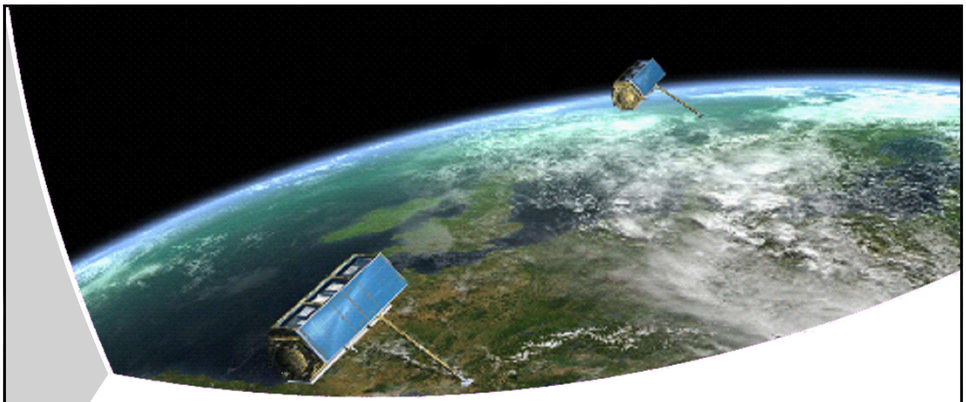

Global Digital Elevation Model from TanDEM-X and the Calibration/Validation with worldwide kinematic GPS-Tracks

<u>D.Kosmann</u>, B.Wessel, V. Schwieger

FIG 2010, TS 8C - New GNSS Applications and Developments , 15. April 2010

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TanDEM

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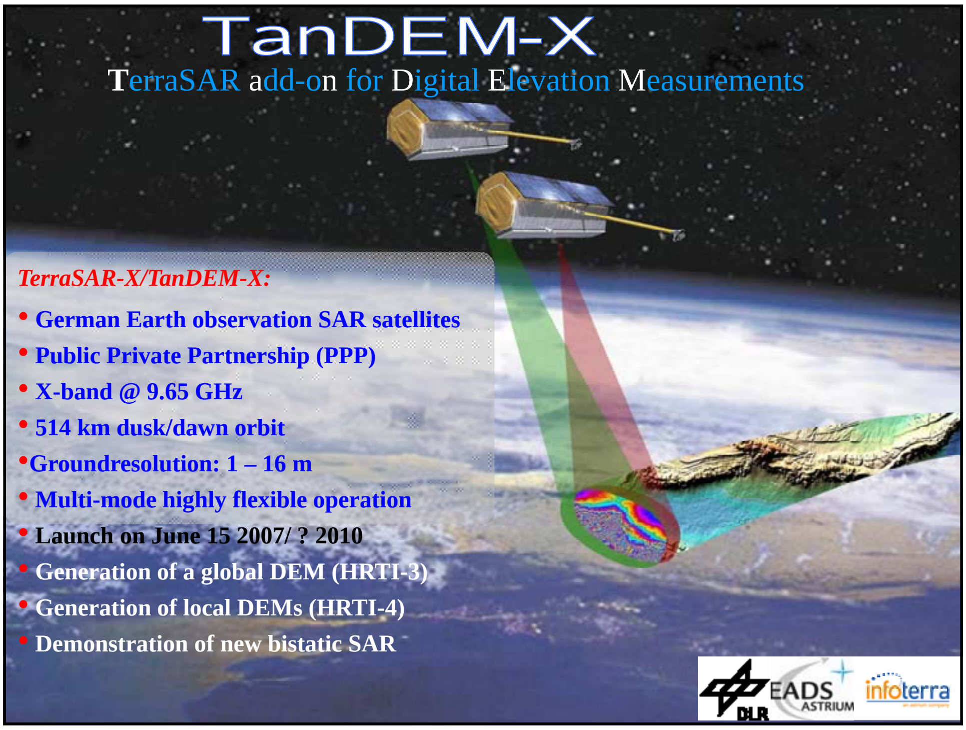
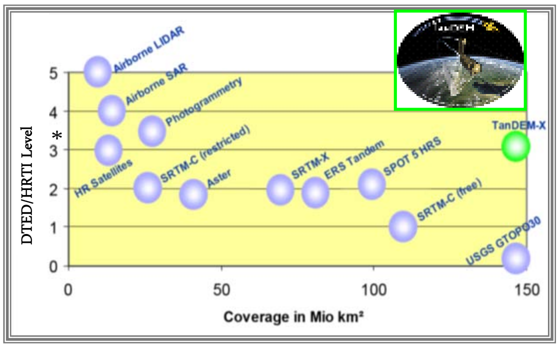


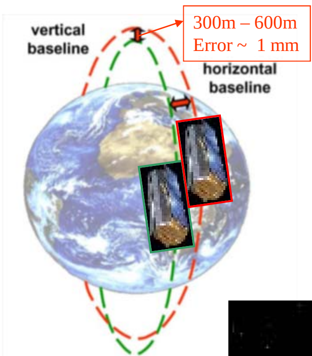
Primary Mission Goal: Generation of a global HRTI-3 DEM

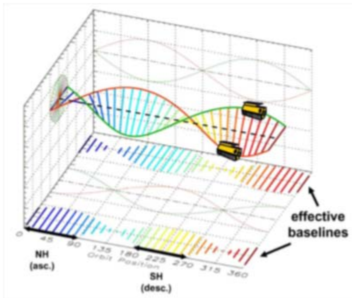


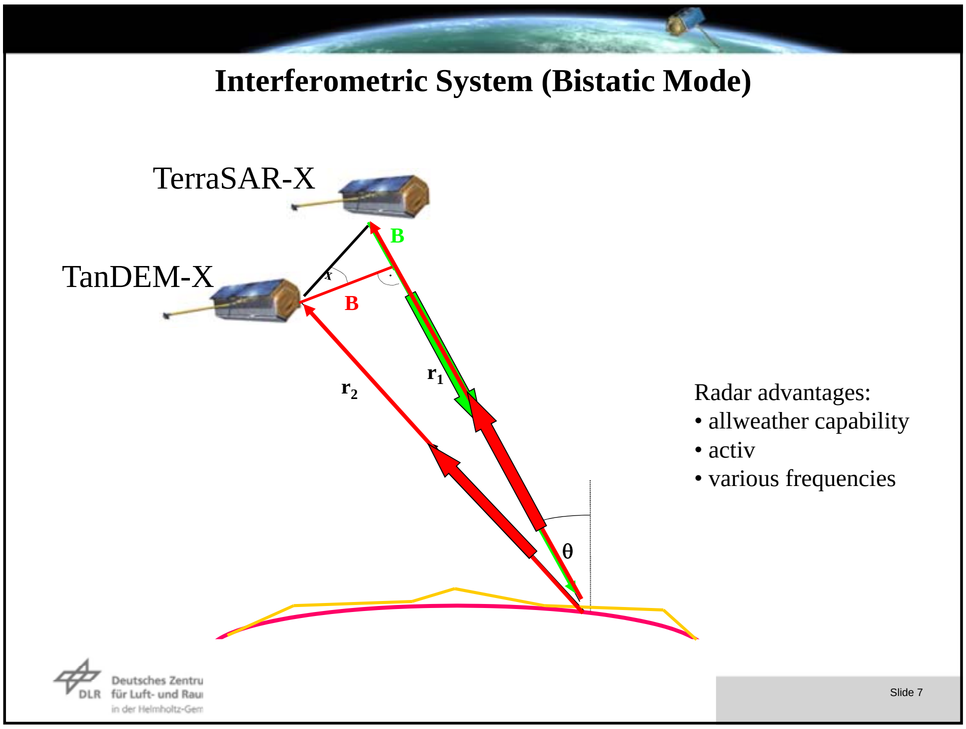
*	Spacing: 12m x 12m	abs. dh < 10 m	abs. dl < 10 m	rel. dh < 2 m (4m,slope>20 %)

HRTI 3 - HRE-GP

Helix Orbit Configuration






Interferometric System (Bistatic Mode)
TerraSAR-X
TanDEM-X
B
B
r1
r2
θ
Radar advantages:
• allweather capability
• activ
• various frequencies
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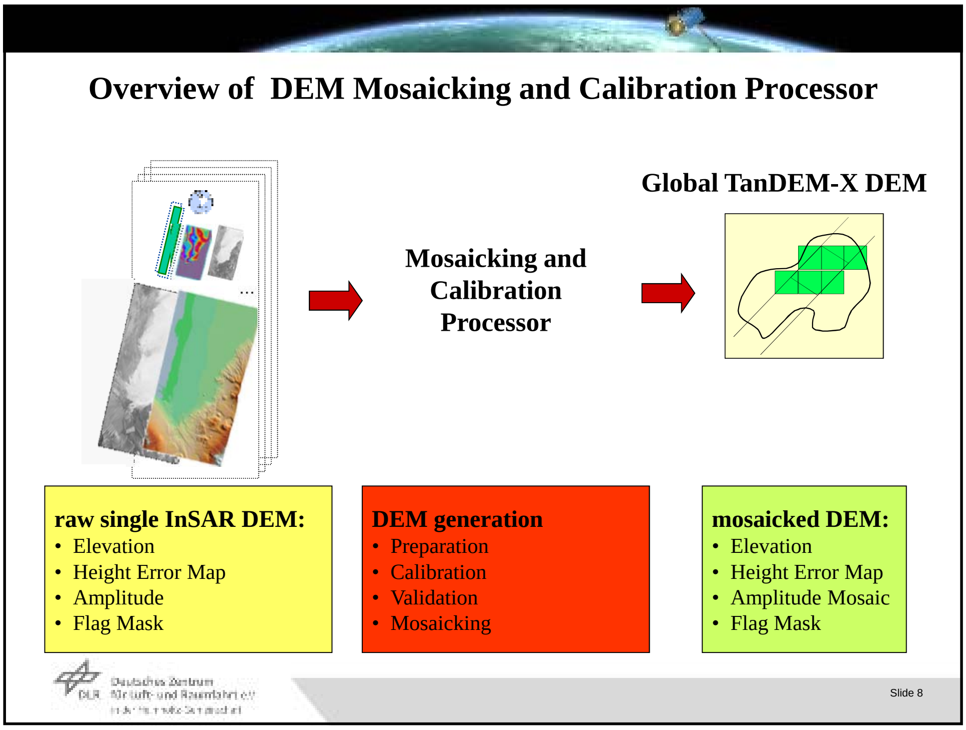
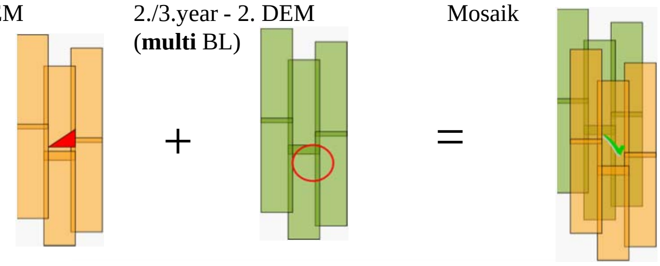

Overview of DEM Mosaicking and Calibration Processor
Global TanDEM-X DEM
Mosaicking and
Calibration
Processor
raw single InSAR DEM:
• Elevation
• Height Error Map
• Amplitude
• Flag Mask
DEM generation
• Preparation
• Calibration
• Validation
• Mosaicking
mosaicked DEM:
• Elevation
• Height Error Map
• Amplitude Mosaic
• Flag Mask
Slide 8

Mosaicking / Fusion

- Applies estimated systematic corrections to raw DEMs
- Mosaic generation: Averages all available raw DEMs to minimize random error
- Followed by operator-conducted quality control
- 1. year: Mosaicked DEM -> intermediate TanDEM-X DEM, 2 years after launch
- 2.+3.year: TanDEM-X DEM -> 4 years after launch (Sep. 2014)

1.year - 1 DEM (***single*** BL)   2./3.year - 2. DEM (**multi** BL)   Mosaik



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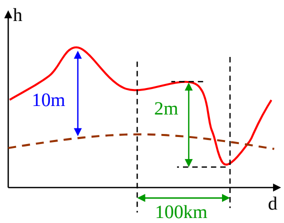
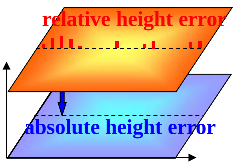
Digital Elevation Models Accuracy

- Goal of the TanDEM-X Mission:
  Global, consistant Digital Elevation Model
- Accuracy Requirements:
  - ~ 12 m spatial posting
  - < 10 m absolute height accuracy
  - < 10 m absolute horizontal accuracy
  - < 2 m relative height accuracy





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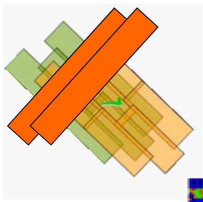
DEM Calibration and Validation

Error Modelling and Adjustment:

- Systematic errors modelled (spacecraft, sensor, orbit, SAR-processor, etc.)
- Least-squares adjustment
- Tie-pointing
- Principle: heights in overlapping areas should be nearly identical after correction

Multiple Ground Coverage:

- Swath overlap (~4 km)
- Land surface covered twice (at least)
- Crossing orbits (3rd year)



Height Reference Data:

•*GLOBAL:* ICESat (Laser Altimeter)

•*LOCAL:* Airborne LIDAR, Radar point targets (corner reflectors),kinematic GPS tracks (for validation)

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Precise Point Positioning

Why PPP?

•No reference station

•No additional data

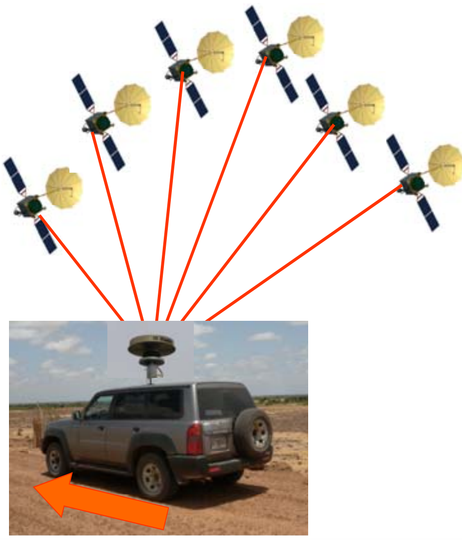
•Worldwide possible

•‚Easy-to-use' ?

•Postprocessing „at home"

Feasibility study and test in Germany

- Quality Study (University Stuttgart)
  Result: Height RMS ~ 0.5 m
- GIPSY and CSRS online Service
- Roundtrip measurements
- Fix and virtuell reference stations
- SAPOS



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Worlwide GPS Tracks

Europe
Munich - Ukraine
Munich - Sao Marinho (Portugal)
Dovzhanck – Tissa (Ukraine)
Russia
Krasnojarsk – Belgorod (Russia)
Asia
Beijing – Gaoquan (China)
Kolkata -Surat (India)
South America
Vina Del Mar - Mar Del Plata (Chile-Argentina)
Laguna Verde - Punta de Choros (Chile)
Recife – Porto Veiho (Brasil)
Africa
Dar es Salaam - Skeleton Coast (Namibia)Conakry - Ife (Niger)
USA/Canada
Los Angeles – Inuvik (Canada)
Vancouver – Nova Scotia (Canada)
Australia
Sydney - Perth
Saudi-Arabia
Dammam – Khamis Mushayt (planned)

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Requirements for Track Acquisition

- **Dual frequency** receiver with **10 Hz**
- Leica GPS1200 is preferred as GPS system (Trimble, Sokkia was also used)
- GPS antenna high as possible
- Speed maximum **100km/h**
- Output format RINEX
- Planning regarding visibility of GPS satellites
- Cut off elevation angle 0 – 10 degree
- DOP > 10
- Satellite visibility check
- PPP **initialization** at start (30 minutes)
- Data take only in dynamic mode
- Track section length **2 hours**
- Maximum single data take 2 hours (30 minutes initialization, 90 measurement of raw data)
- 30 minutes synchronisation at the end of the day
- Online data quality check
- The track should be in east-west or vice versa direction
- Measurement of 2 large intersections (if possible)
- Integration of available **international GPS reference** stations in a distance of 20 km and driving with a reduced speed or a stop of about 10 minutes

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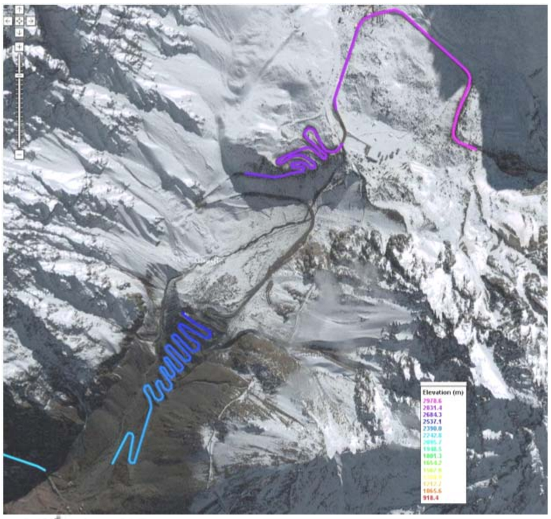
Problems and Quality of the Tracks



Andean

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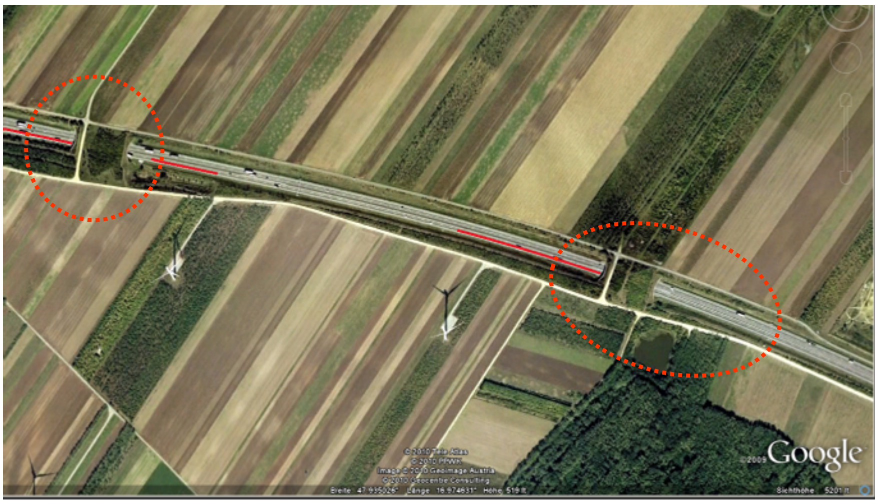
Problem: Signal lost , Buildings



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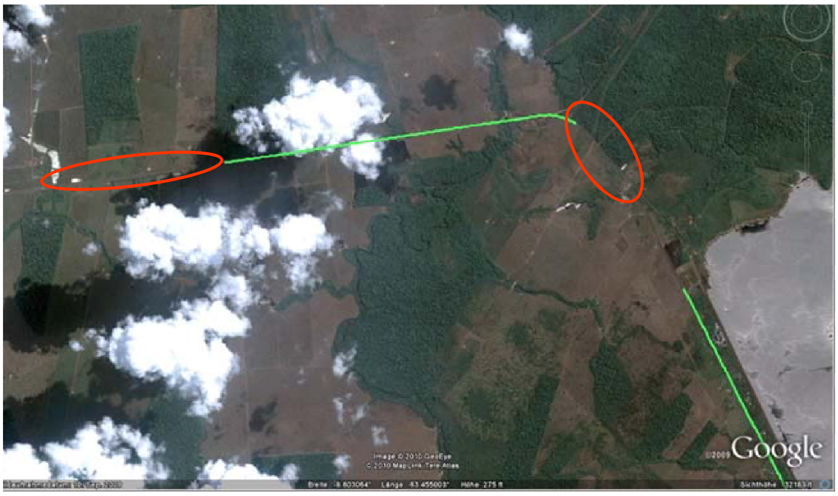
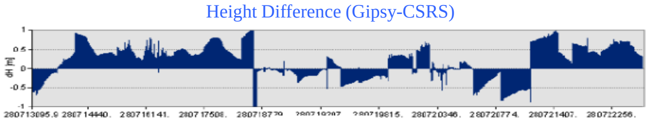
Problem: Forest and ?



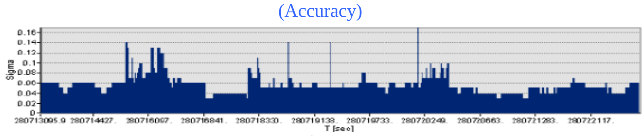
Validation of GPS tracks

- Validation with two indenpendant post-processing approaches (GIPSY, National Resources Canada) processed at Uni Stuttgart
- IGS Information

Height Difference (Gipsy-CSRS)



(Accuracy)



IGS Reference Stations

Reference Station	Mean dh (m)	RMS dh(m)
URUM (China)	-0.03	0.39
SANT (Chile)	0.37	0.79 (large dist. to station)
NVSK (Russia)	0.39	0.15
OBE3 (Germany)	0.21	0.5
SALA (Spain)	0.18	0.37
BRAZ (Brazil)	-0.16	0.24

Track Statistics (March 2010)

Track	Track Length (km)	Valid track	RMS dh (m)
Chile- Argentina	1714	47 %	0.51/0,57
Chile	566	58 %	0.5/0.49
China	3991	71 %	0.52
Europe	900	61 %	0.48
Europe	2400	59 %	0.48/0.48
Russia	4585	59 %	0.46
Brazil	4984	36 %	0.53
	SUM: 19140	**~ 56 %**	**~0.49**

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Cooperation with FIG

FIG Newsletter 2008:
Kinematic GNSS for Evaluation of
TanDEM-X Digital Elevation Model

Feedback:
More than 20 interessted groups from all over the world
Selection of 8 partners (sientific and commercial)

Further cooperation:
TanDEM-X Science team at DLR
Science Coordinator: Irena Hajnsek (Irena.Hajnsek @dlr.de)
Validation of DEMs with access to TanDEM-X products (DEM, Radar)
Scientific usage of GPS Tracks

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TanDEM-X Product Classes

DEM Products

- **Intermediate DEM (2 years after launch)**
- **Standard global DEMs (4 years)**
  - Δh = 2m @ 12m posting (HRTI-3)
  - also: 1m @ 25m and 0.5m @ 50m
    4m @ 6m (on special request)
  - global access
- **Customised DEMs**
  - improved resolution (e.g. 1m @ 6m ~ HRTI-4)
  - multiple DEMs (different seasons/years)
  - only on local/regional basis
- **Supporting information**
  - coherence maps
  - geocoded SAR products
  - height error maps

Radar Data Products

- **Deliverables for scientific User**
  - SLC SAR images
  - auxiliary data (baselines, …)
  - interferograms (if applicable)
  - SAR raw data (on special request)
  - Geocoded products
  - Optional amplitude mosaik
- **Commercial products support by Infoterra**

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Conclusions and Outlook

- Kinematic PPP is a suitable calibration approach
- Height accucracy better than 0.5m
- Postprocessing is very important and time consuming
- TanDEM satellite is at the kosmodrom Baikonur
- Lauch date summer 2010
- First intermediate DEM ^two years after launch
- Access for scientific user via DLR

Acknowledgements:

The TanDEM-X project is partly funded by the German Federal Ministry for Economics and Technology (Förderkennzeichen 50 EE 0601):

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???????

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Thank You
???????

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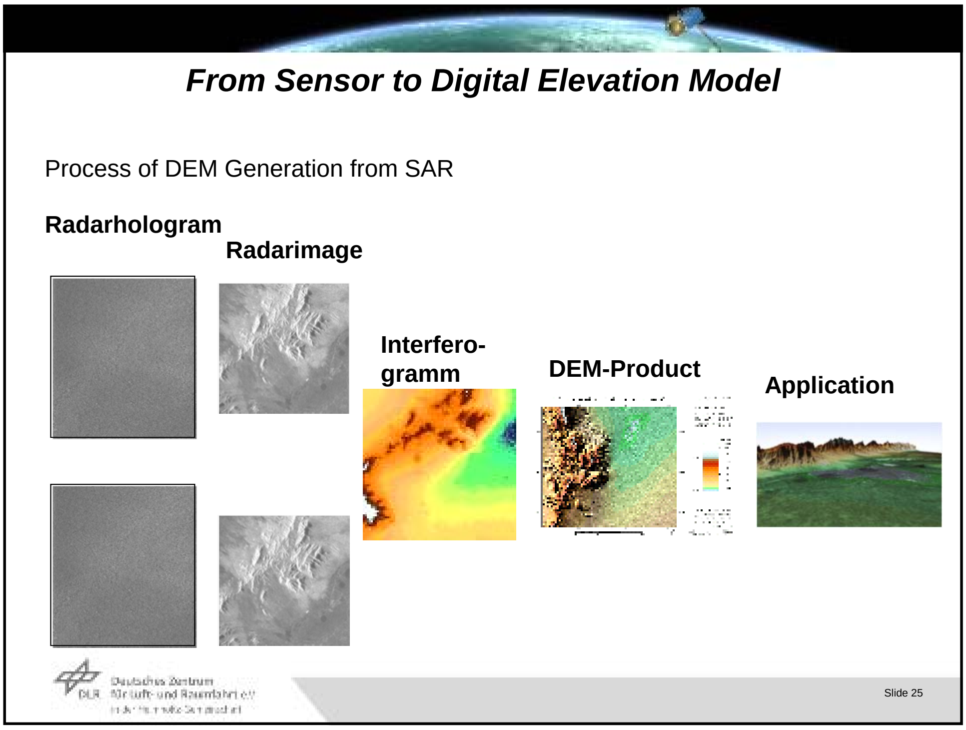
From Sensor to Digital Elevation Model
Process of DEM Generation from SAR
Radarhologram
Radarimage
Interfero-
gramm
DEM-Product
Application
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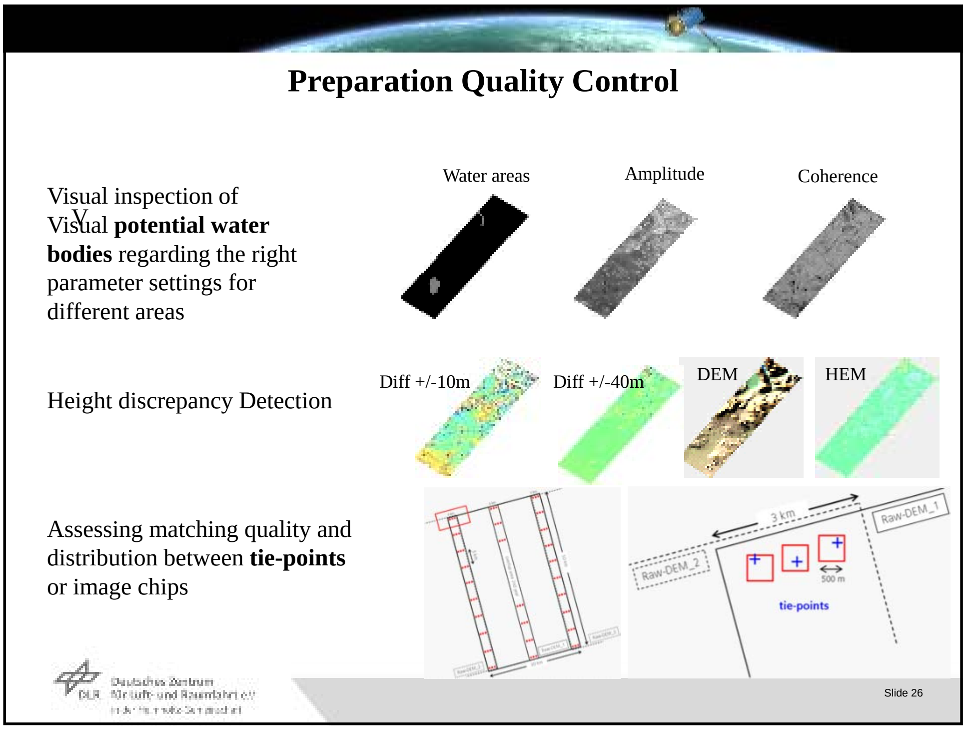
Preparation Quality Control
Visual inspection of potential water bodies regarding the right parameter settings for different areas
Water areas
Amplitude
Coherence
Height discrepancy Detection
Diff +/-10m
Diff +/-40m
DEM
HEM
Assessing matching quality and distribution between tie-points or image chips
3 km
Raw-DEM_1
Raw-DEM_2
500 m
tie-points
Slide 26

TanDEM-X Data Acquisition Strategy

Terrain Type	Percentage of Total Landmass	Number of Acquistions	Required Time
Moderately Sloped Areas	50 %	1 (h_{amb} ~ 35 m)	~ 7 months
Hilly Areas, Tall Forests	30 %	2 (+ different h_{amb})	~ 8 months
Mountainous Areas	< 20 %	4 (+ asc. / desc.)	~ 11 months
Total	100 %	1 - 4	~ 26 months

TanDEM-X Mission Scenario for 3 Years	
Global HRTI-3 DEM (incl. multiple acquisitions for difficult terrain)	~ 70 %
Additional Applications (local HRTI-4, ATI, new techniques, ...)	~ 30 %

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HRTI-3 Specification

	Spatial Resolution	Absolute Horizontal Accuracy (90%)	Absolute Vertical Accuracy (90%)	Relative Vertical Accuracy (90%)
DTED-1	90m x 90m	< 50 m	< 30 m	< 20 m
DTED-2	30m x 30m	< 23 m	< 18 m	< 12 m (15m,slope>20 %)
HRTI-3	12m x 12m	< 10 m	< 10 m	< 2 m (4m,slope>20 %)
HRTI-4	6m x 6m	< 10 m	< 5 m	< 0.8 m (1m,slope>20 %)

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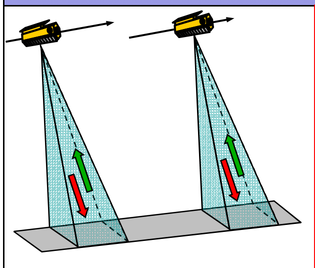
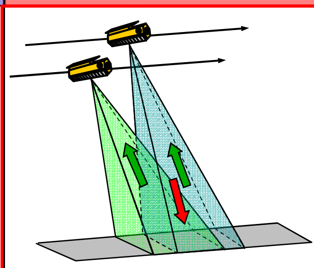
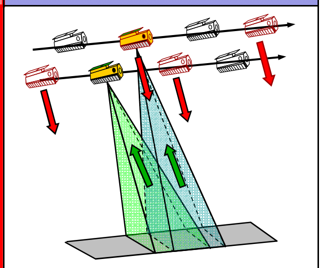
TanDEM-X Data Acquisition Modes

Pursuit Monostatic	Bistatic	Alternating Bistatic
		
• both satellites transmit and receive independently • susceptible to temporal decorrelation and atmospheric disturbances	• one satellite transmits and both satellites receive simultaneously • small along-track displacement required for Doppler spectra overlap	• transmitter alternates between PRF pulses • provides three inter-ferograms with two baselines in a single pass • enables precise phase synchronisation, calibration & verification

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