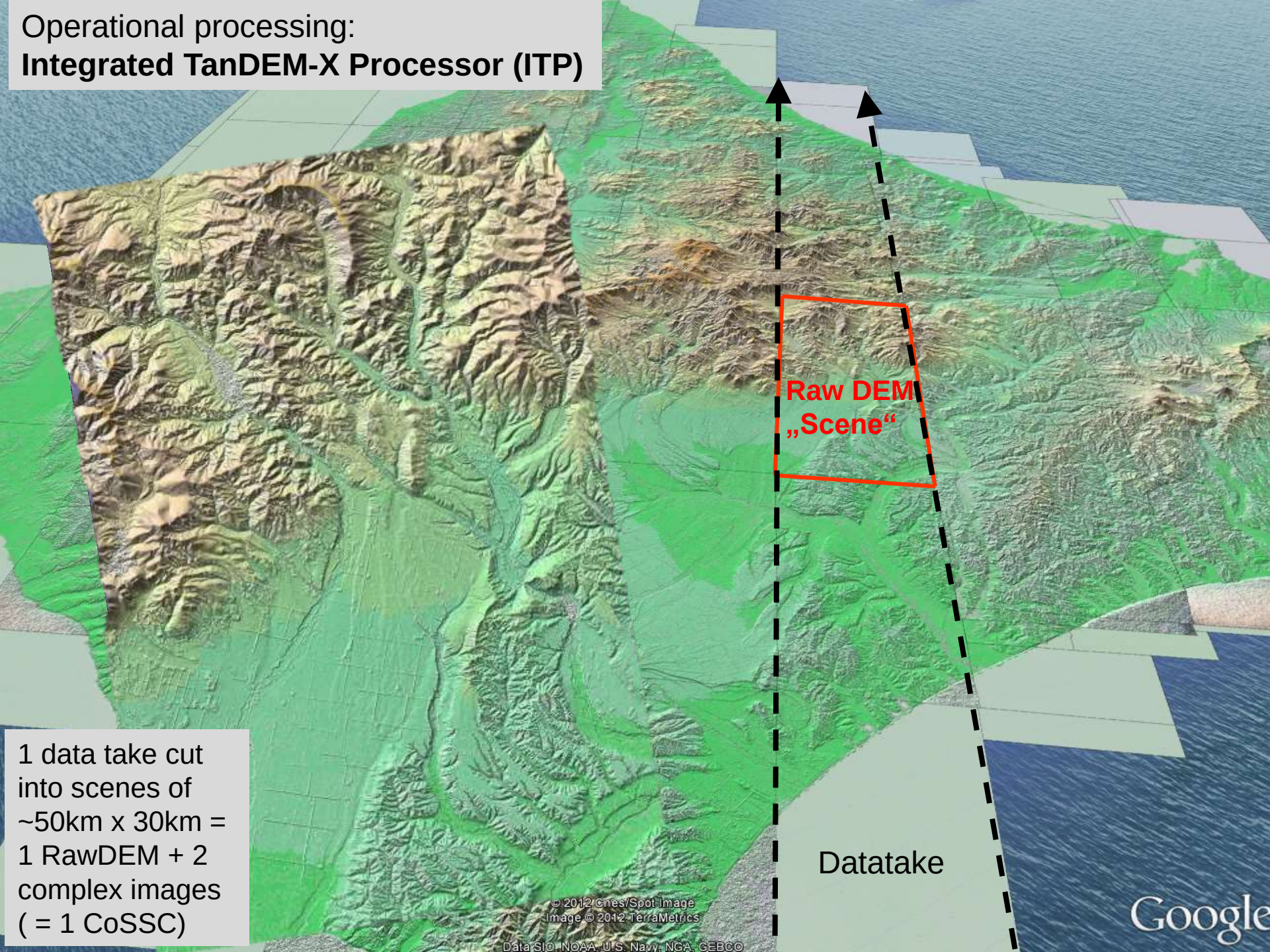
Acquisition Sequence - Relative Height Error

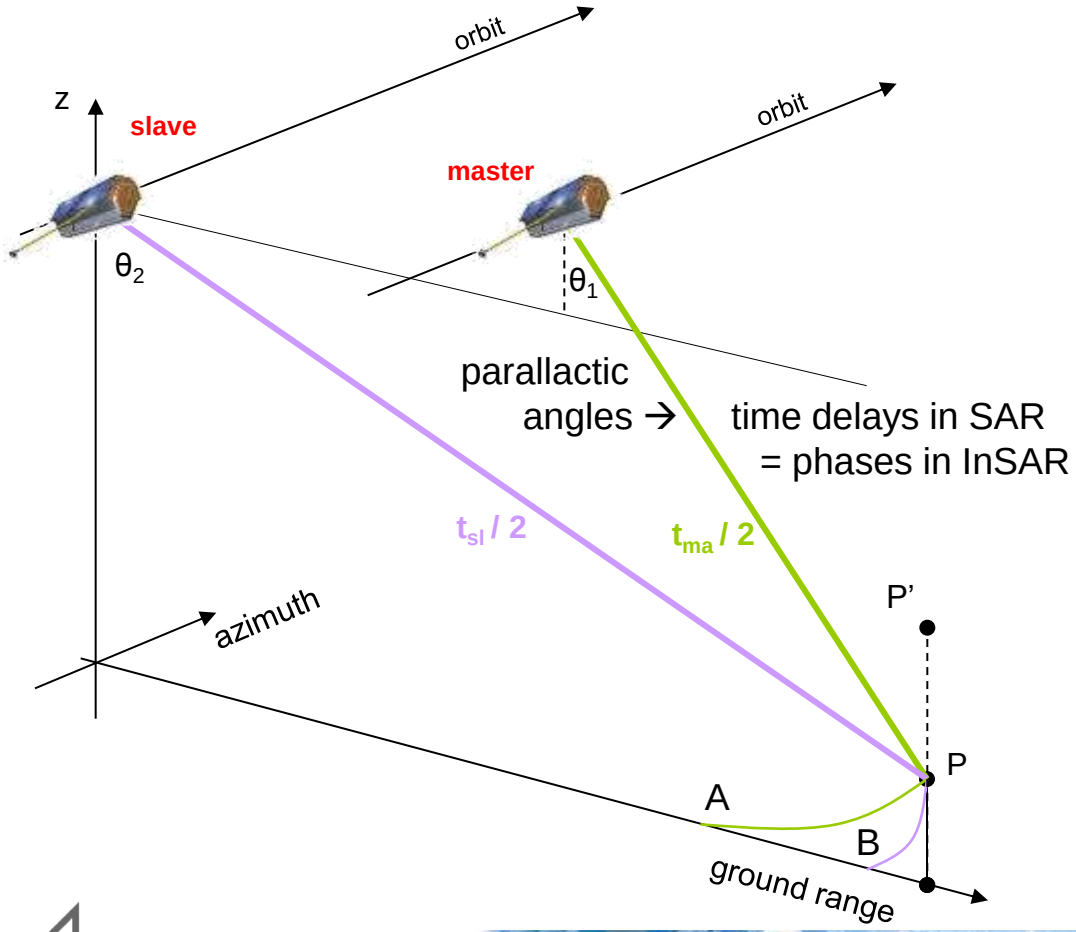
Operational processing:
Integrated TanDEM-X Processor (ITP)

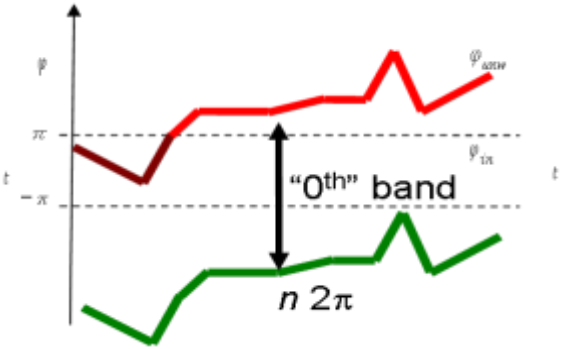


1 data take cut into scenes of ~50km x 30km = 1 RawDEM + 2 complex images (= 1 CoSSC)

Radargrammetry to Resolve Phase Ambiguity Band

→ requires delay calibration of the system to mm accuracies





- especially important in regions > 60 deg latitude where no SRTM is available
- becoming globally independent of SRTM as reference DEM for phase unwrapping

Calibration of the Interferometric System

- Baseline calibration to mm accuracy achieved
- Accurate calibration of differential delays and correction of relativistic effects enables use of radargrammetry for resolving ambiguities
  → works for 99% of all RawDEMs
- Global phase constant adjusted to minimize offset w.r.t. ICESat corrected SRTM
- Correction of differential troposheric path delay

→ 90% of all data within ±10 m (w.r.t. to SRTM + ICESat)

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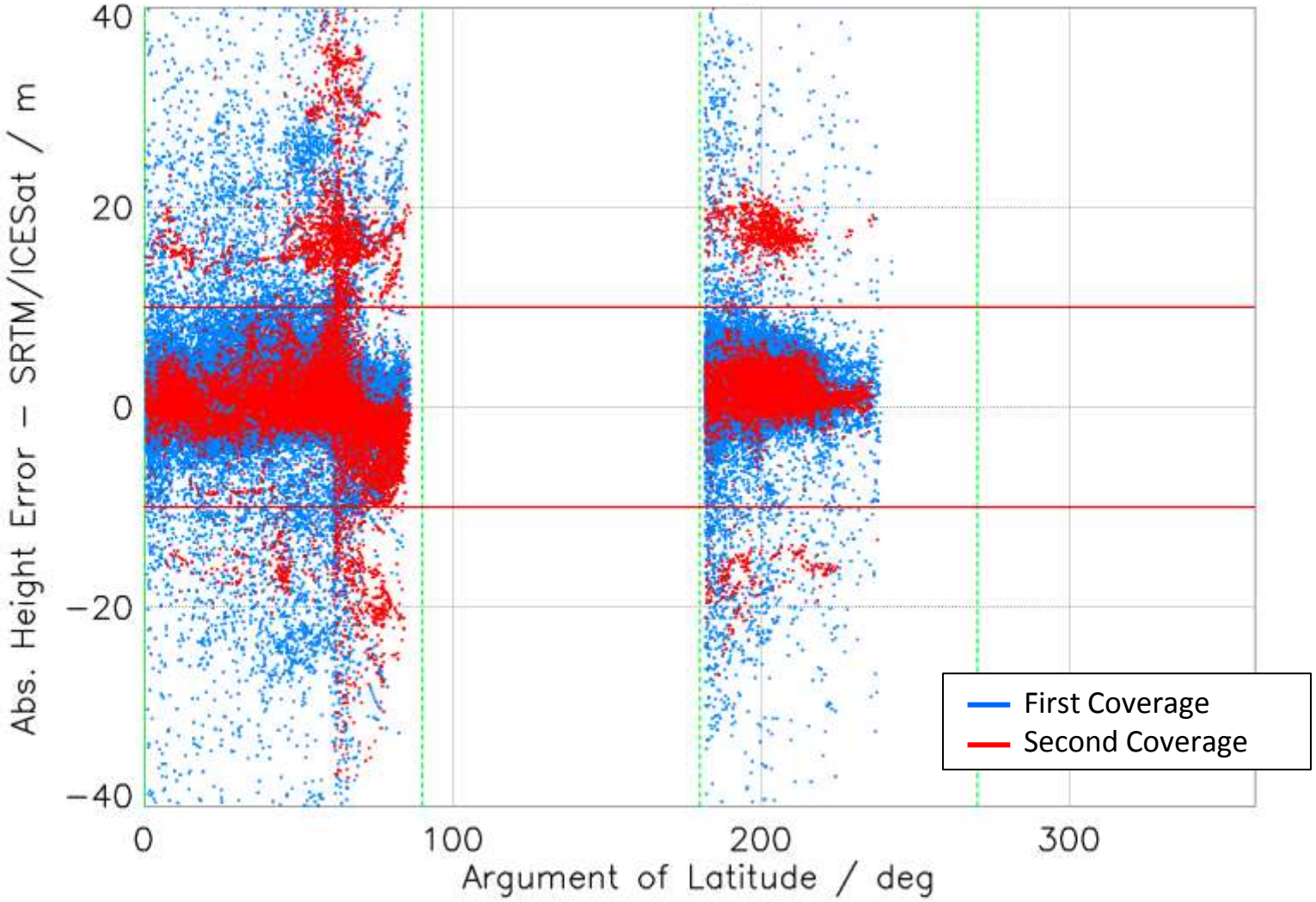
Absolute Height Error of Scene-Based RawDEMs



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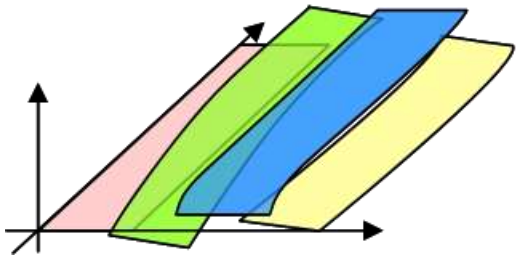
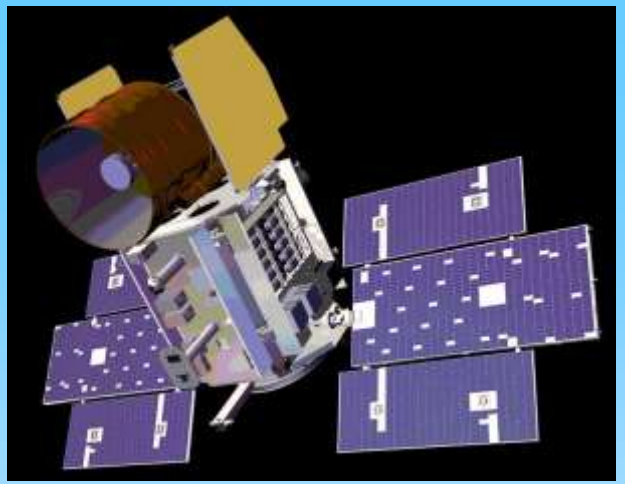
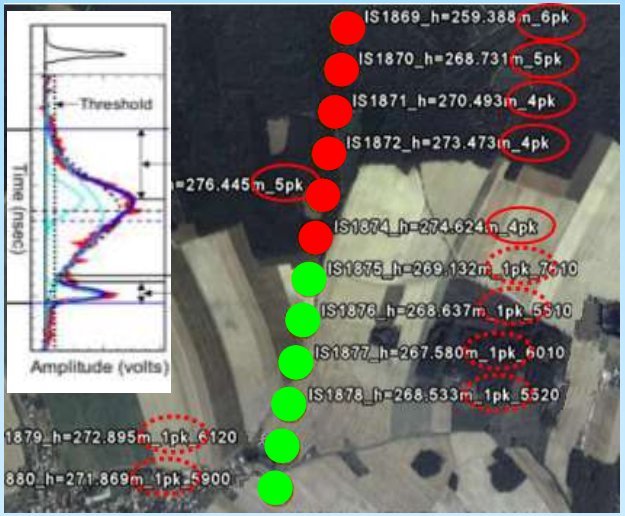
Final DEM Adjustment using ICESat Altimeter Data



Errors Corrected:
- Offsets
- Gradient in azimuth
- Tilt in range





- Filtering of ICESat points (flat areas, no or low vegetation)
- Selected set of ca. 100 ICESat points per geocell are used for absolute calibration
- Remaining majority of points (> 15 Mio.) are used for validation

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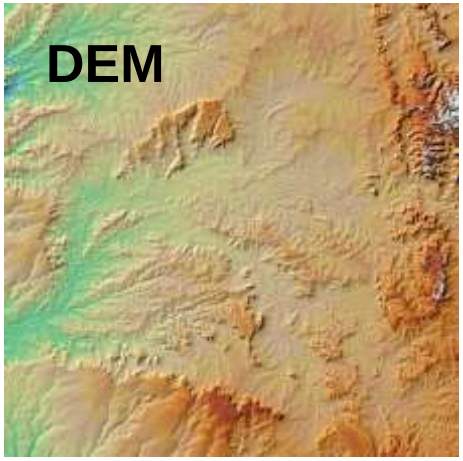
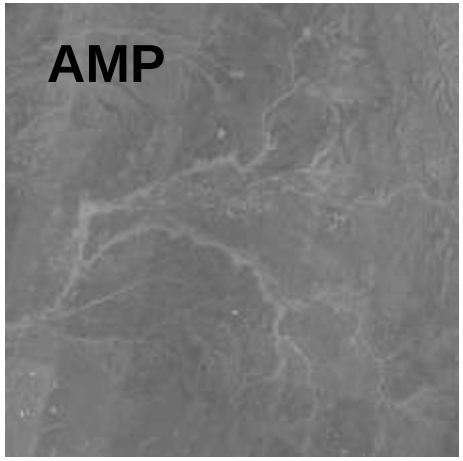
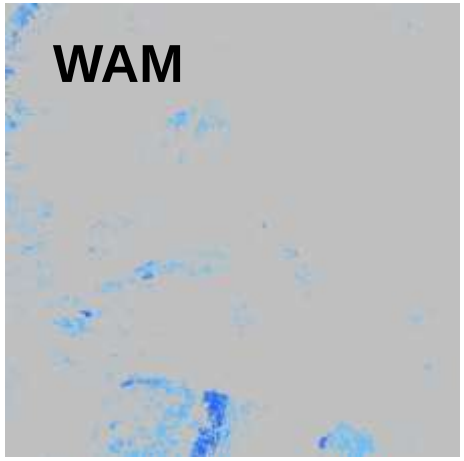
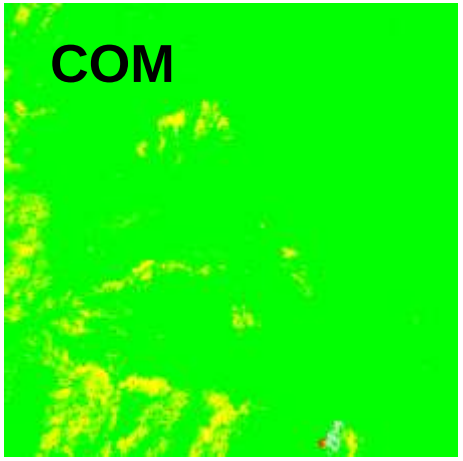
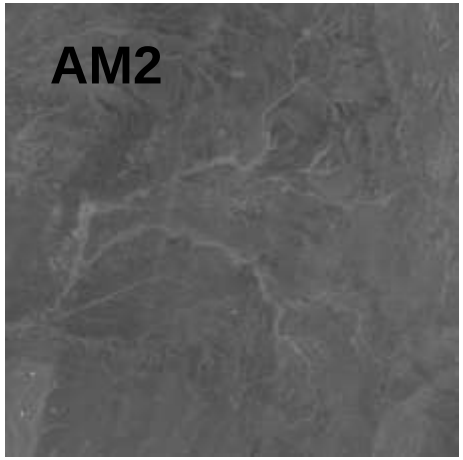
DEM Product Layer Overview

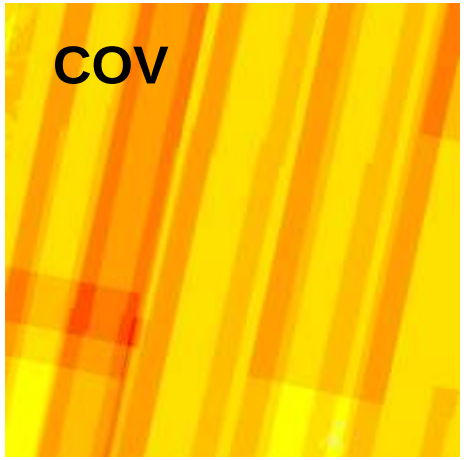












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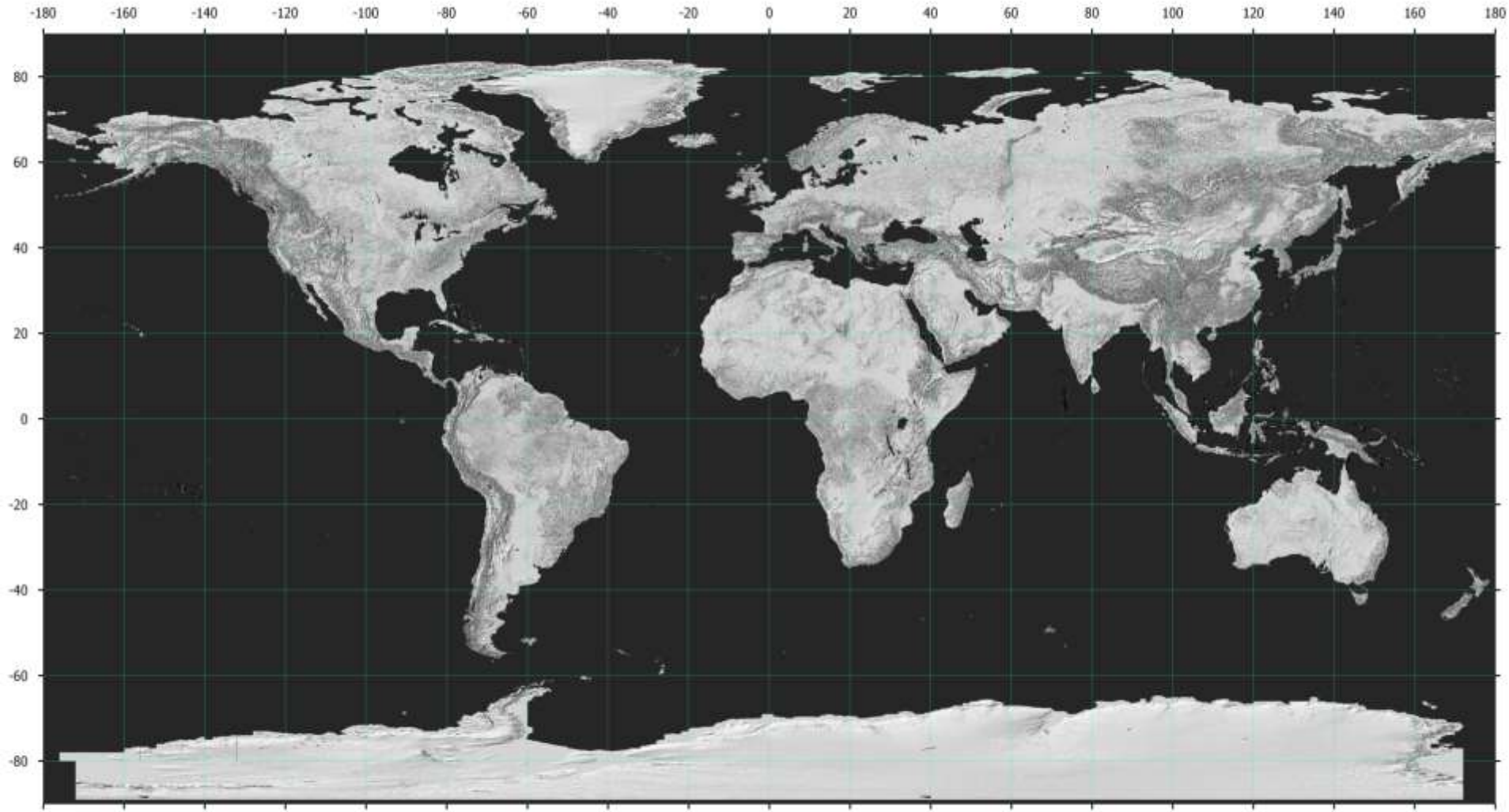
DEM Production Status (August 30, 2016)



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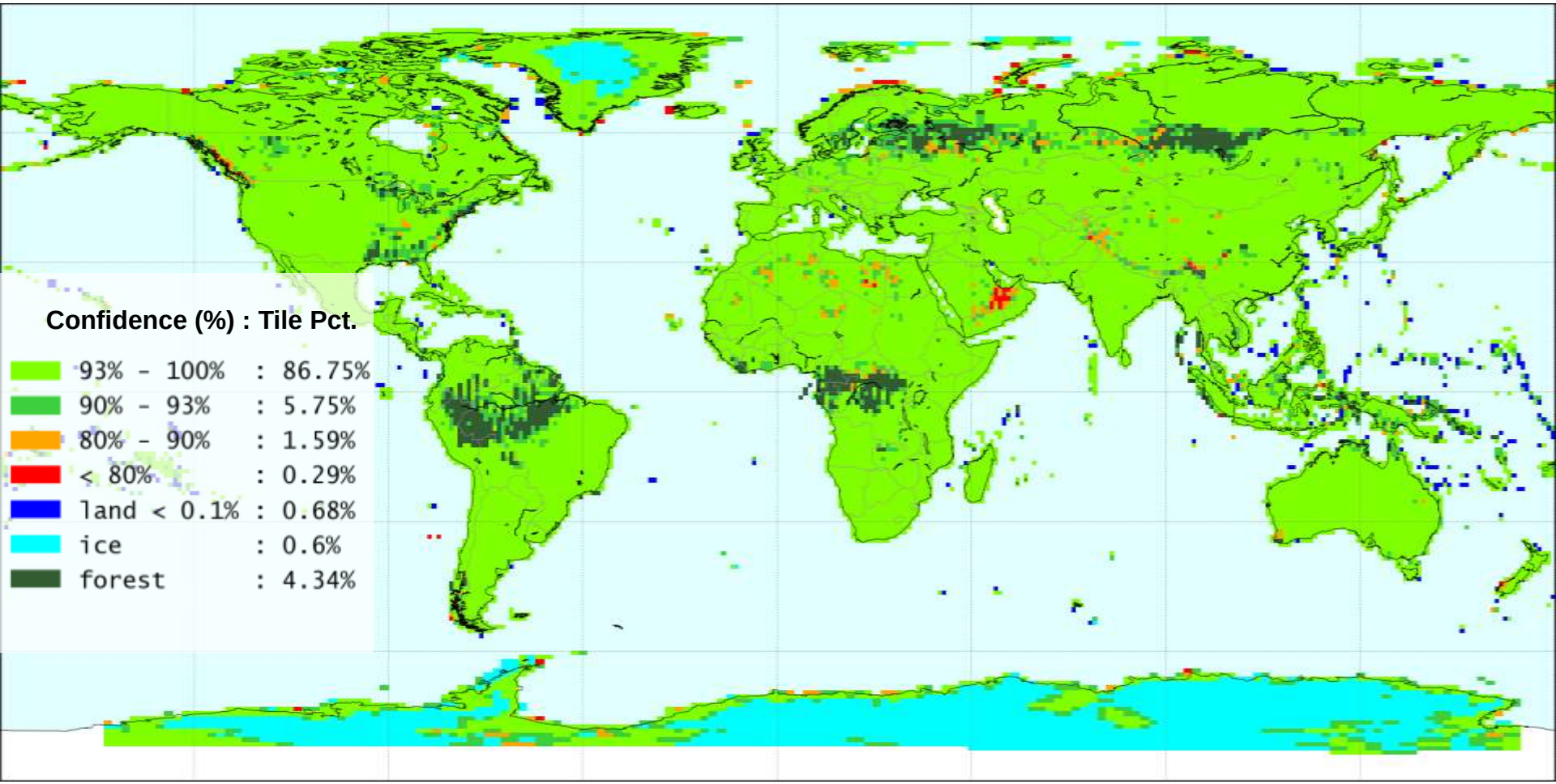
Relative Height Accuracy



96,4% of Final DEMs Achieve Relative Height Accuracy Specification

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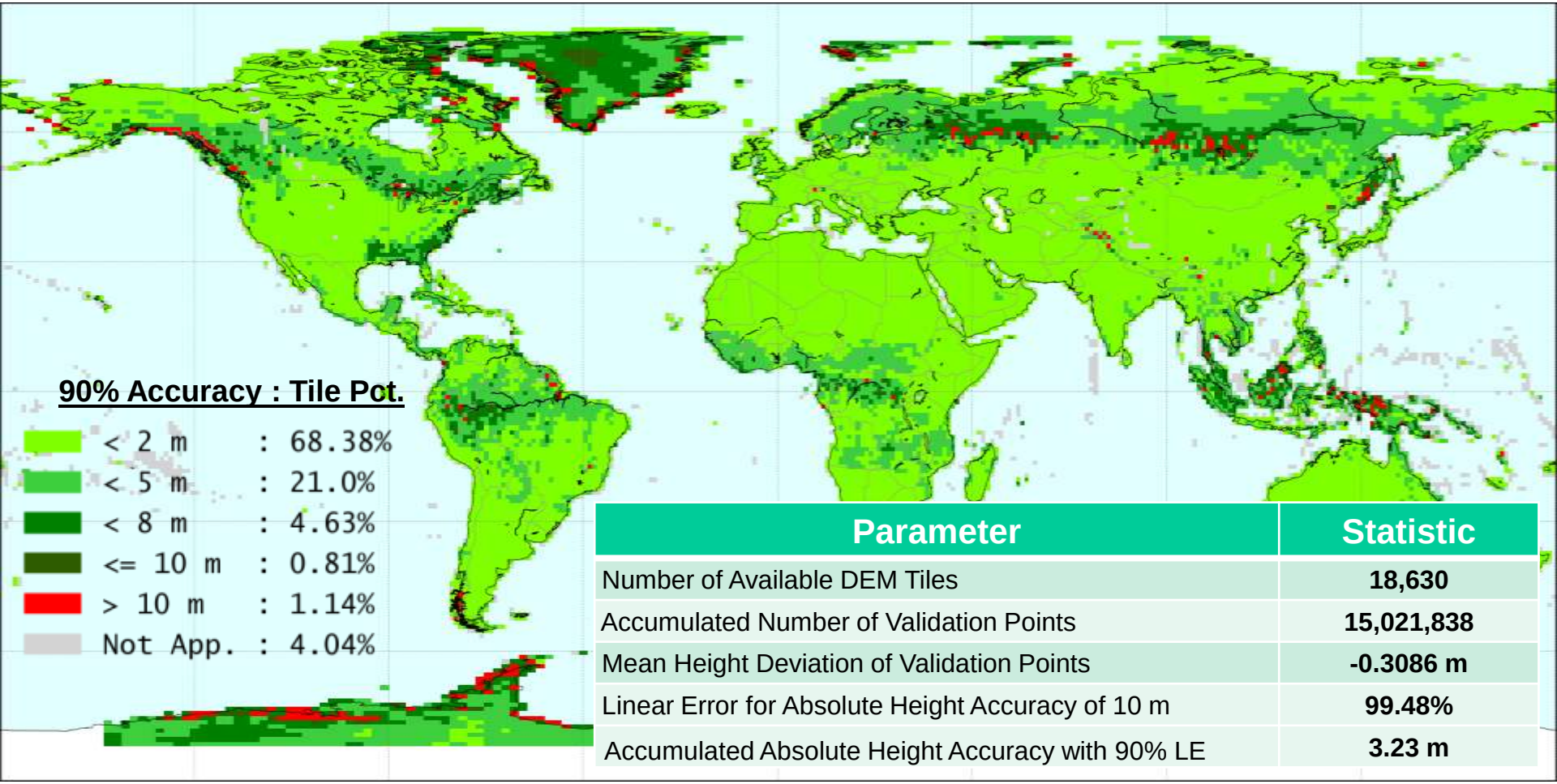
Absolute Height Accuracy



Parameter	Statistic
Number of Available DEM Tiles	**18,630**
Accumulated Number of Validation Points	**15,021,838**
Mean Height Deviation of Validation Points	**-0.3086 m**
Linear Error for Absolute Height Accuracy of 10 m	**99.48%**
Accumulated Absolute Height Accuracy with 90% LE	**3.23 m**

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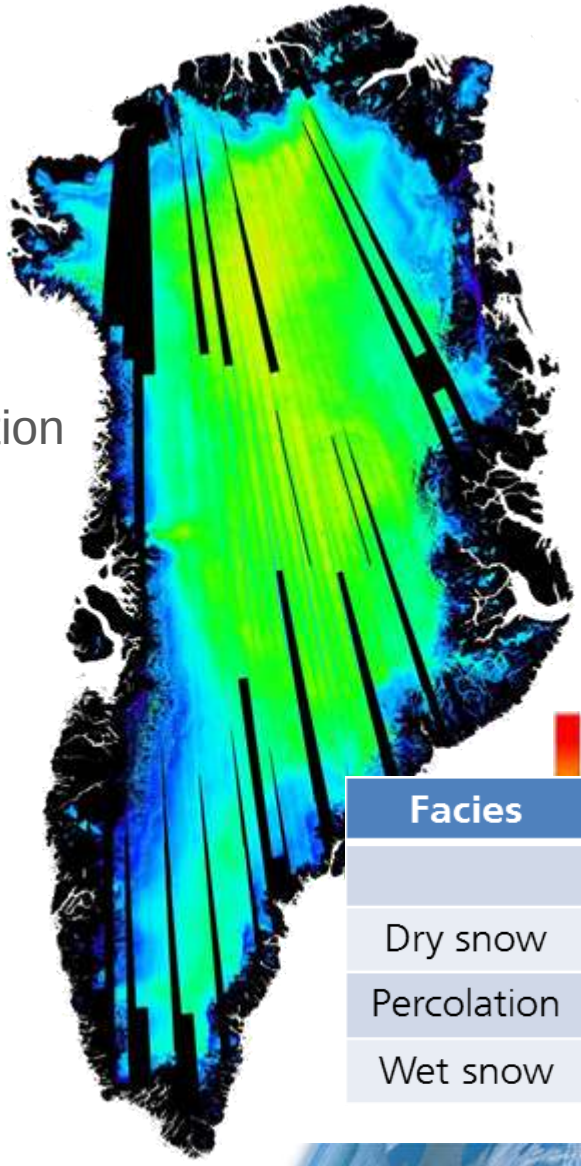
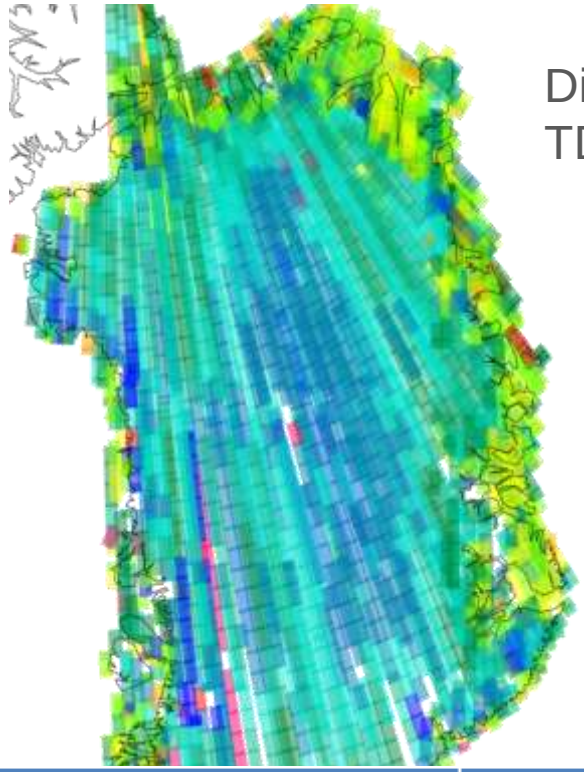
Penetration Depth - Greenland Ice Sheet

Penetration Depth





Difference:
TDX DEM - ICESat

[m]

Facies	Penetration depth		TDX DEM - ICESat	
	Mean [m]	Std. Dev. [m]	Mean [m]	Std. Dev. [m]
Dry snow	7.7	1.0	-6.9	1.4
Percolation	5.8	0.8	-5.4	1.8
Wet snow	4.2	0.8	-4.5	1.9

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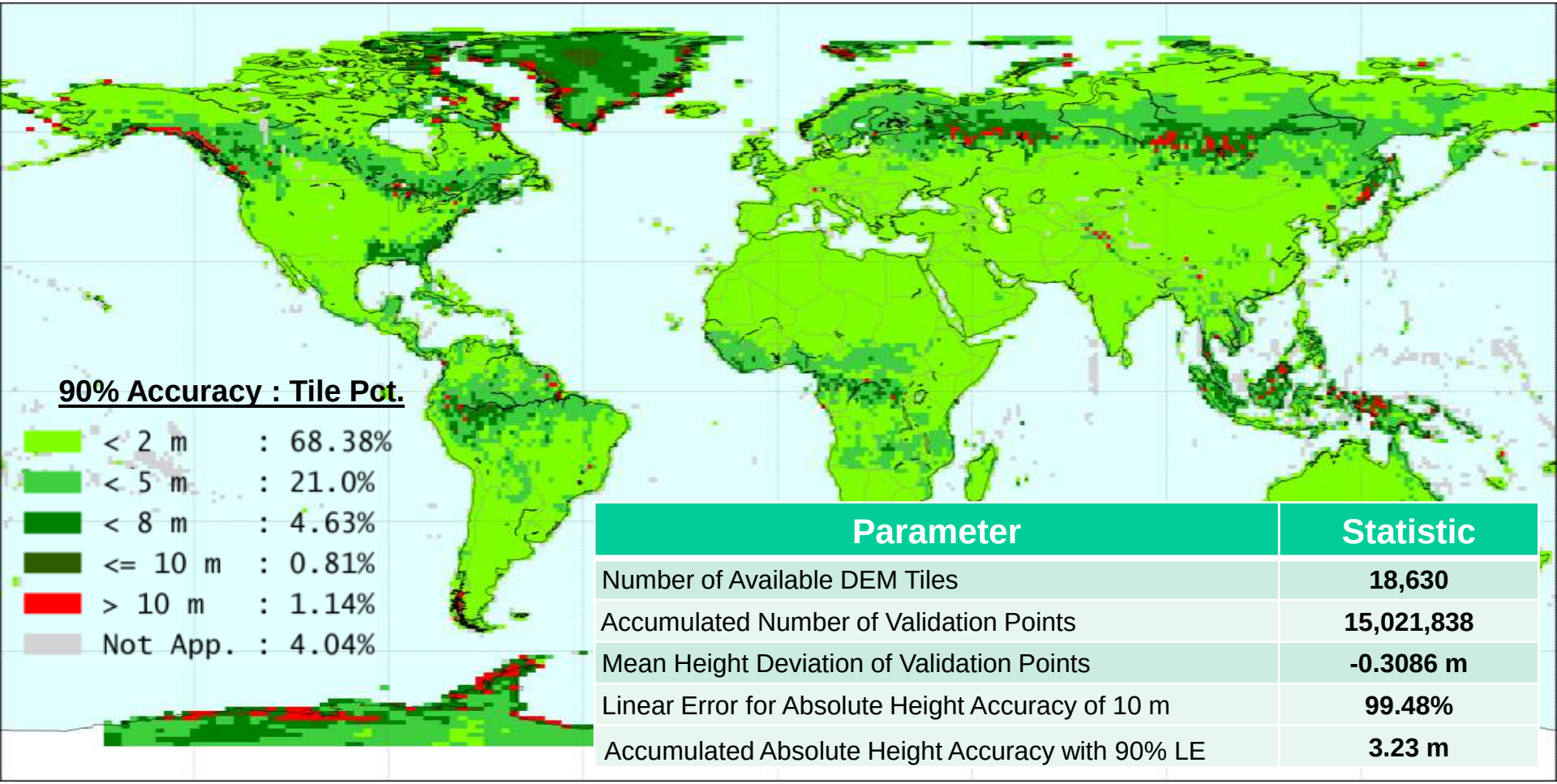
Absolute Height Accuracy



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Accumulated Absolute Height Accuracy with 90% LE	**3.23 m**

Accumulated Absolute Height Accuracy (without Greenland & Antarctica): 1.13 m

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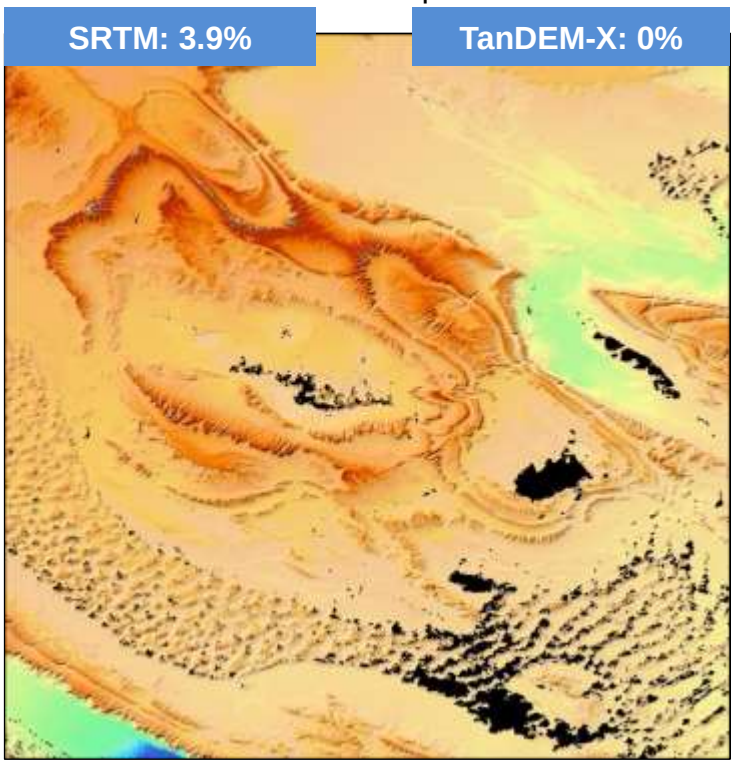
Data Coverage: Comparison with SRTM Rev. 1.0

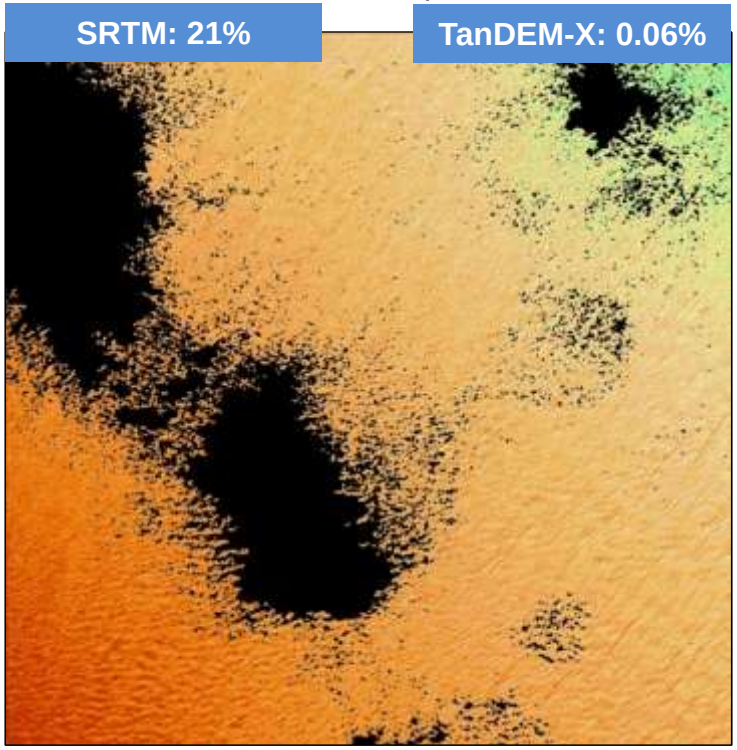
Percent Invalid per Tile



Low Signal Return

N29W003: Algeria

Percent Invalid per Tile



Low Signal Return

N20E051: Saudi Arabia

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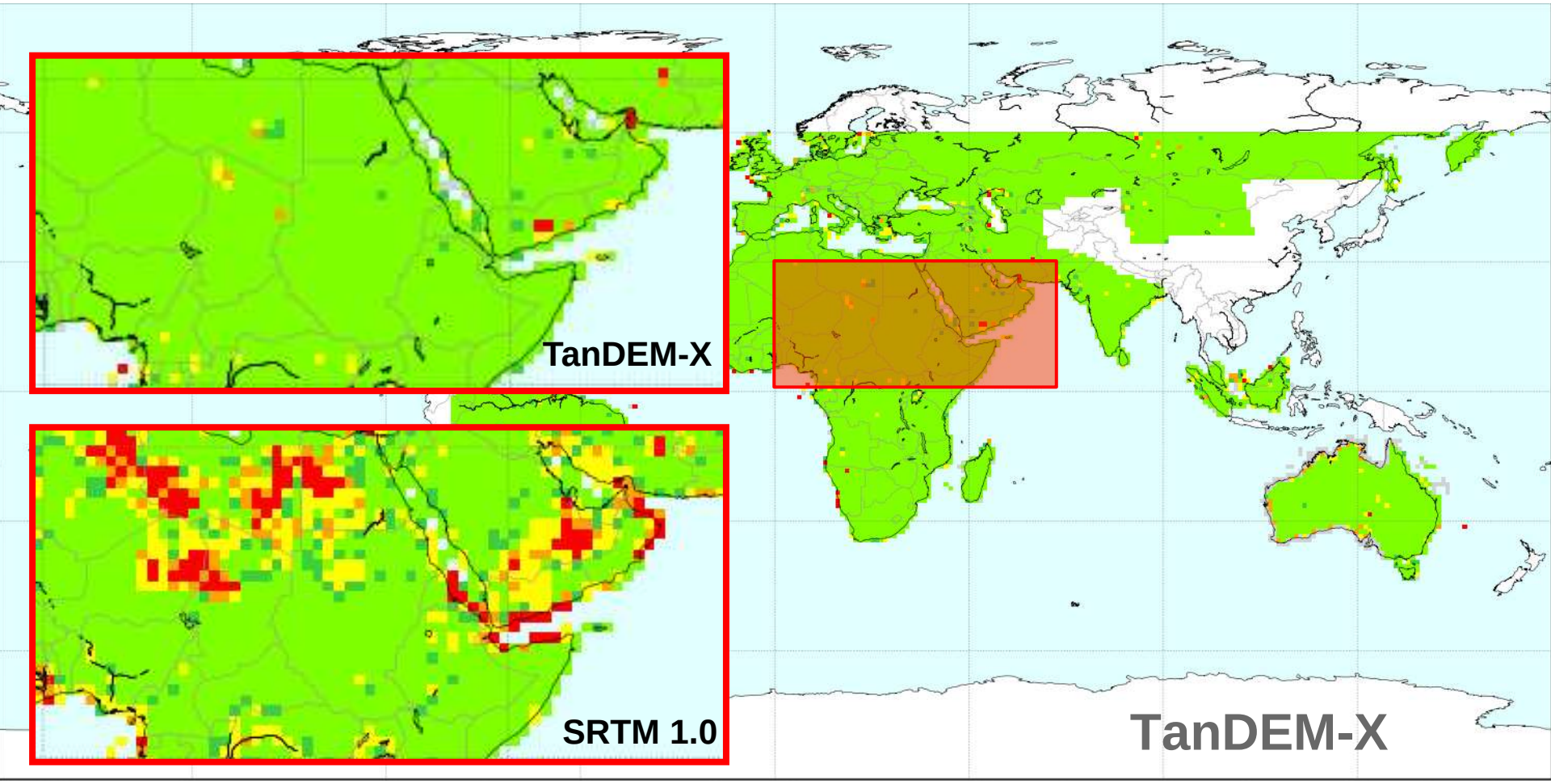
Data Coverage: Comparison with SRTM Rev. 1.0



TanDEM-X Data Set shows significantly less voids

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Data Coverage TanDEM-X (Analysis ongoing)

< 0.5 % : 92.26%
< 1 % : 2.03%
< 5 % : 3.12%
< 10 % : 0.86%
>= 10 % : 1.53%
N/A : 0.19%

15,292 Tiles have been analyzed covering approx 83% of Earth‘s land mass
The TanDEM-X DEM has a 99.89% global data coverage

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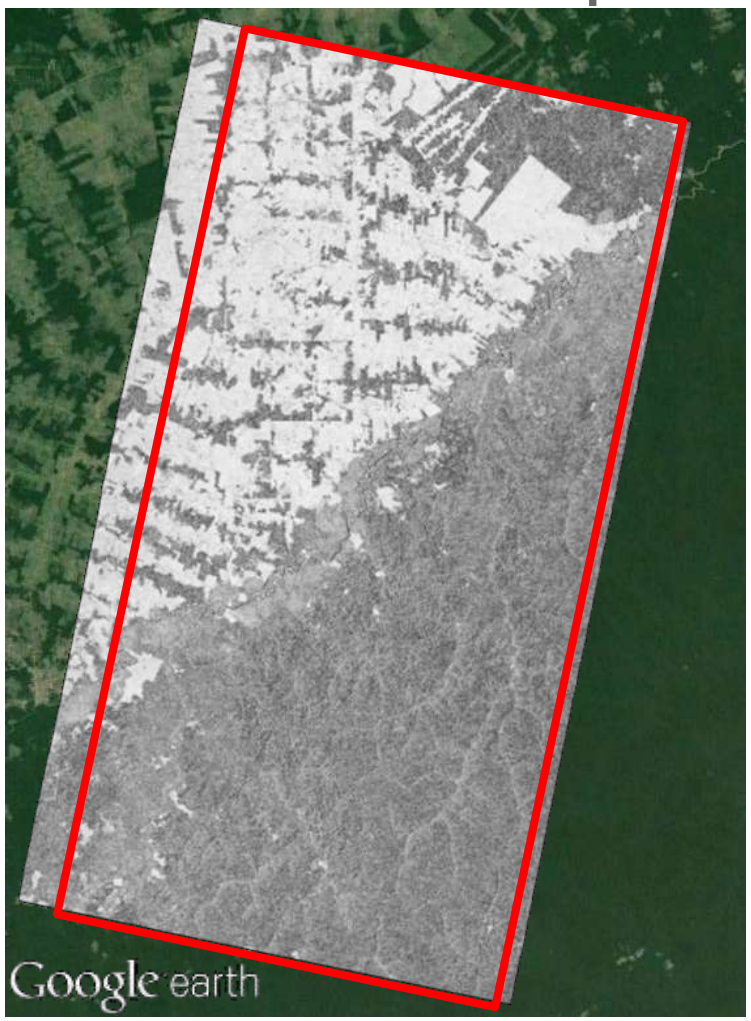
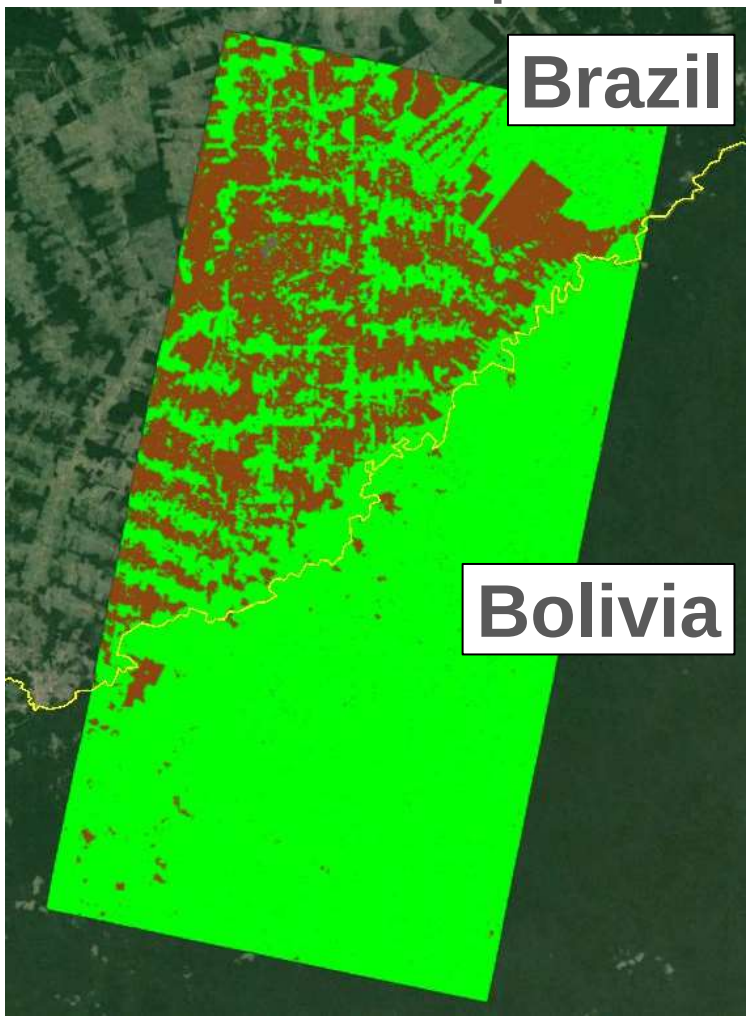
From Coherence to Forest/Non-Forest

Deforestation in Amazon rainforest, Brazil [10°S, 67°W]

Coherence map



Forest map



Forest

Non-Forest

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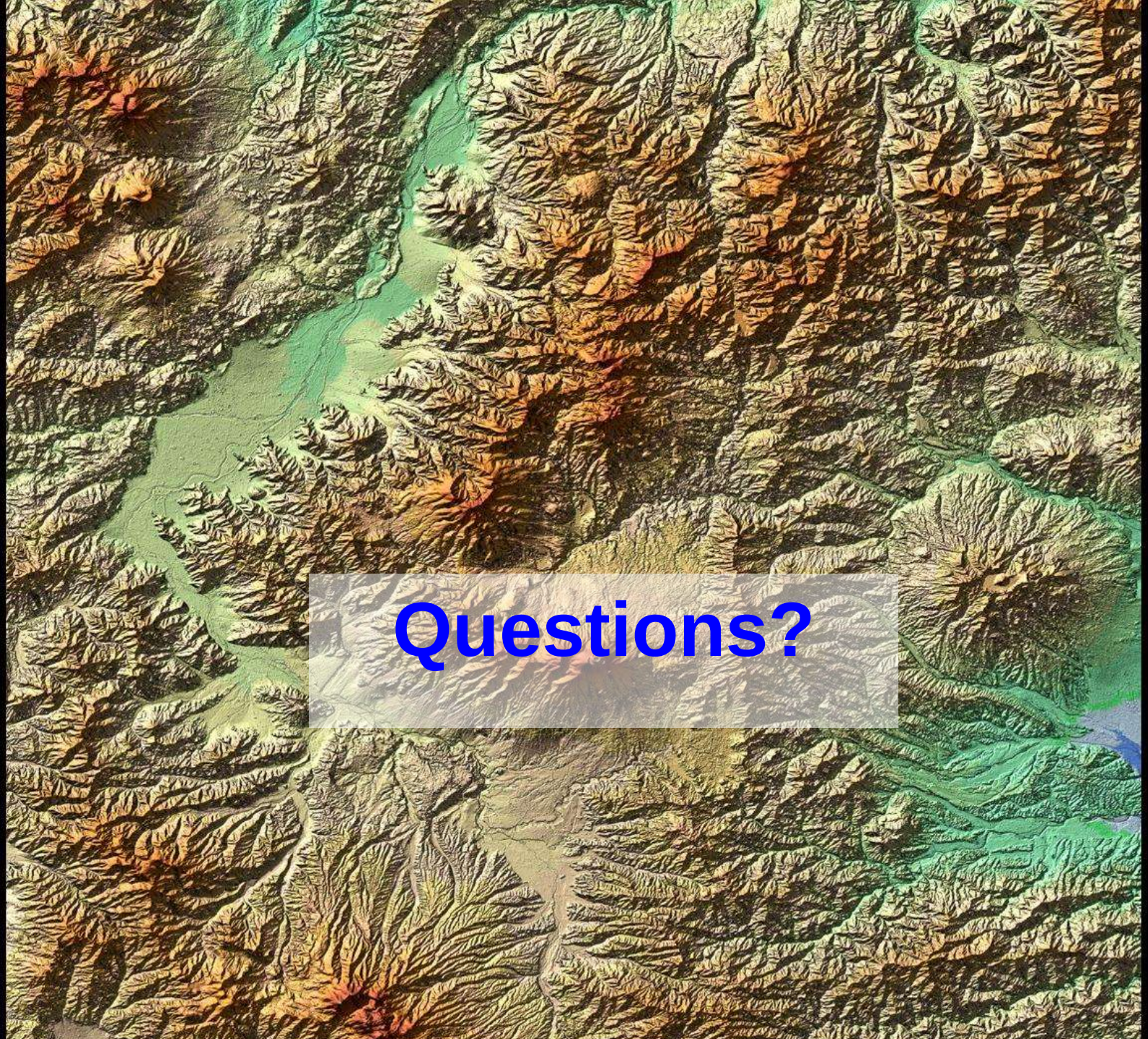
TerraSAR-X/TanDEM-X Mission Status

- Stable operations since 2007, in close formation since Oct-2010
- Outstanding calibration of the interferometric system
- Global TanDEM-X DEM just completed
- Data well within specifications
- Absolute height error one order of magnitude better than requirement
- AO for global DEM issued: https://tandemx-science.dlr.de/
- Both satellites fully functioning, fuel resources for several additional years


Questions?