

# TanDEM-X Mission Status: DEM Acquisition and Science Phase

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Knowledge for Tomorrow

# Outline

- The TanDEM-X Mission
- Global DEM Acquisition Plan
- DEM Performance
- TanDEM-X Science Phase
- Summary



# 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*

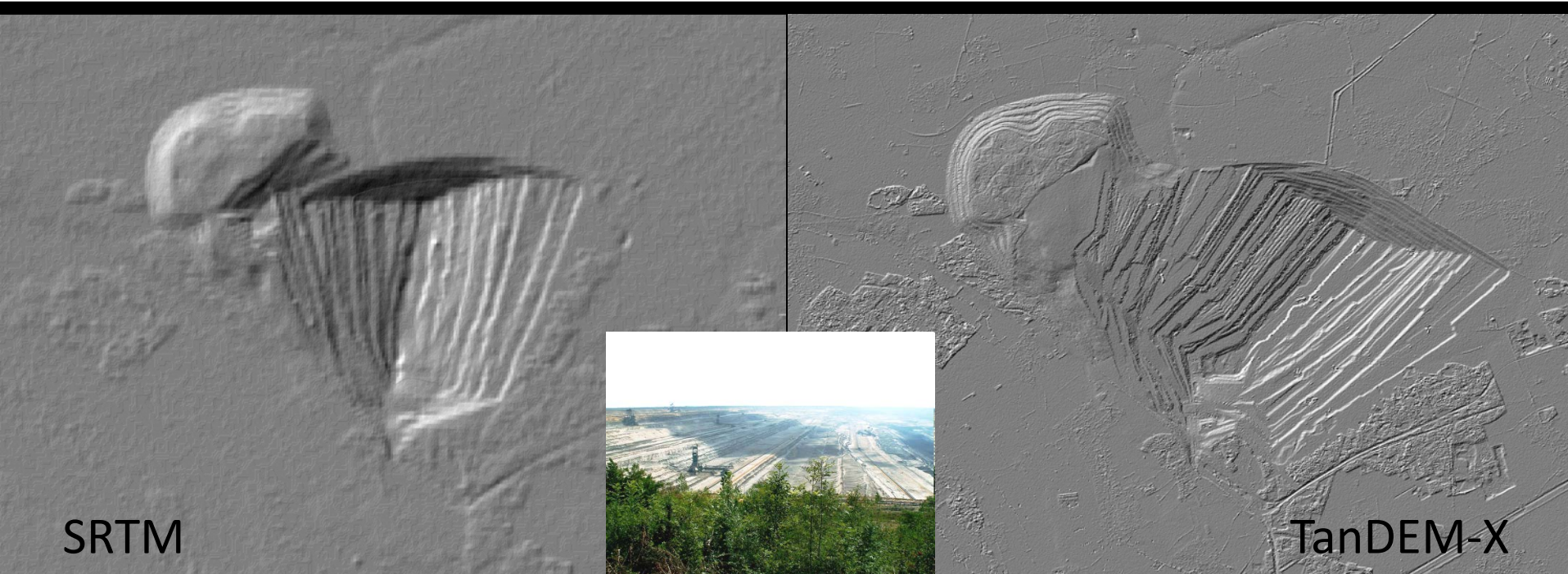
*demonstration of innovative  
bistatic imaging techniques  
and applications*



# Standards for Digital Elevation Models

\* slopes below/above 20%

	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



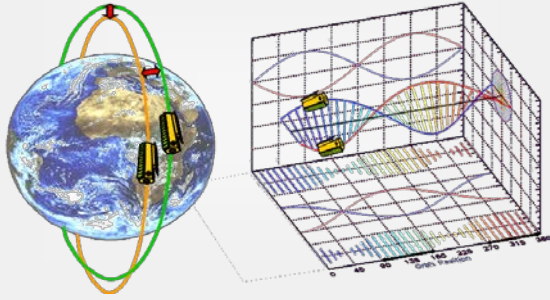
SRTM

TanDEM-X

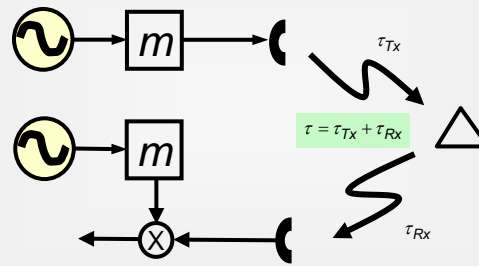
Coal Mine Hambach - Germany

# TanDEM-X Challenges

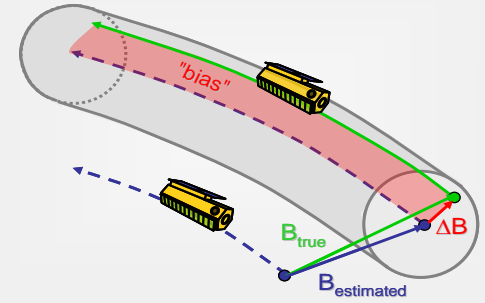
## Safe Formation Flying



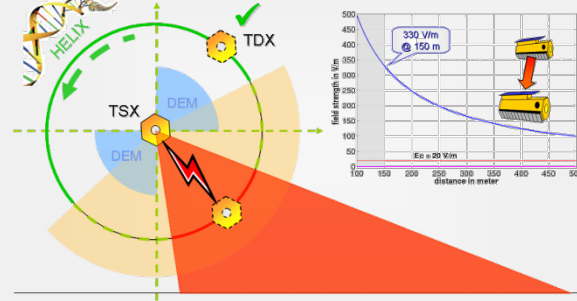
## Synchronisation



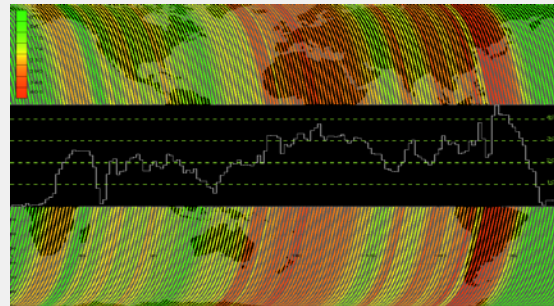
## 3-D Baseline Estimation



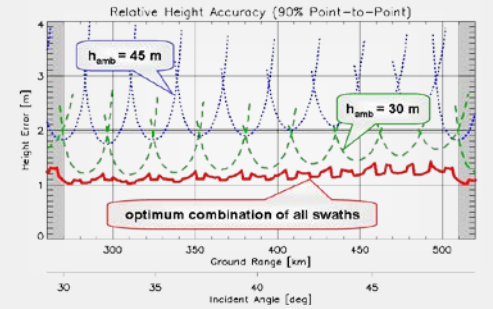
## Mutual Illumination Risk



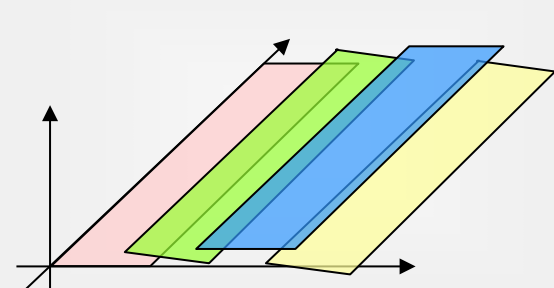
## Resource Management



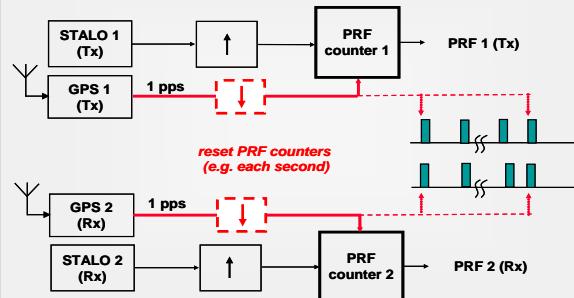
## Performance Optimization



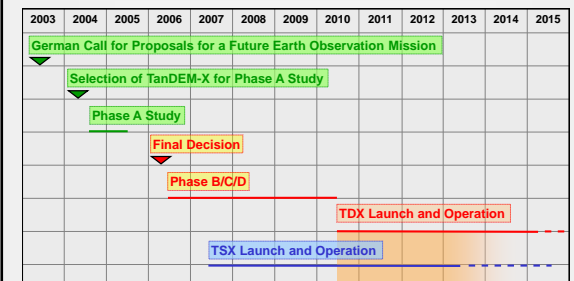
## DEM Calibration



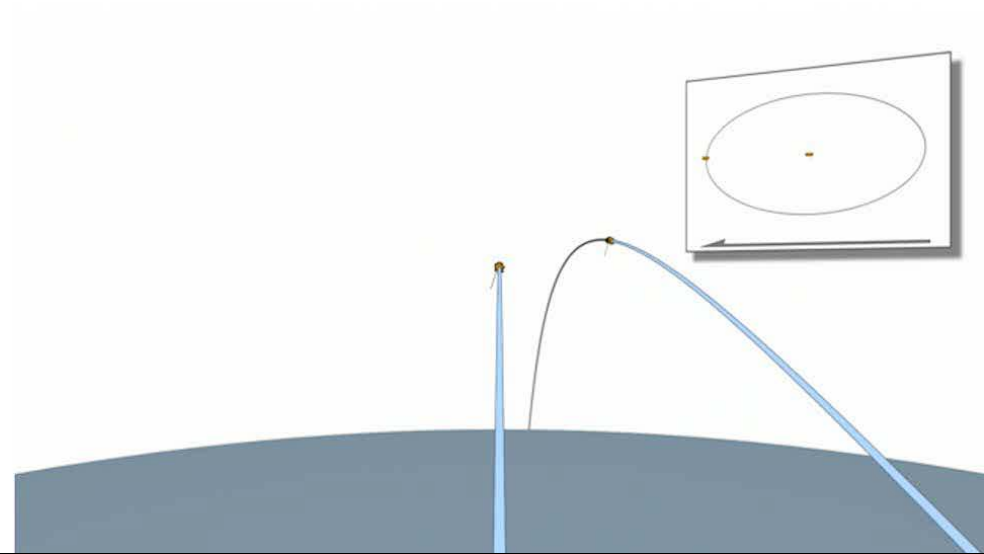
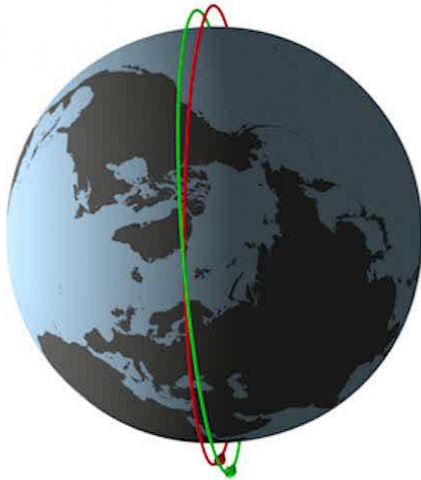
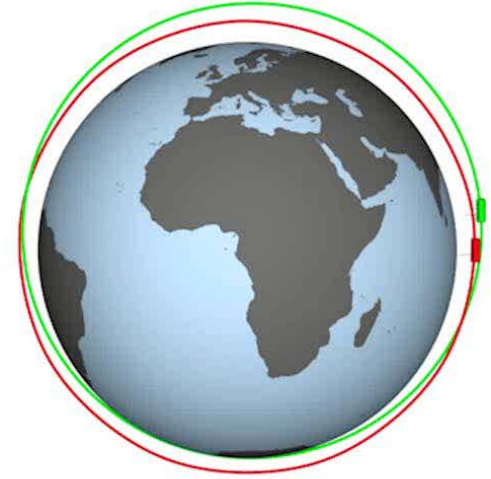
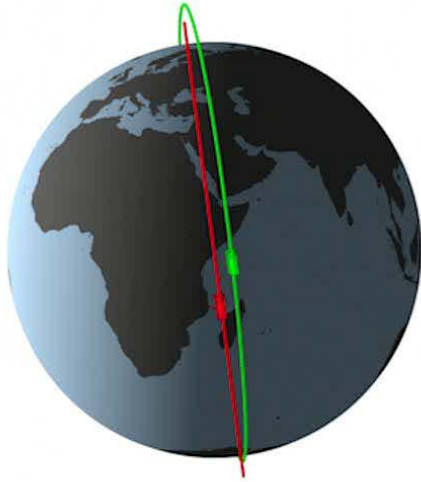
## Commanding



## Schedule



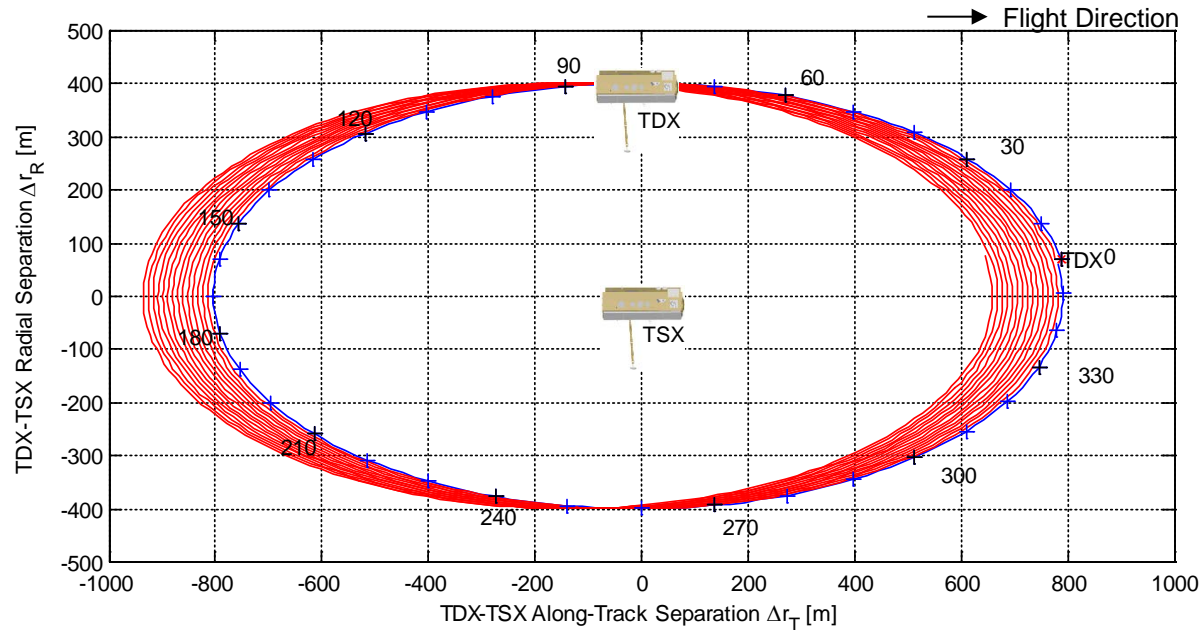
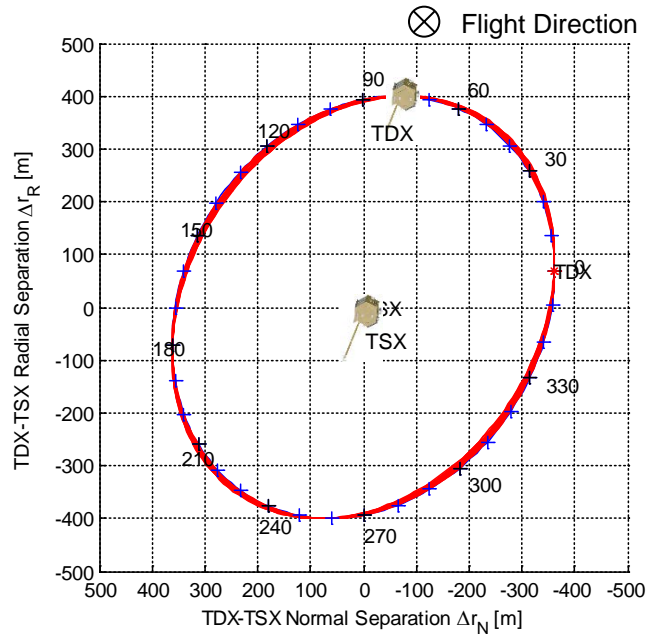
# Helix Formation



# Precise Formation Control on a Daily Basis

Example: bi-static phase (Oct. 15 – Dec. 12, 2010)

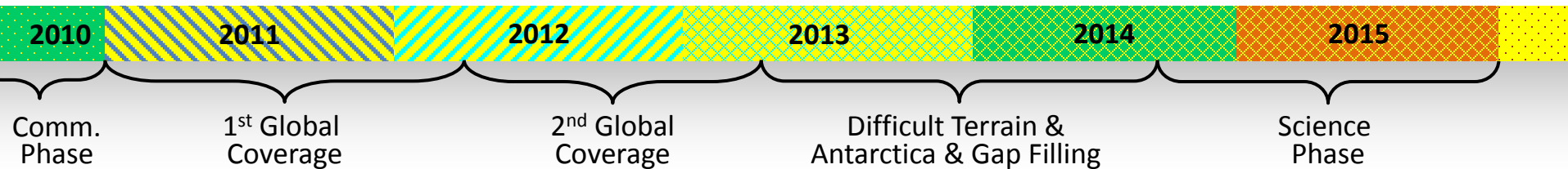
- Achieved formation control accuracy:  
Cross-track (2D) < 7 m R.M.S. and Along-track < 30 m R.M.S.



**TanDEM-X Autonomous Formation Flying Experiment (TAFF):  
Successful TAFF Closed Loop Campaign 29. - 31.03.2011 !**



# TanDEM-X Global DEM Acquisition Plan



## 1<sup>st</sup> Global Coverage

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



## 2<sup>nd</sup> Global Coverage

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

### Combination:

- Dual Baseline Phase Unwrapping
- Improved relative height accuracy

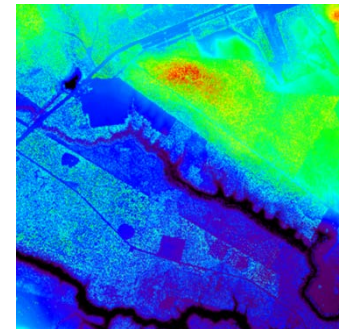
## 3<sup>rd</sup> Year

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



## 4<sup>th</sup> Year & Beyond

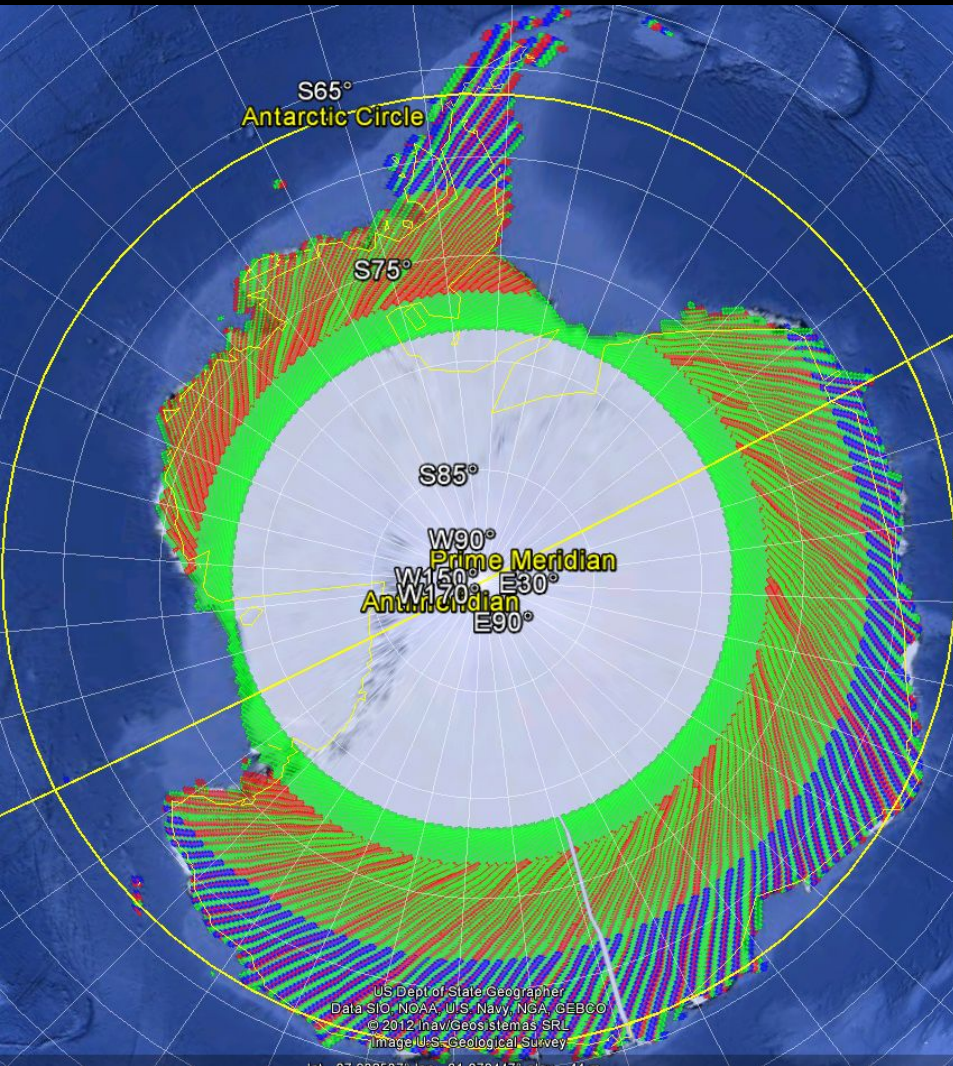
- TanDEM-X Science Phase
- Local High-Resolution DEMs
- Global DEM improvement &
- Complementary products



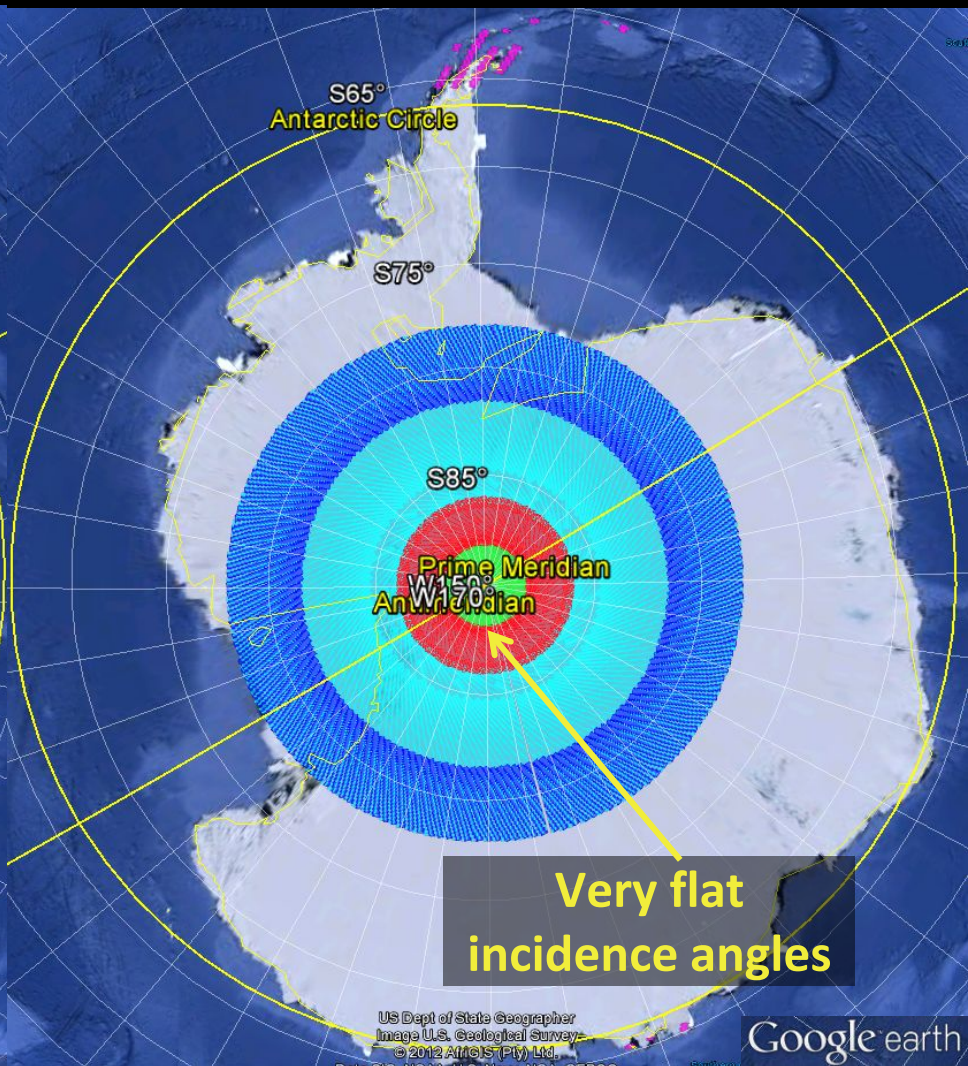


# 3<sup>rd</sup> Year Antarctica Acquisitions – May - July 2013 + 2014

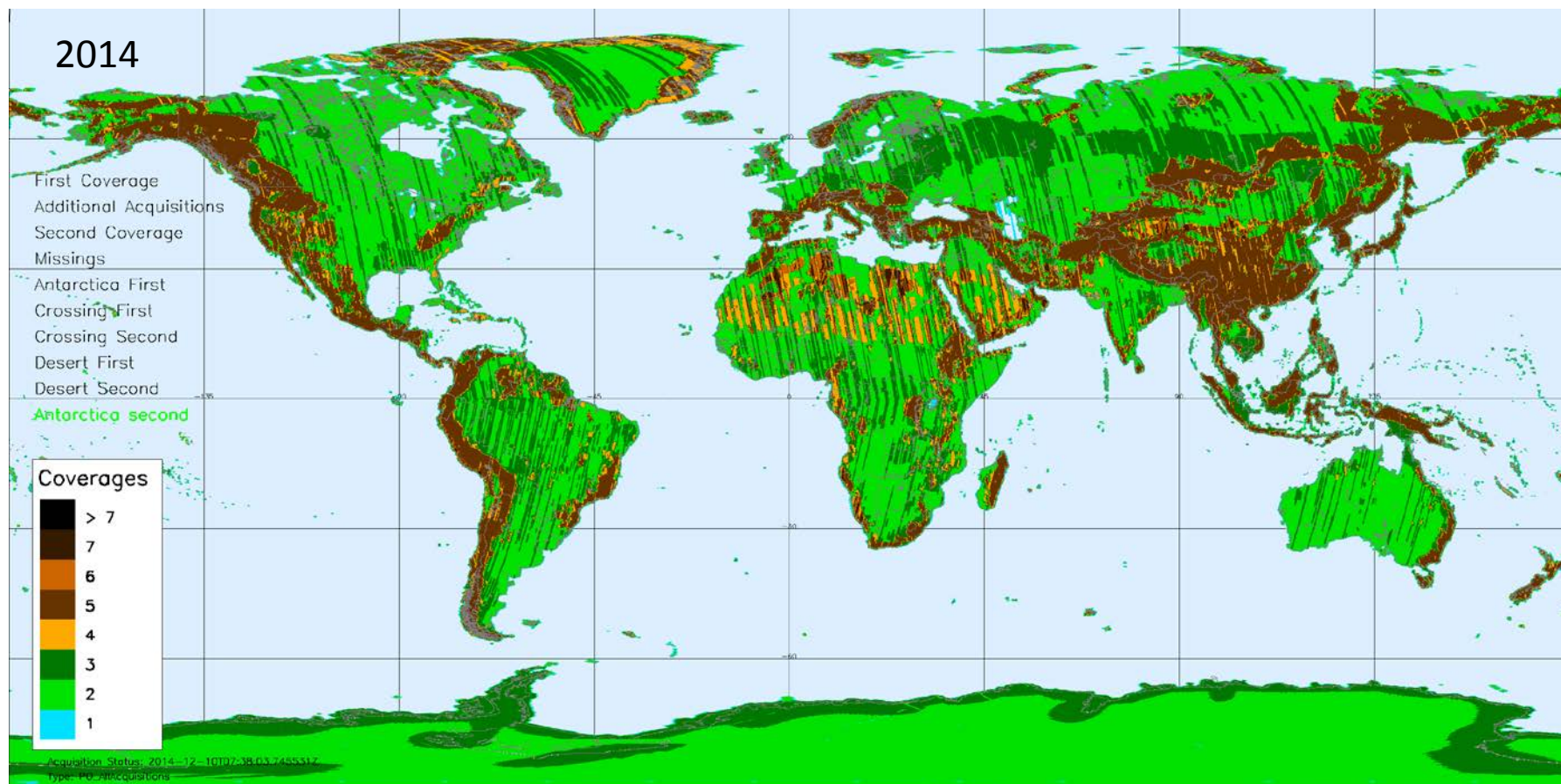
## Right-Looking



## Left-Looking

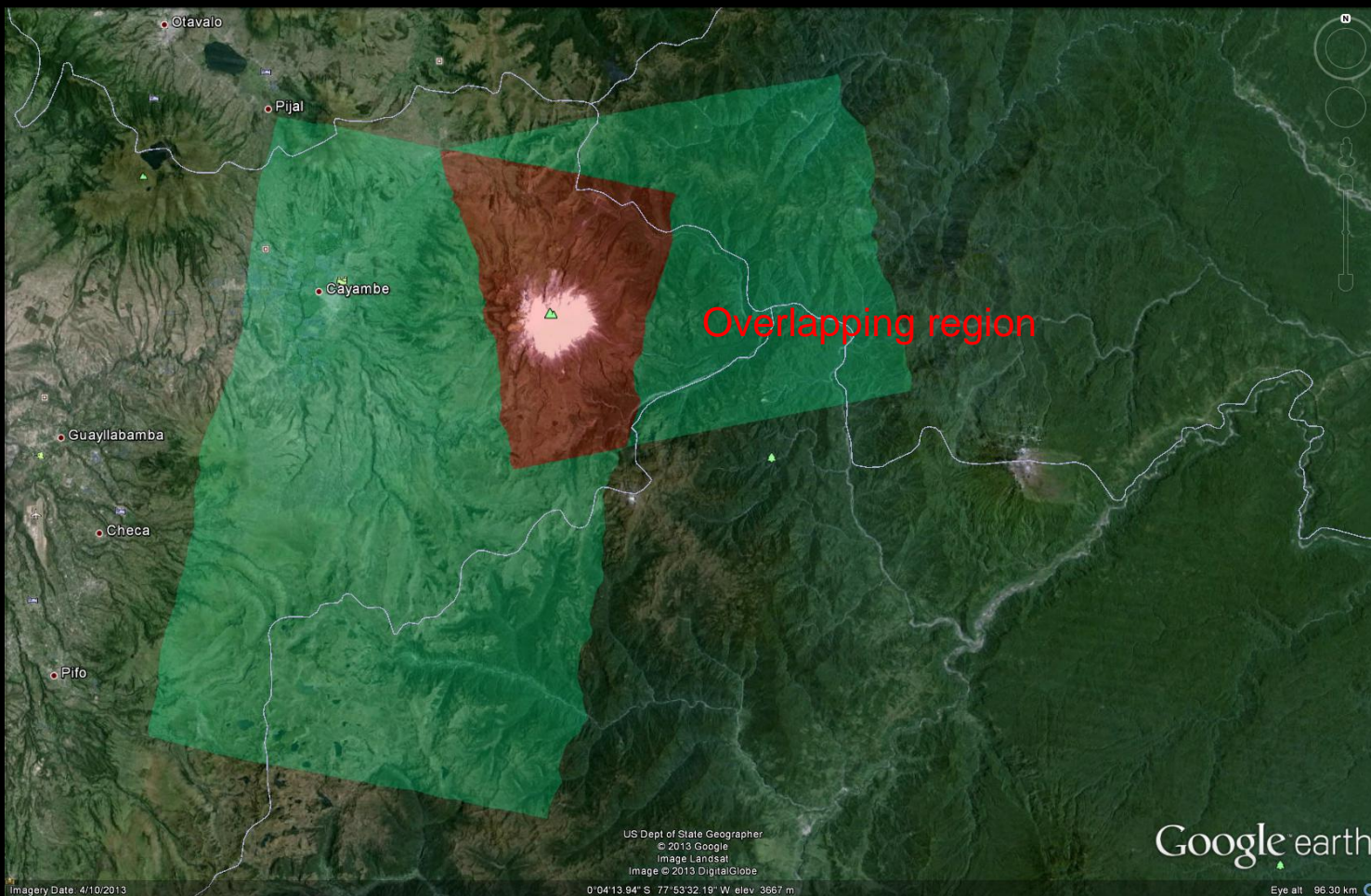


# 3<sup>rd</sup> Year: Additional Coverage of Difficult Terrain



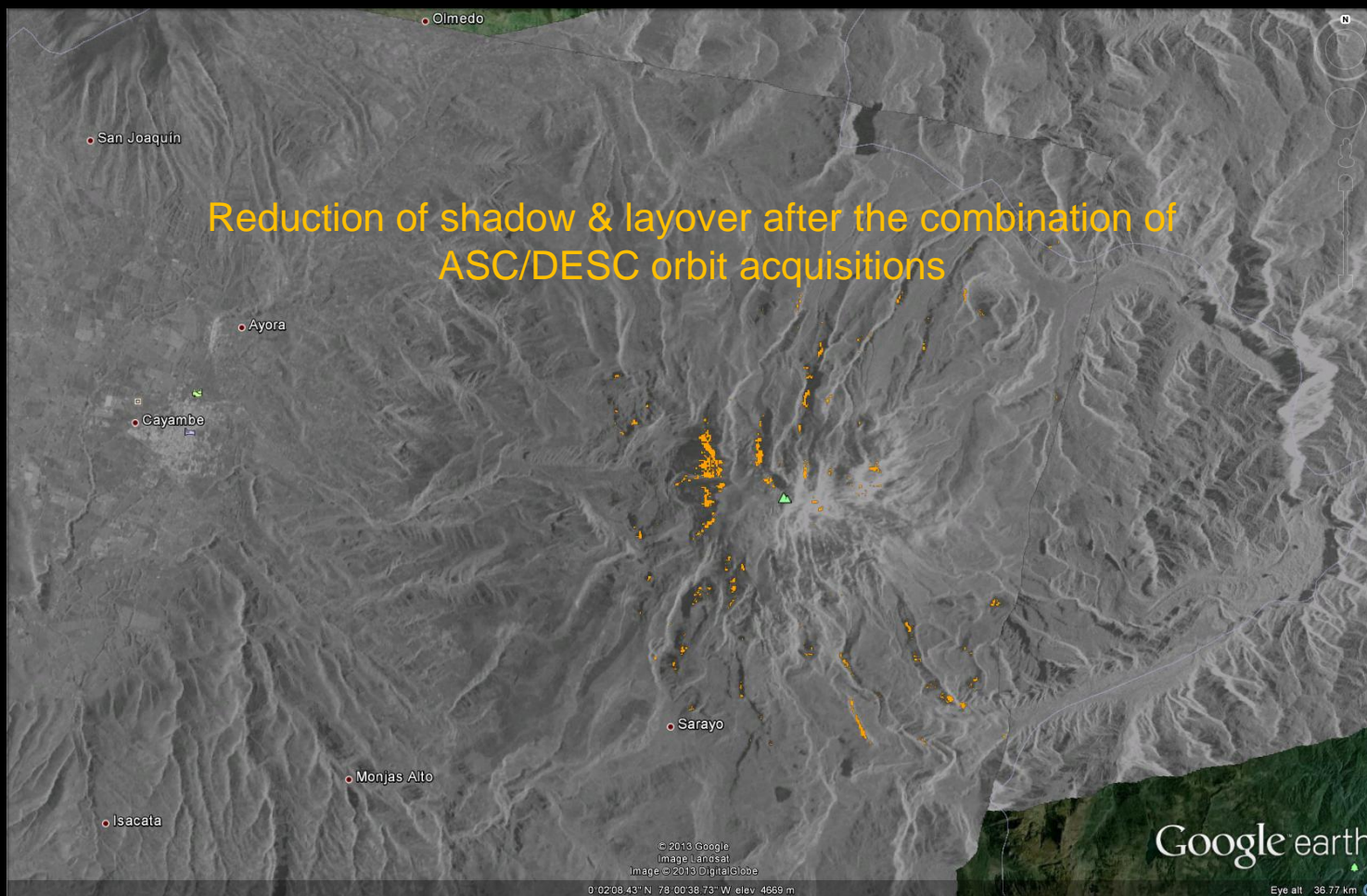
# Difficult Terrain: Shadow/Layover

2 overlapping acquisitions available: ASCENDING + DESCENDING



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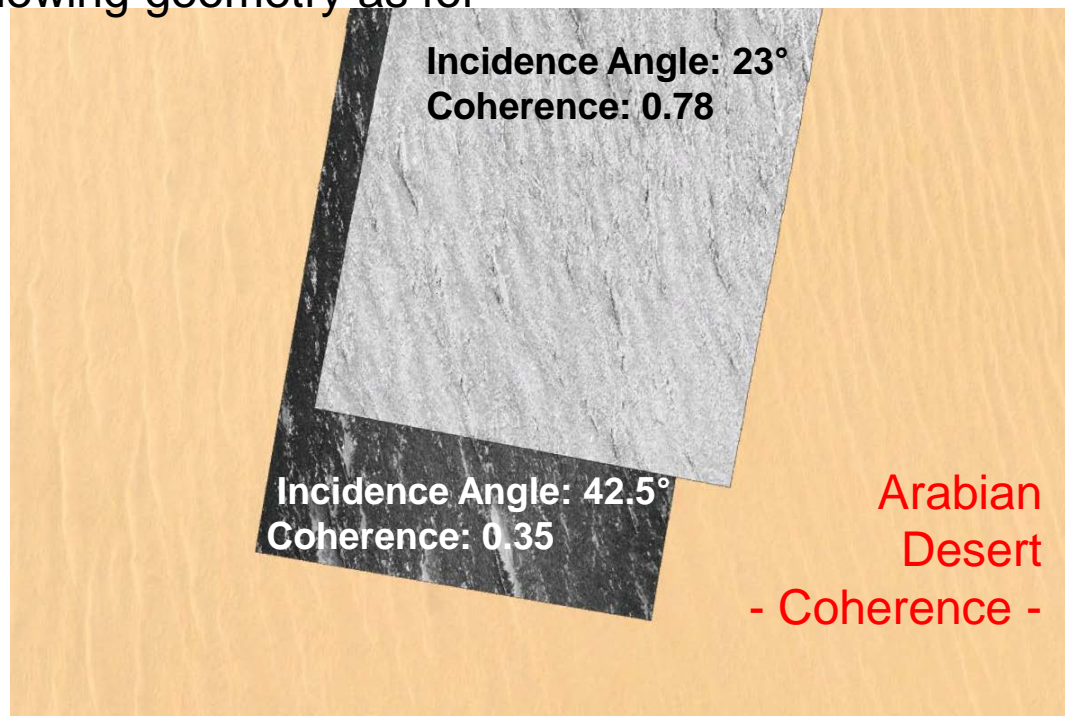
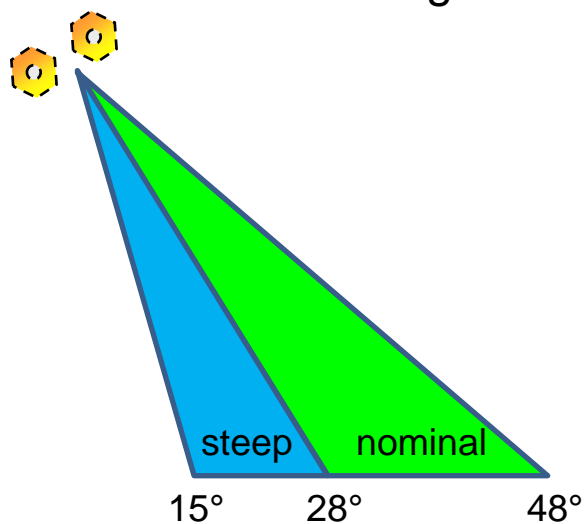
# Acquisition of Sandy Deserts

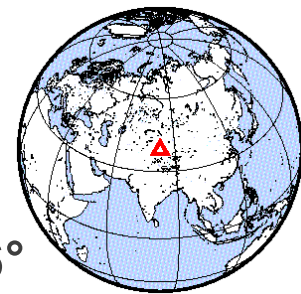
Sandy Deserts: low backscatter => low coherence => high relative height error

- Smaller incidence angles:  $15^\circ - 28^\circ$  (nominal  $28^\circ - 48^\circ$ )

Sandy Deserts with topography

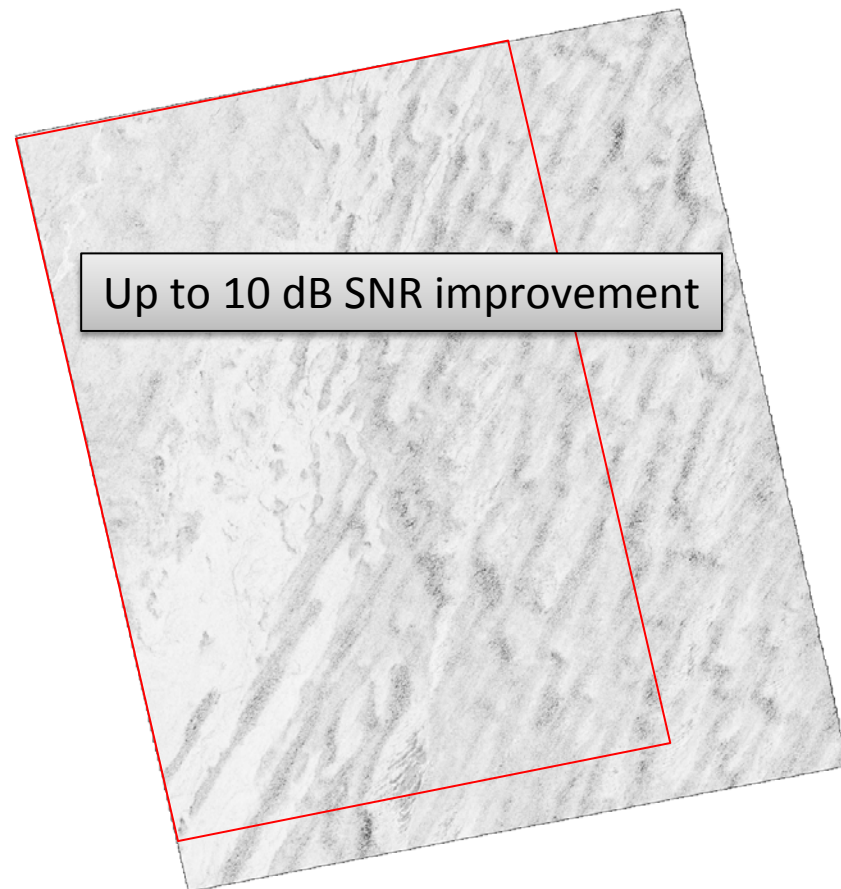
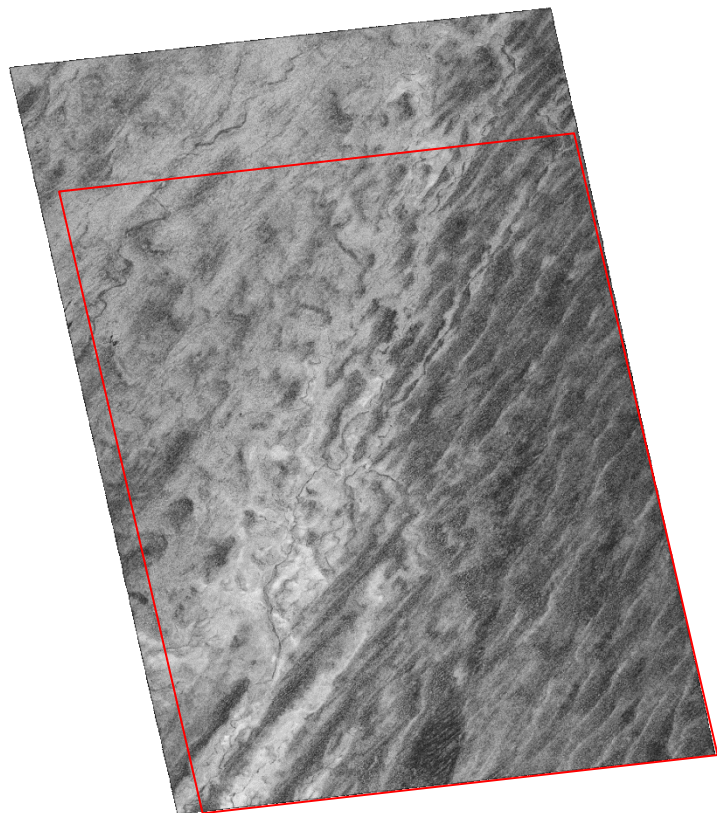
- acquisition with different viewing geometry as for mountainous regions

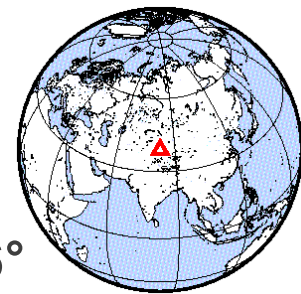




# Example – Taklamakan Desert (China)

- Flat inc. angle,  $\theta_i \sim 48^\circ$
- Mean coherence: **0.52**
- Steep inc. angle,  $\theta_i \sim 16^\circ$
- Mean coherence: **0.84**



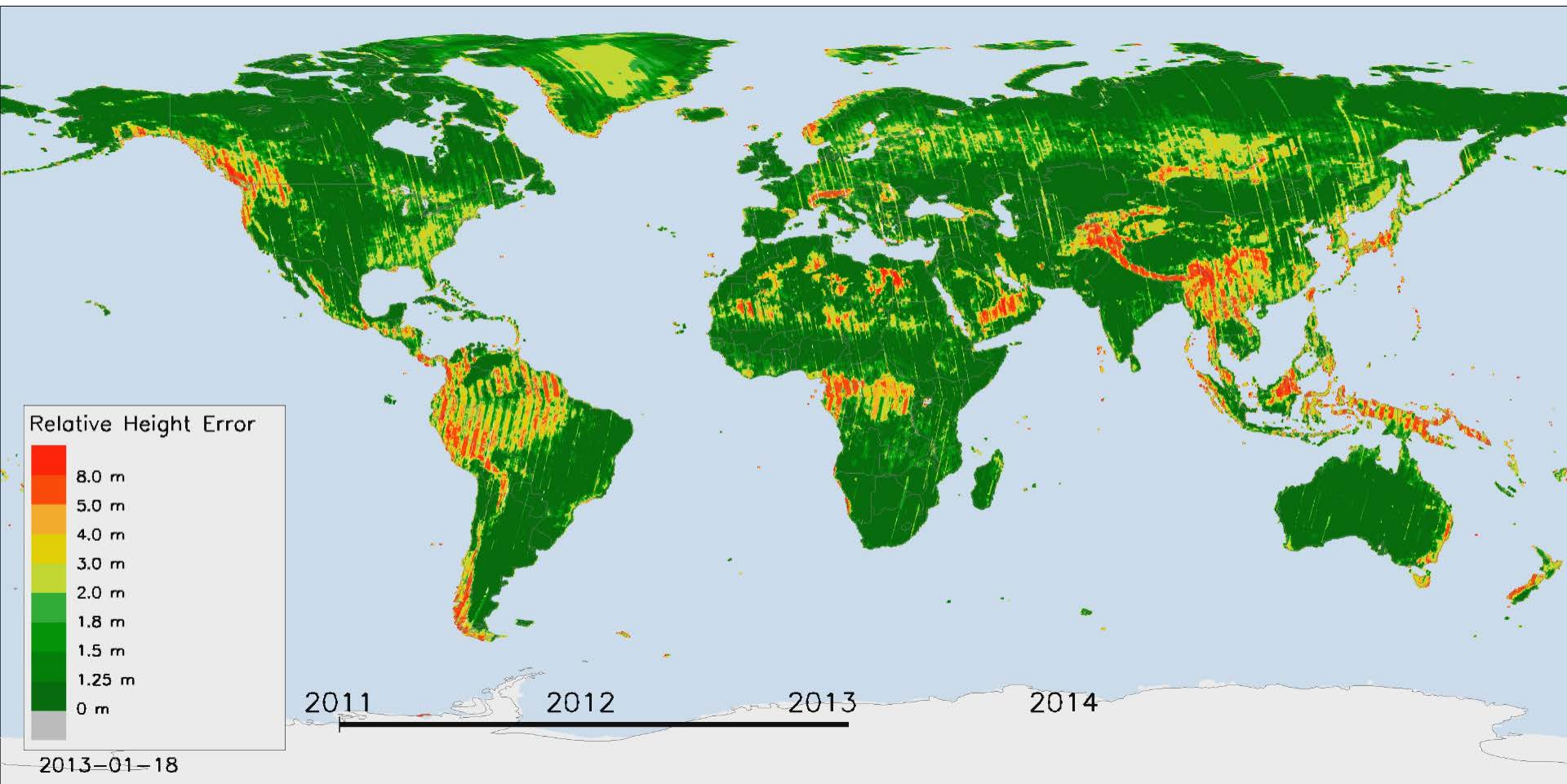


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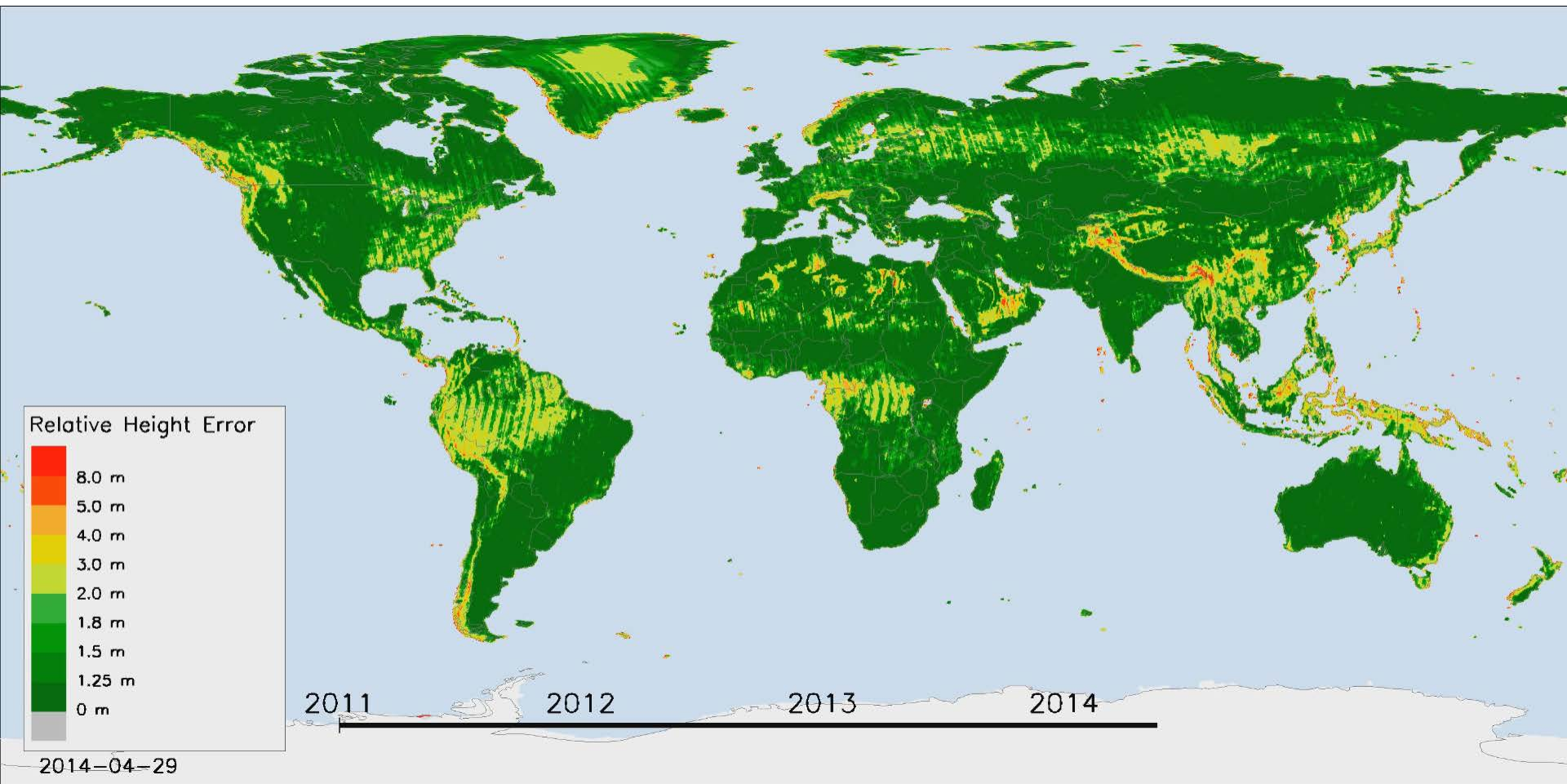


# Relative Height Error – Evolution over Time

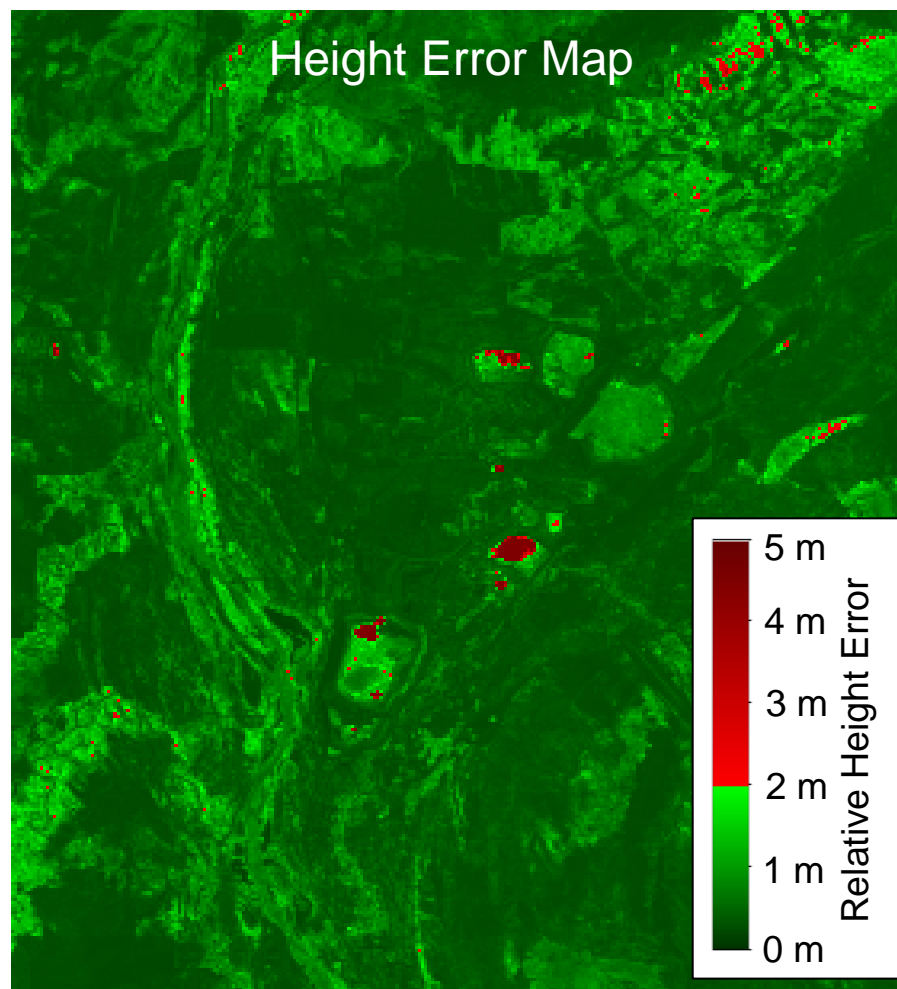
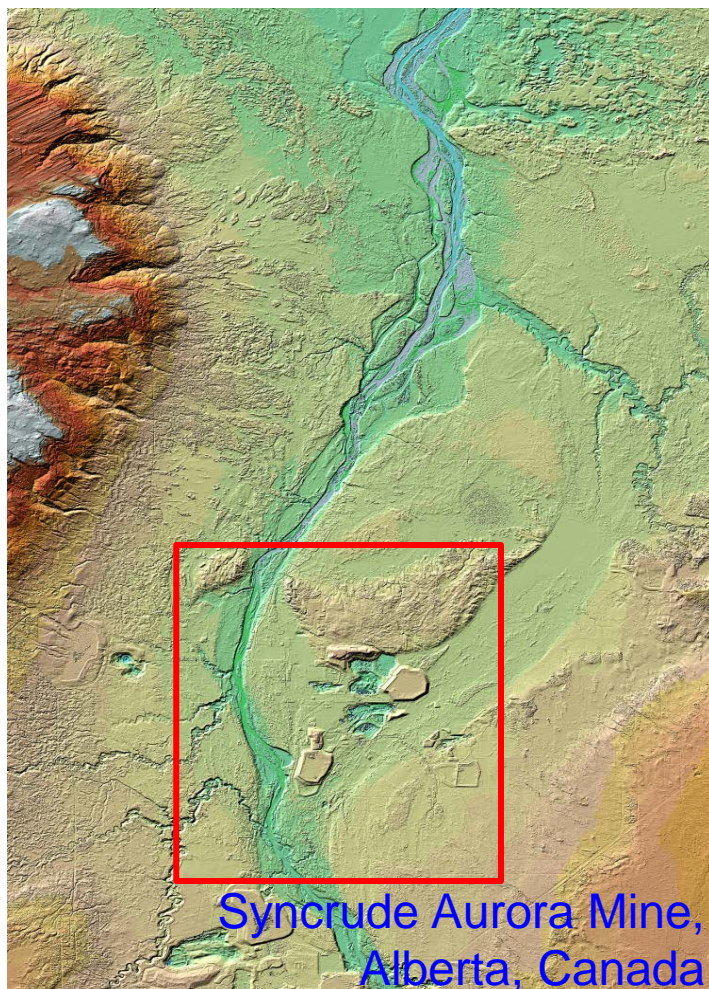




# Relative Height Error – Evolution over Time



# Quality of final DEM Tile N57W112



relative height error for 93.03% of the whole tile below 2 m

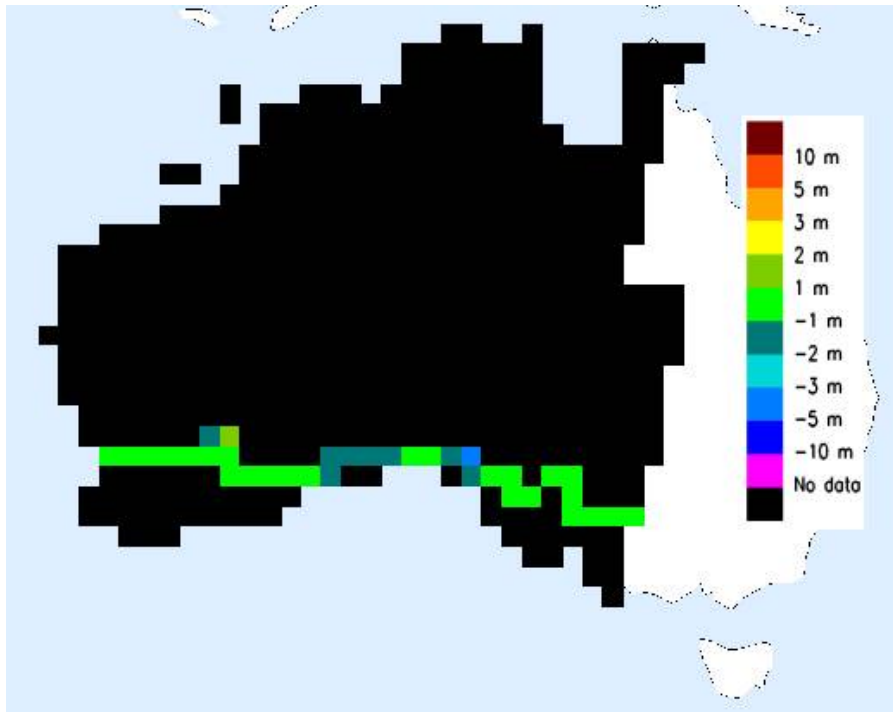


# Verification of Final DEM Performance

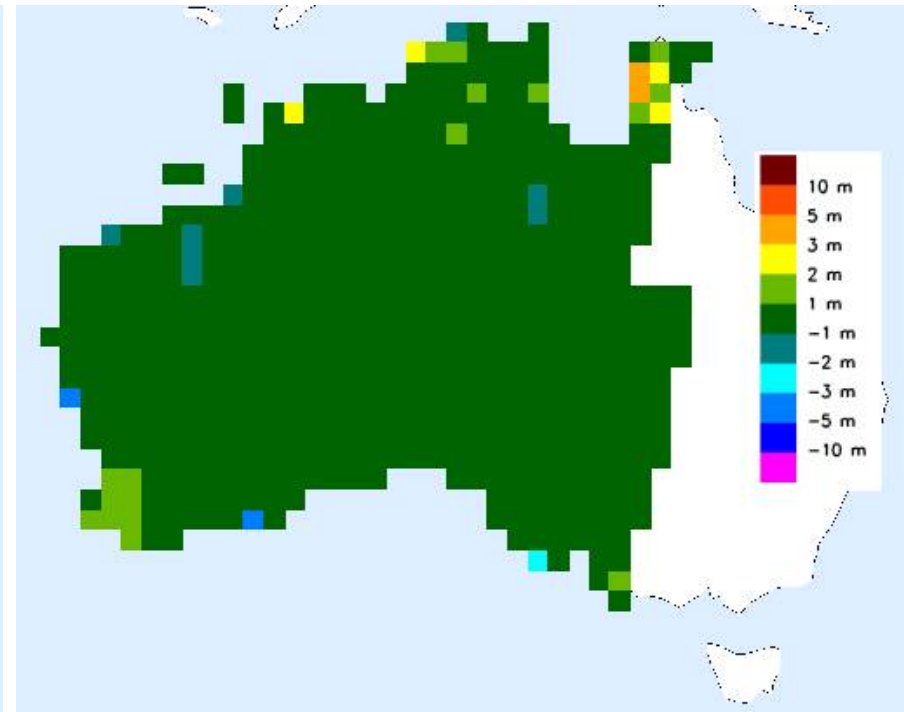
Absolute Height Error (mean offsets after final DEM calibration):

-0.37m versus GPS ( $\sigma = 1.10\text{m}$ )

+0.26m versus ICESat ( $\sigma = 1.48\text{m}$ )



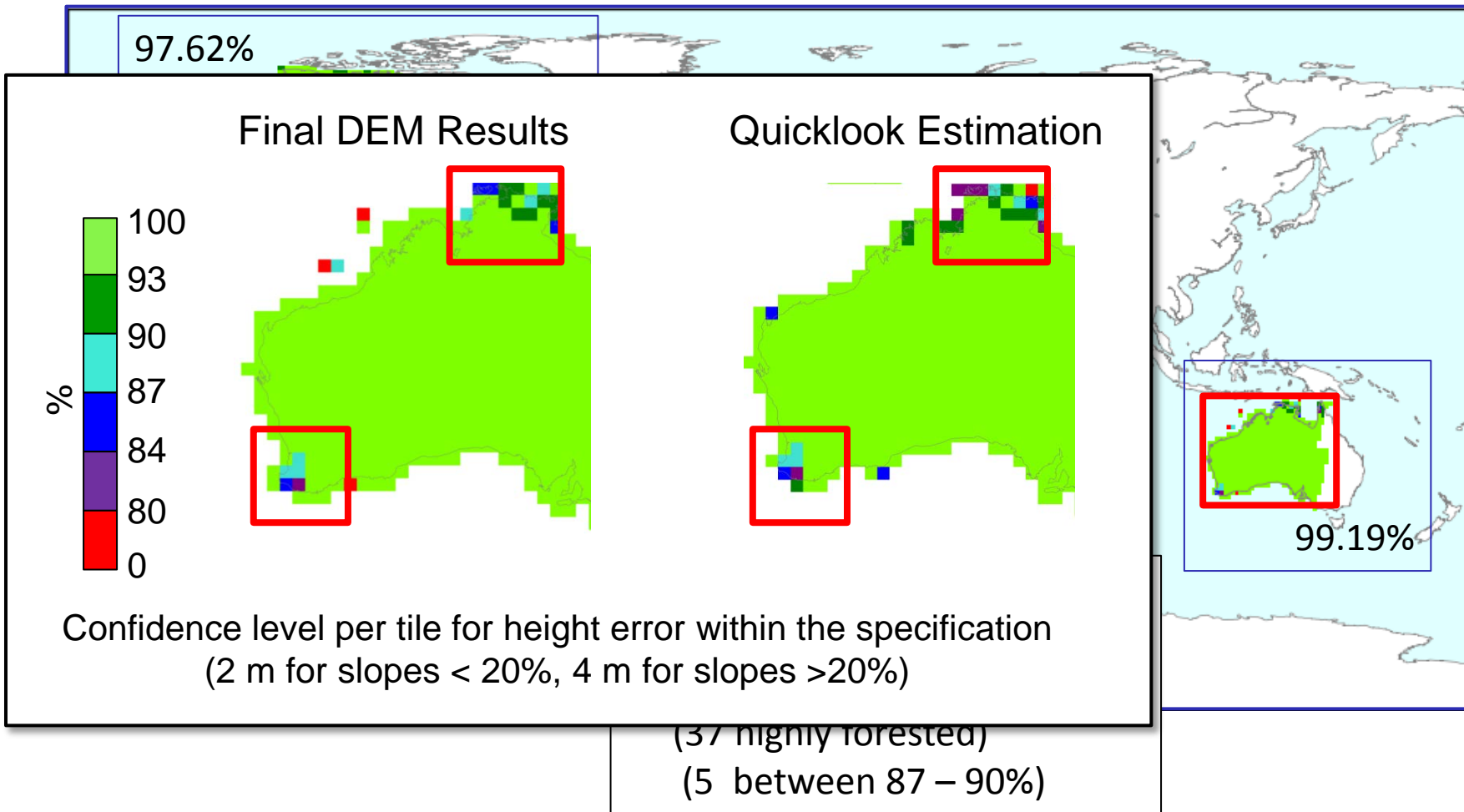
Deviation TanDEM-X vs. GPS



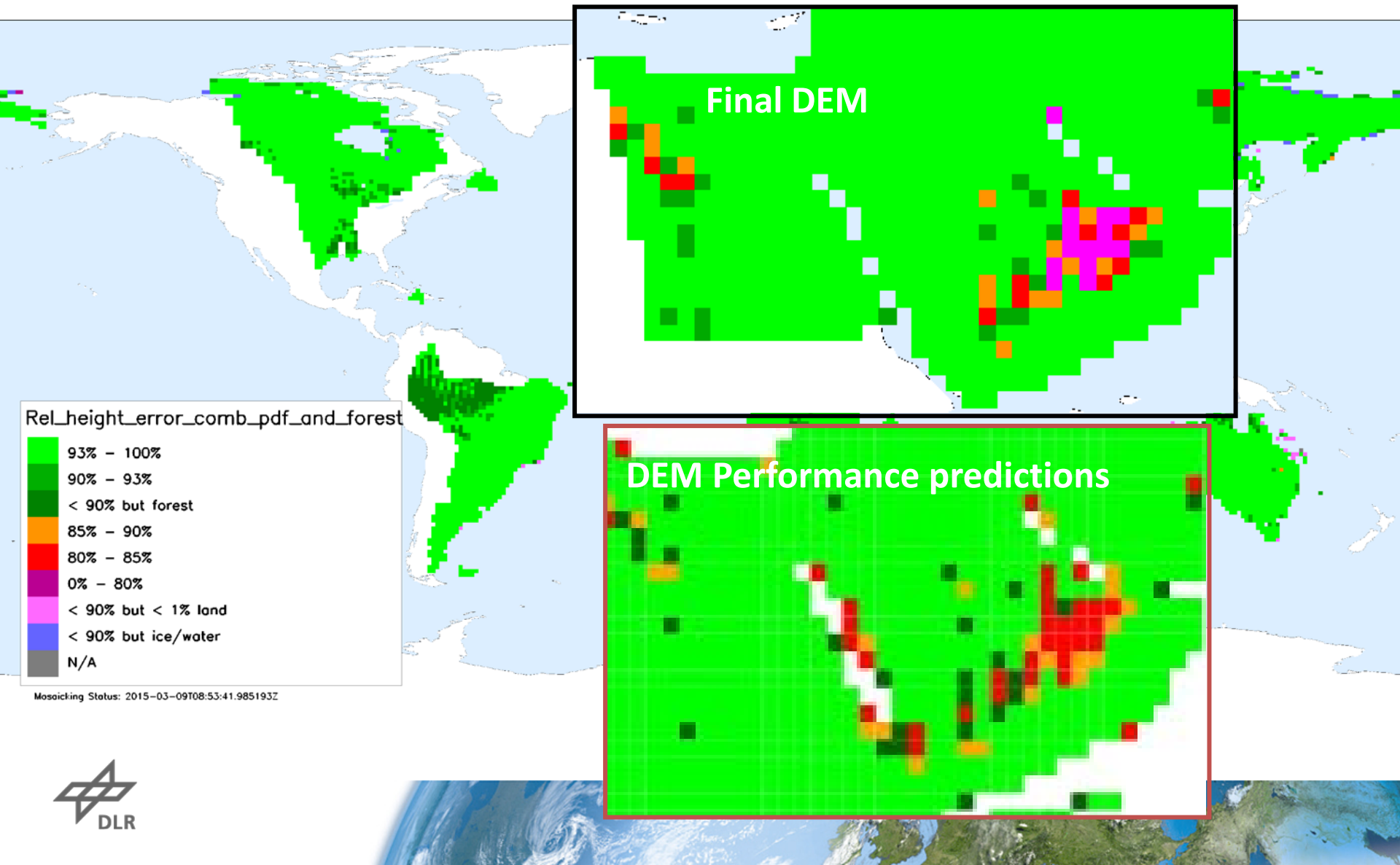
Deviation TanDEM-X vs. ICESat



# Relative Height Error of Final DEM Products



# Relative Height Error of Final DEM Products



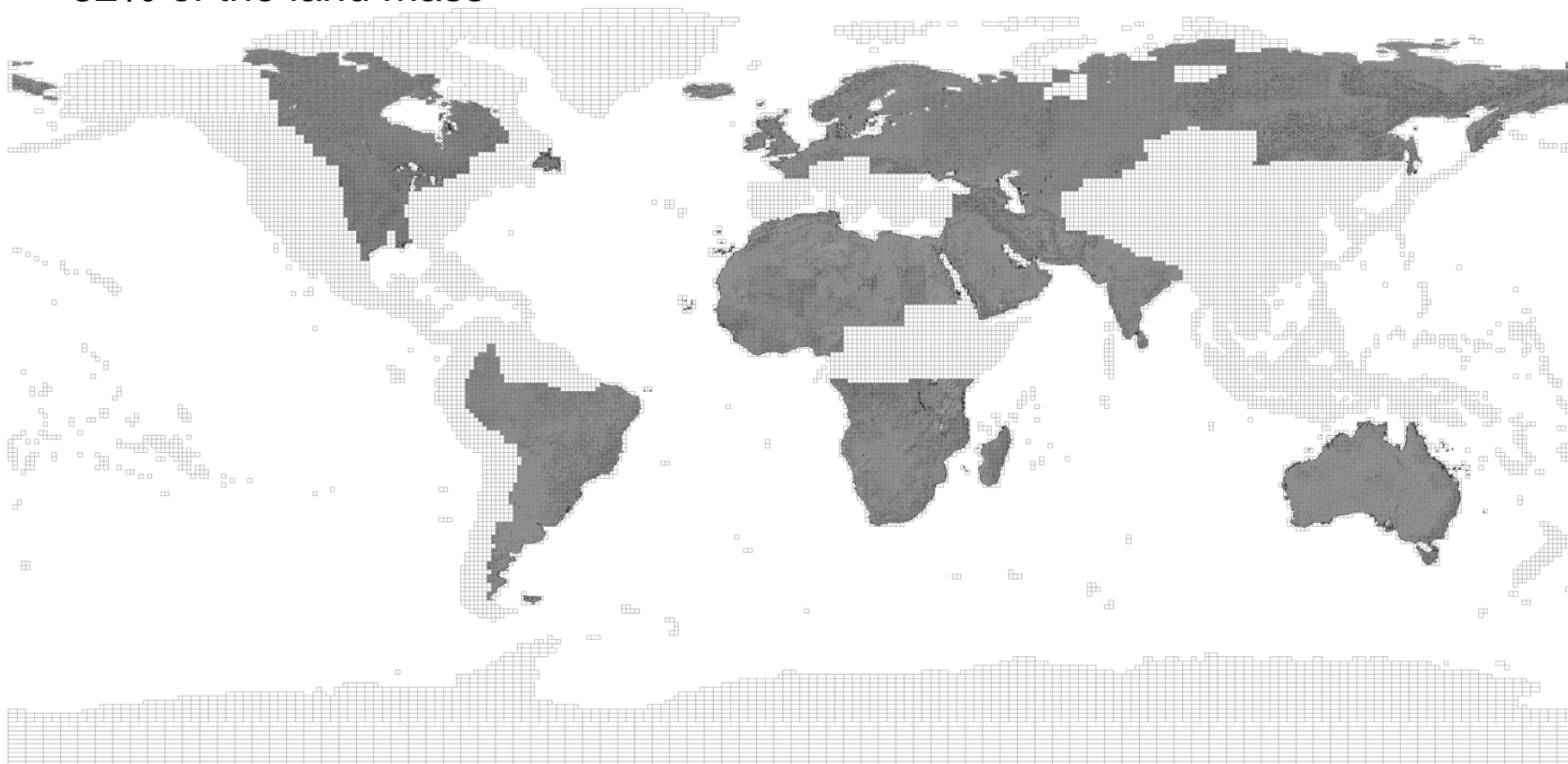
Rel\_height\_error\_comb\_pdf\_and\_forest

- 93% - 100%
- 90% - 93%
- < 90% but forest
- 85% - 90%
- 80% - 85%
- 0% - 80%
- < 90% but < 1% land
- < 90% but ice/water
- N/A

Mosaicking Status: 2015-03-09T08:53:41.985193Z

# Production of FinalDEM Tiles

- 40% of all RawDEMs have been mosaicked
- 46% of all final DEM Tiles finished (~9000)
- 52% of the land mass



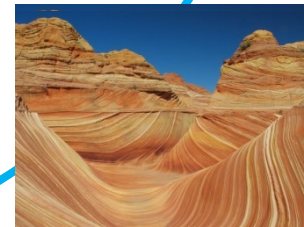
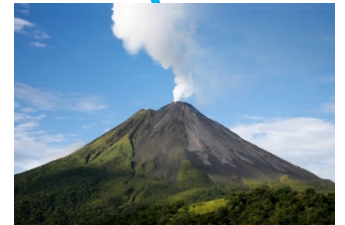
# TanDEM-X Science Phase



- 15 months duration (October 2014 ... December 2015)
- Dedicated to the demonstration of innovative techniques and experiments (secondary mission objective of the TanDEM-X mission)
- Science requirements collected at the beginning of the mission and during TanDEM-X science meetings
- 92 scientific proposals accepted after an Announcement of Opportunity in May 2014
- Link: <https://tandemx-science.dlr.de>



# Science Phase

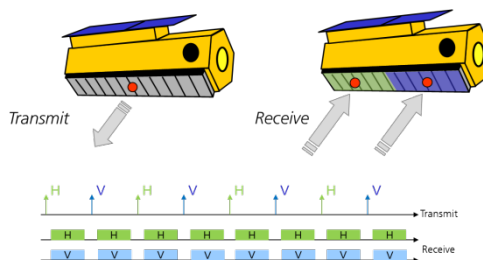
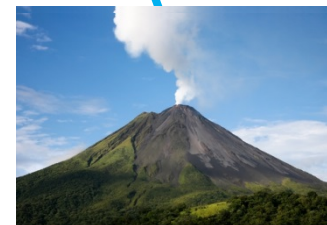




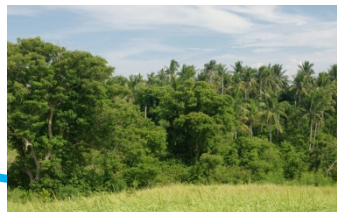
# Science Phase



- Formation Flying
- Interferometric modes
- Imaging modes
- in single/dual or quad polarization



Dual Receive Antenna



# Formation Configuration during the Science Phase

Aug-Sept 14

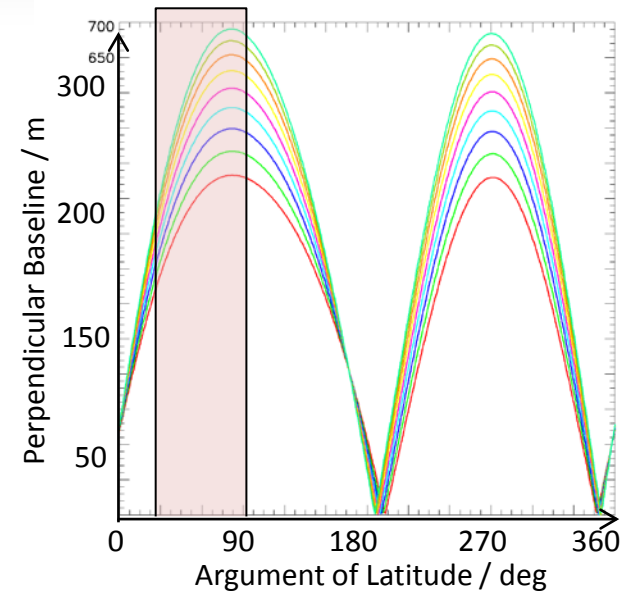
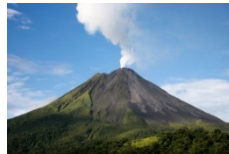
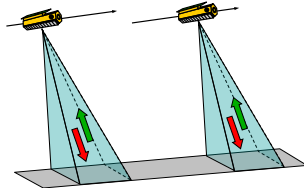
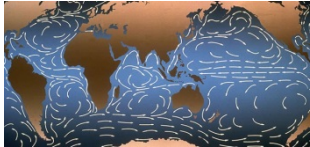
Oct 2014 –Feb 2015

Mar – Aug 2015

Sept –Dec 2015

Close bistatic  
Small along-track  
Northern Hemisphere

Pursuit Monostatic  
76 km along-track  
Satellite drift in 104 days



from Dec. 2014: Dual Receive Antenna Mode



# Formation Configuration during the Science Phase

Aug-Sept 14

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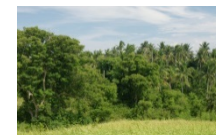
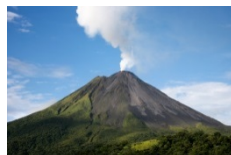
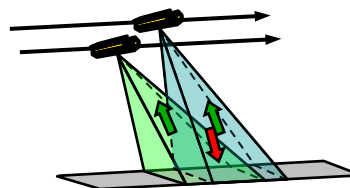
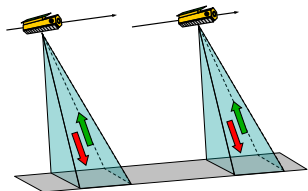
Sept –Dec 2015

Close bistatic  
Small along-track  
Northern Hemisphere

Pursuit Monostatic  
76 km along-track  
Satellite drift in 104 days

Large bistatic  
~ 3.6 km cross-track  
at the equator

Close bistatic  
Small along-track  
Southern Hemisphere



New Imaging Modes:

- Spotlight
- Staring Spotlight
- Scan/WideScansar

from Dec. 2014: Dual Receive Antenna Mode



# Summary

- Stable operations in close formation for more than 4 years!
- TSX & TDX Satellites and the combined TerraSAR-X/TanDEM-X Ground Segment are performing remarkably well
- All data required for the global DEM has been acquired
- DEM quality monitoring indicates good agreement with performance predictions
- Final DEM production ongoing, „about half way through“
- Science Phase ongoing since October 2014 with combination of interferometric modes and imaging modes and a variety of baselines

<https://tandemx-science.dlr.de/>

