A Tandem TerraSAR-X Configuration for Single-Pass Interferometry

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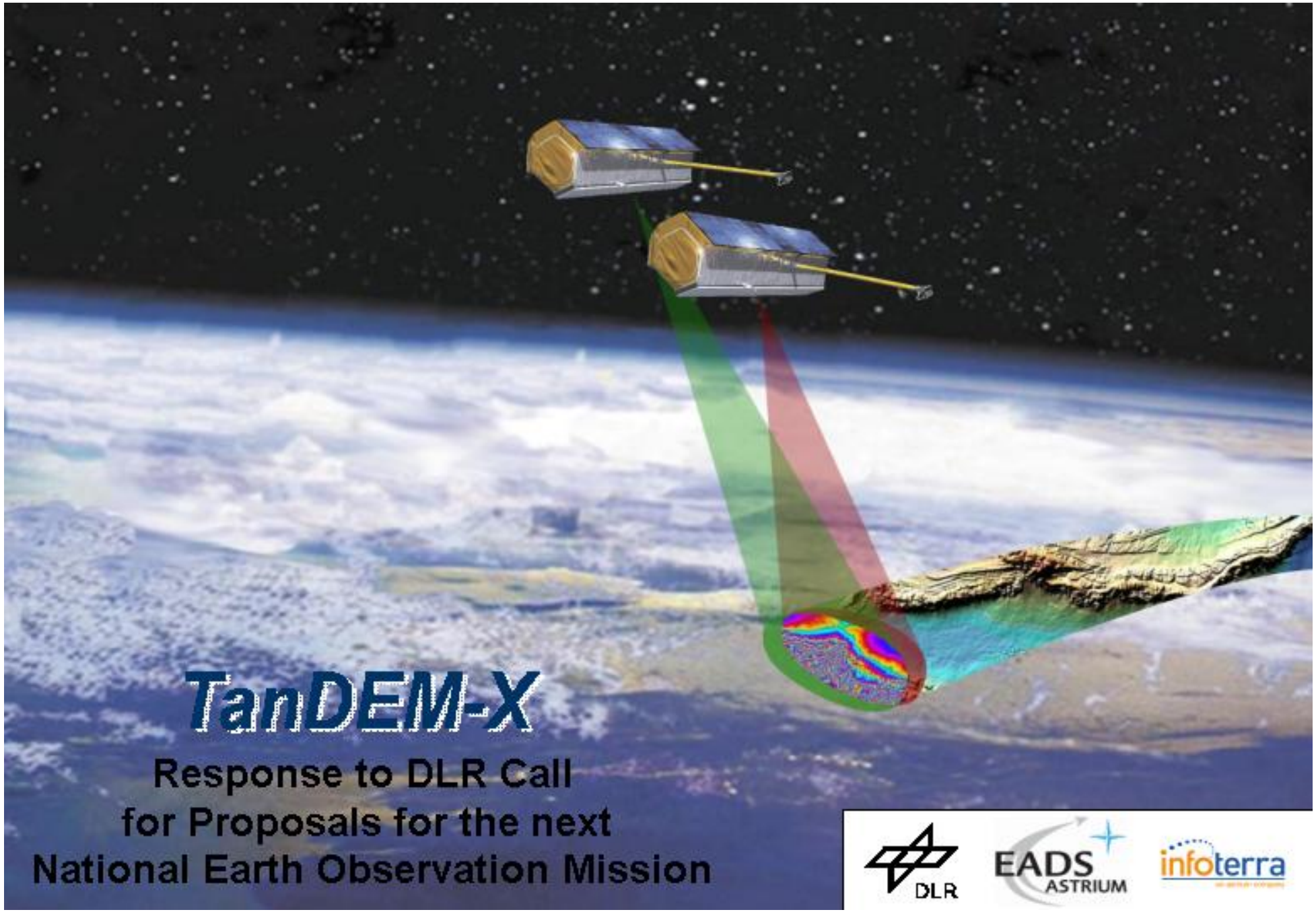
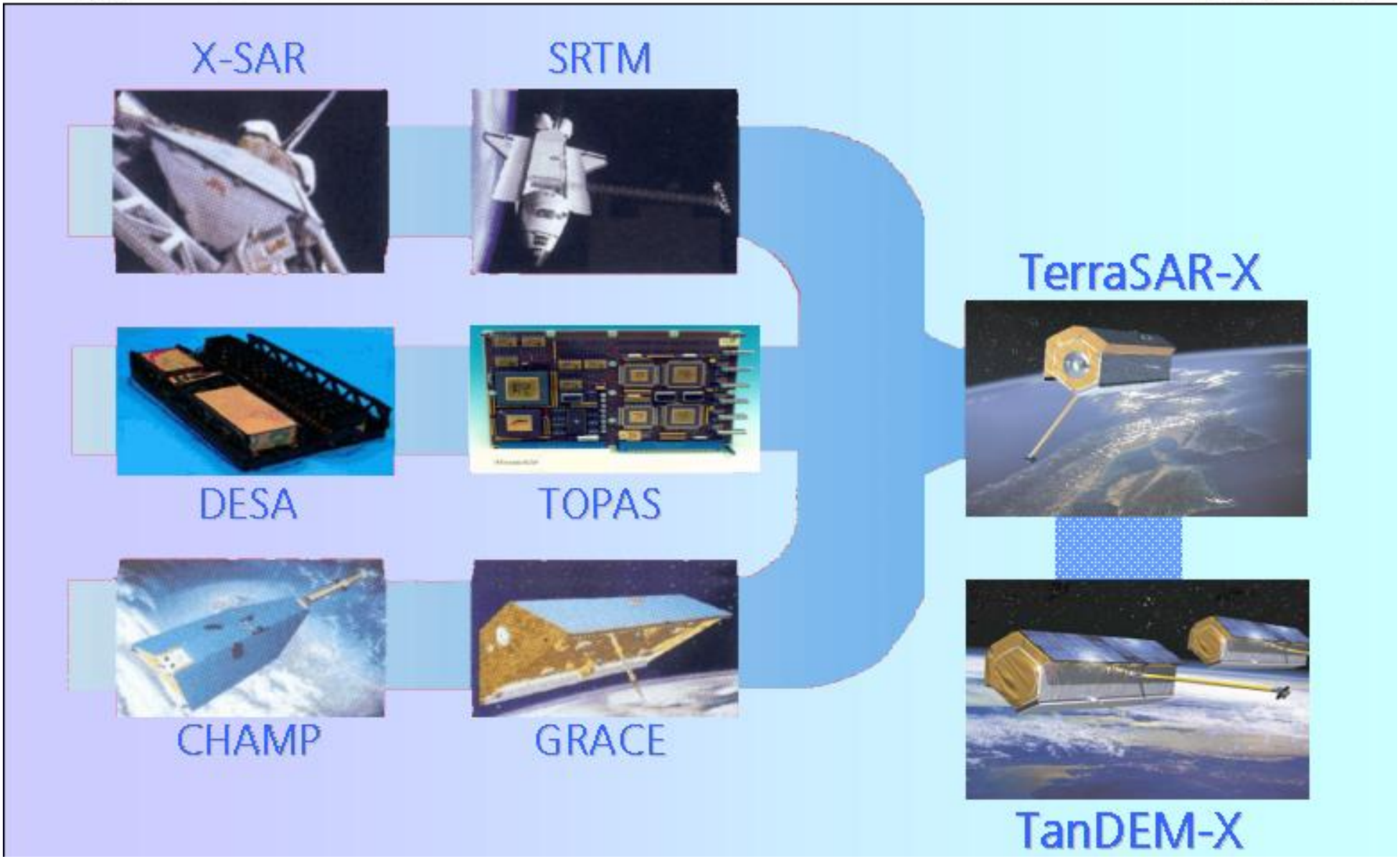
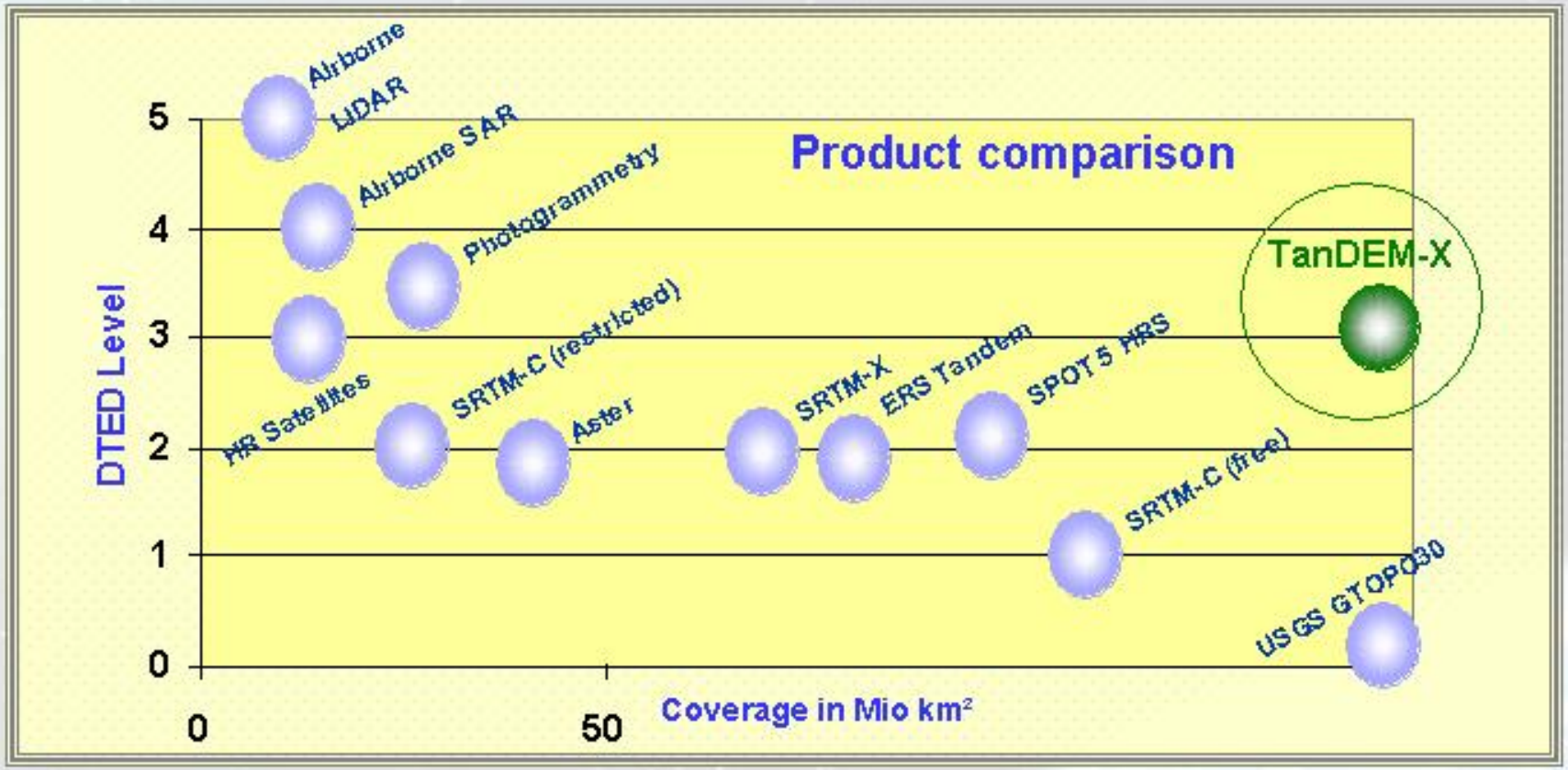

TanDEM-X
Response to DLR Call
for Proposals for the next
National Earth Observation Mission
DLR
EADS
ASTRIUM
infoterra

System and Mission Heritage



TanDEM-X: Primary Mission Goal

Interferometry with TanDEM-X



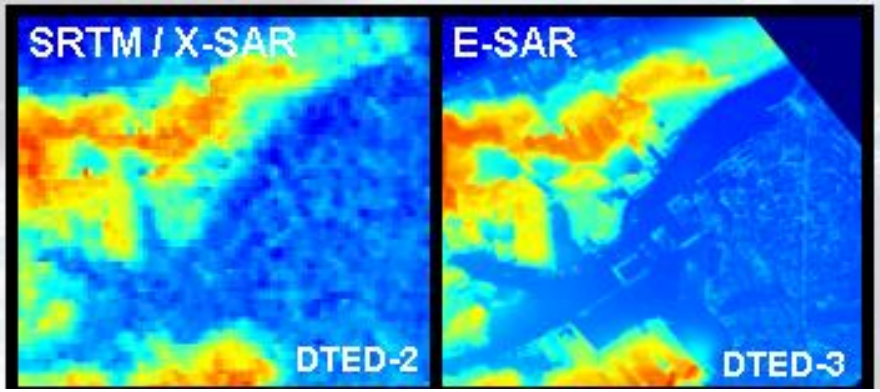
Primary Mission Goal:

- **DEM generation corresponding to HRTI-3 (DTED-3) standard with global coverage with minimum 3 years of nominal operation with TerraSAR-X**

Interferometry with TanDEM-X

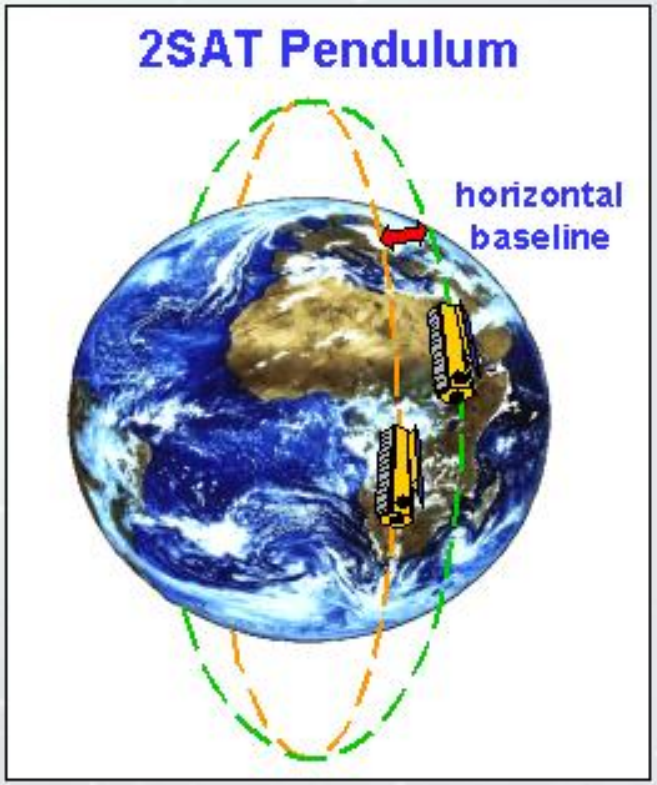
	Spatial Resolution	Absolute Vertical Accuracy (90%)	Relative Vertical Accuracy (90%)	Absolute Horizontal Accuracy (90% circ.)	Relative Horizontal Accuracy (90% circ.)
DTED-1	90m x 90m	< 16 m	< 10 m	< 60 m	< 45 m
DTED-2	30m x 30m	< 16 m	< 10 m	< 20 m	< 15 m
DTED-3 (HRTI-3)	10m x 10m	< 10 m	< 2 m (4m, slope>20 %)	< 10 m	< 3 m

Other product specifications will be considered during phase A with respect to users requirements

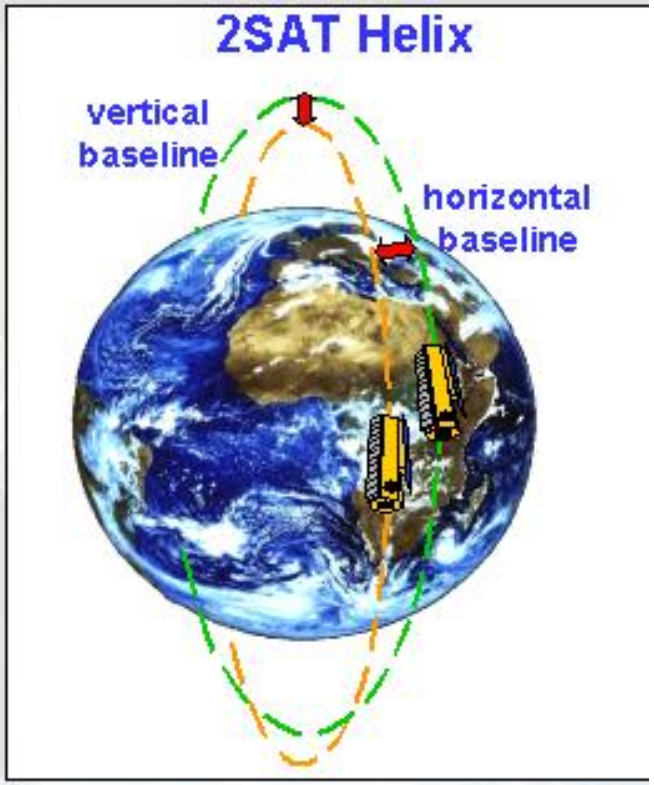


TanDEM-X: Orbit, Operation Modes and Performance

Interferometry with TanDEM-X




Digital Elevation Model (DEM) from SRTM Mission

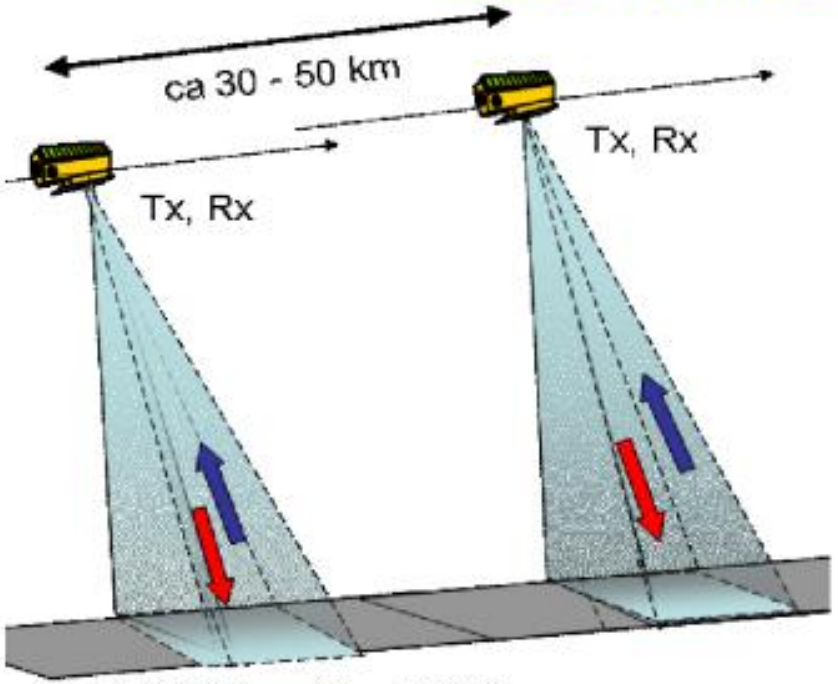


Single-Pass Cross-Track Interferometry with TerraSAR-X Tandem:

- ***no temporal surface decorrelation (as opposed to repeat-pass interferometry)***
- ***almost no atmospheric distortions (as opposed to repeat-pass interferometry)***
- ***large interferometric baselines***

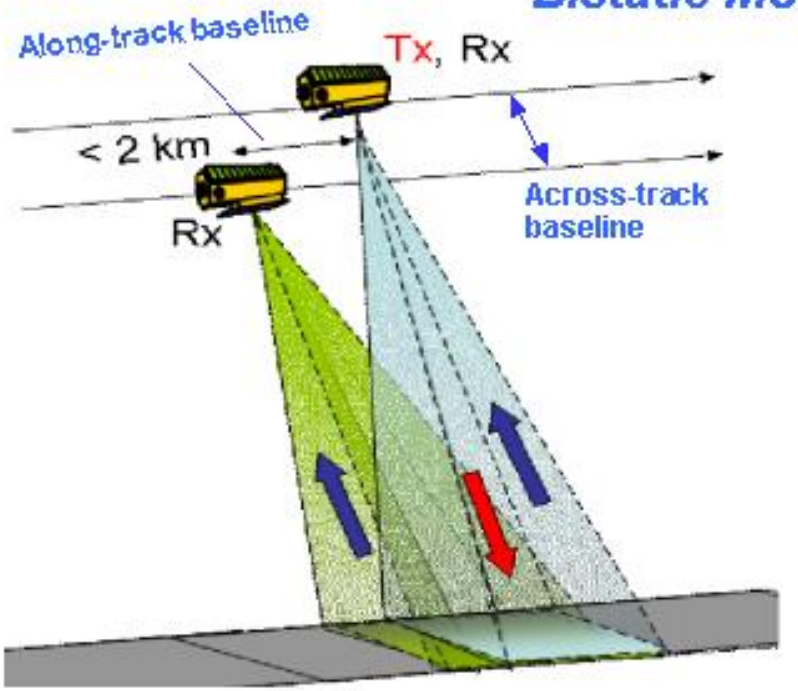
TanDEM-X: Operational Modes

Monostatic Mode



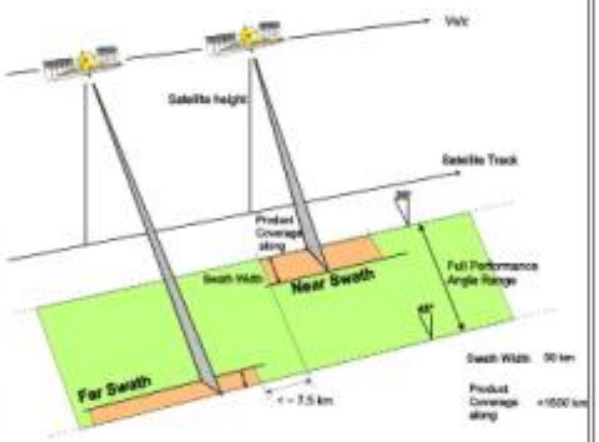
- TerraSAR-X 1 and TanDEM-X transmit and receive independently
- Large along-track separation (> 30 km) to avoid interference
- Temporal decorrelation (~ 10 sec)
- Higher overall power consumption
- More stringent requirements with regard to orbit accuracy (smaller interferometric baselines)

Bistatic Mode



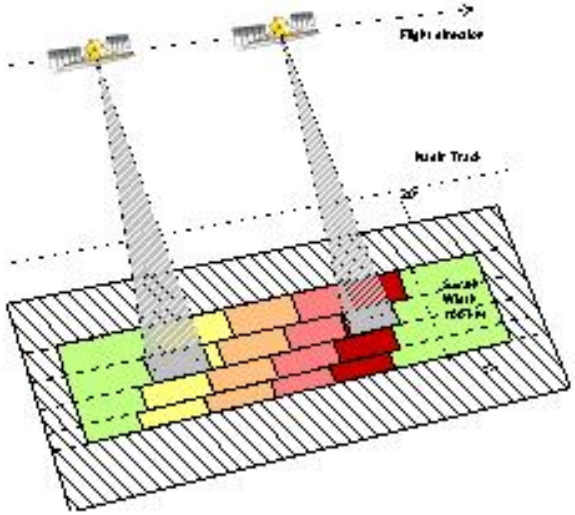
- Only TerraSAR-X 1 transmits (or only TanDEM-X transmits)
- TerraSAR-X 1 and TanDEM-X receive simultaneously
- Antenna footprints must overlap
- Along-track displacement has to be small (< 2 km) (to ensure overlapping Doppler spectra)
- More stringent requirements on oscillator stability

TerraSAR-X Imaging Modes



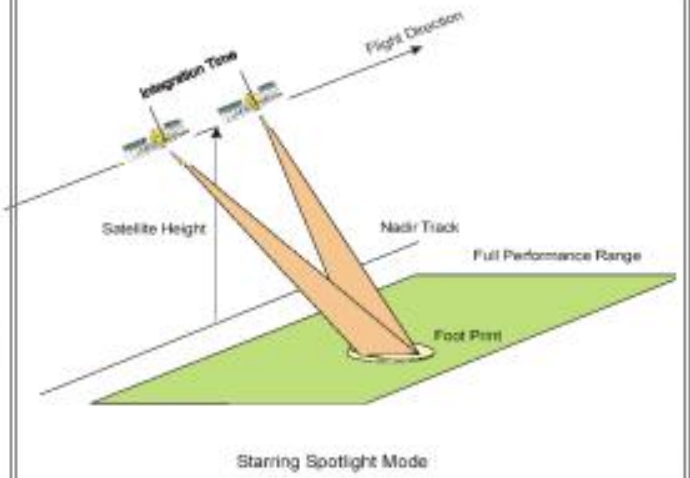
Stripmap Mode

Resolution: 3 m × 3 m
Scene Size: 100 km × 30 km



ScanSAR Mode

Resolution: 16 m x 16 m
Scene Size: 100 km × 100 km



Spotlight Mode

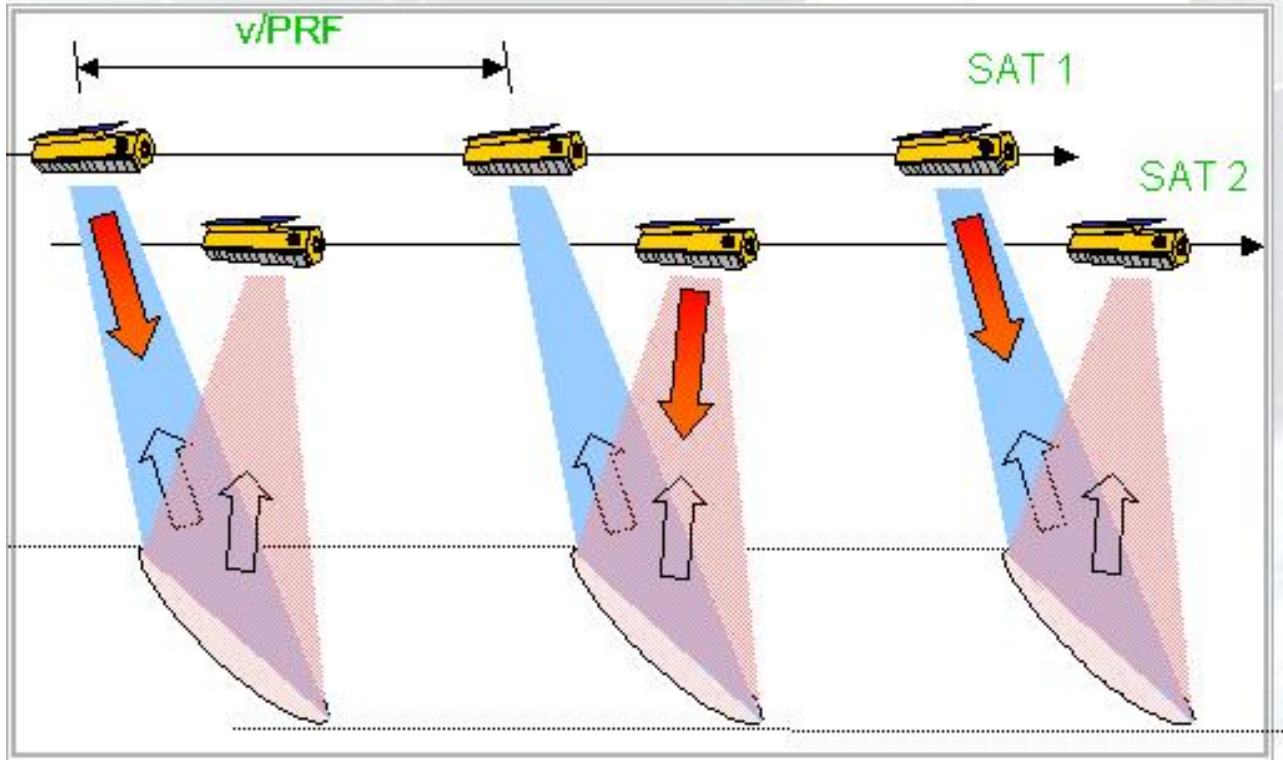
Resolution: 1 m × 1 m (2 m x 2 m)
Scene Size: 5 km x 10 km (10 × 10 km)

- Incidence angle range from 15° to 60°
- Dual polarisation data acquisition in all operational modes
- 300 MHz experimental mode with 0.5 m slant range resolution (1 m ground range @ 30 deg. incidence angle)
- Further experimental modes with Dual Receiving Antenna configuration (full polarimetric and along-track interferometry)

Bistatic Mode with Alternating Transmitters

Three interferograms with two "effective baselines":

$B_{monostatic} = 2 \cdot B_{bistatic}$



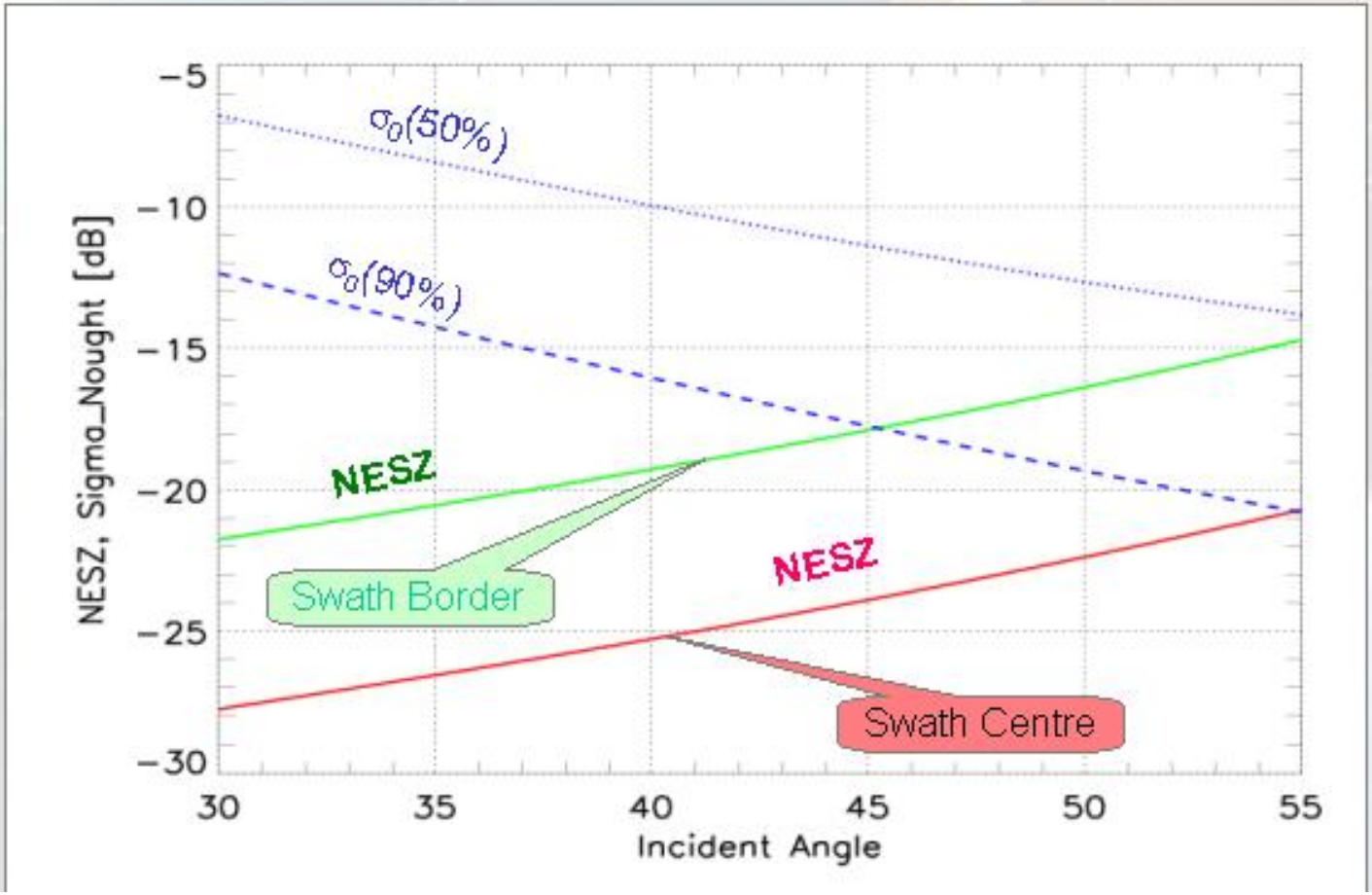
+ good height accuracy (use large monostatic baseline)
+ improved phase unwrapping (use smaller bistatic baselines)
+ phase synchronization possible
– requires increased PRF (as in polarimetric mode)

$$\left.\frac{\partial \varphi}{\partial h}\right|_{monostatic} = 2 \cdot \left.\frac{\partial \varphi}{\partial h}\right|_{bistatic}$$

Interferometric Performance Estimation

Noise Equivalent Sigma Zero

$$= \frac{4^4 \pi^3 r_{Tx} r_{Rx}^2 v \sin(\Theta_i) k T B F}{P_{Tx} G_{Tx} G_{Rx} \lambda^3 c_0 \tau \, PRF}$$



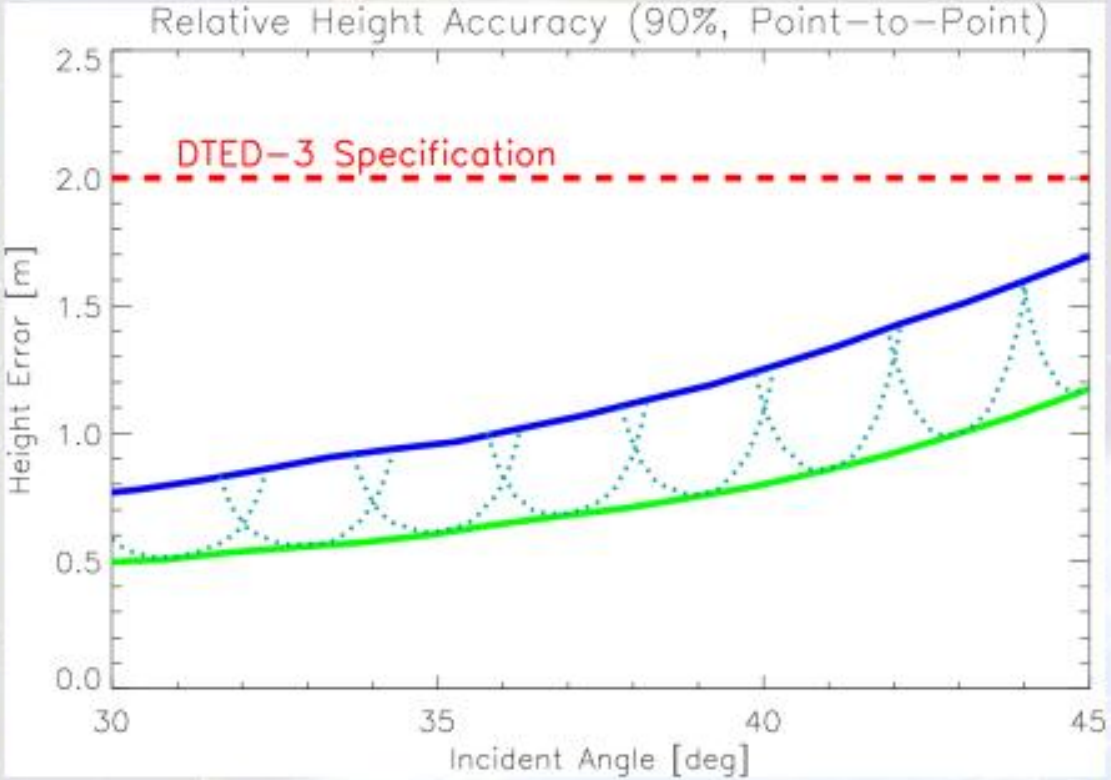
Assumptions:

- no antenna tapering for small incident angles
- swath width: 30km
- 6dB losses at swath border

Interferometric Performance Estimation

Parameter	Value
Wavelength	0.031 m
Chirp Bandwidth	100 MHz
Peak Transmit Power	2260 W
Duty Cycle	18 %
Noise Figure	4.5 dB
Atmospheric Losses	0.5 dB
Antenna Size (Tx , Rx)	4.8 m x 0.7 m
PRF	3500 Hz
Processed Bandwidth	2300 Hz
Co-Registration Accuracy	1/10 pixel
Quantization	3 bit (BAQ)
Sigma Nought Model (90% occurence levels)	Ulaby (X-Band, HH, Soil)
Effective Baseline	1 km
Along-Track Displacement	1 km
Swath Width	30 km
Post Spacing	12 m x 12 m

Relative Height Accuracy



TanDEM-X Mission: Scientific Exploration

Scientific Areas

Applications derived from across-track interferometry

– Land Environment	Topographic Mapping, Cartography, Urban Areas, Disaster and Crisis Management, Navigation, Archaeology, Change Detection
– Hydrology	Ice and Snow, Wetlands, Morphology, Flooding
– Renewable Resources	Land use mapping, agriculture, forestry and grassland
– Oceanography	Wind and Waves, Ocean Dynamics, Ship Detection, Bathymetry
– Geology	Geological mapping, Earthquake /Tectonics, Volcanoes, Landslides

Scientific Areas

Applications with Along-Track Interferometry

– Oceanography	Ocean currents, coastal zone mapping
– Traffic	Traffic flow monitoring
– Glaciology	Ice flow monitoring

New Techniques

- Pol-InSAR
- Digital beamforming
- Multi-Angle Observations
- –Bi-static Processing
- –Super Resolution
- –Formation Flying

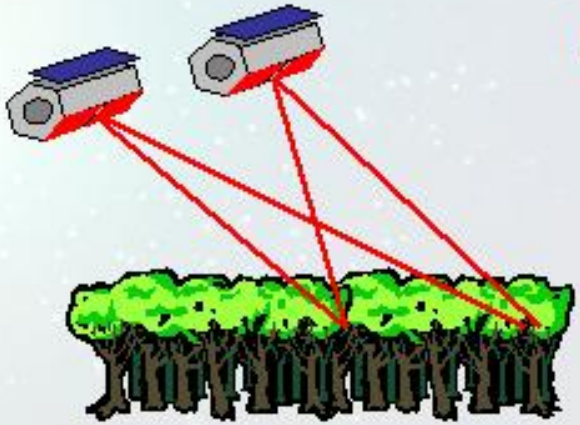
Pol-InSAR

Single Pass
Polarimetric SAR Interferometry

DLR

TanDEM-X

Pol-InSAR



Observables

3 Interferometric Coherences

3 Interferometric Phases

for one baseline and three polarisation states

I Step:
Model and Validation Development

Coherent Scattering Model

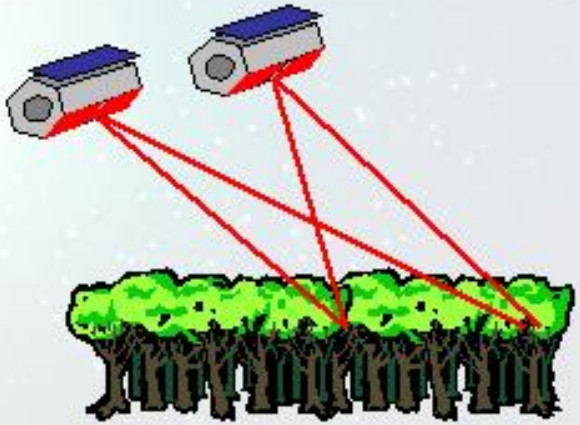
Natural Scatterers

- **Forest Parameters**
- **Surface Parameters**
- **Agricultural Parameters**
- **Land Ice Parameters**

Single Pass
Polarimetric SAR Interferometry

TanDEM-X

Pol-InSAR



Observables

3 Interferometric Coherences

3 Interferometric Phases

for one baseline and three polarisation states

II Step: Model and Validation Inversion

Coherent Scattering Model

Natural Scatterers

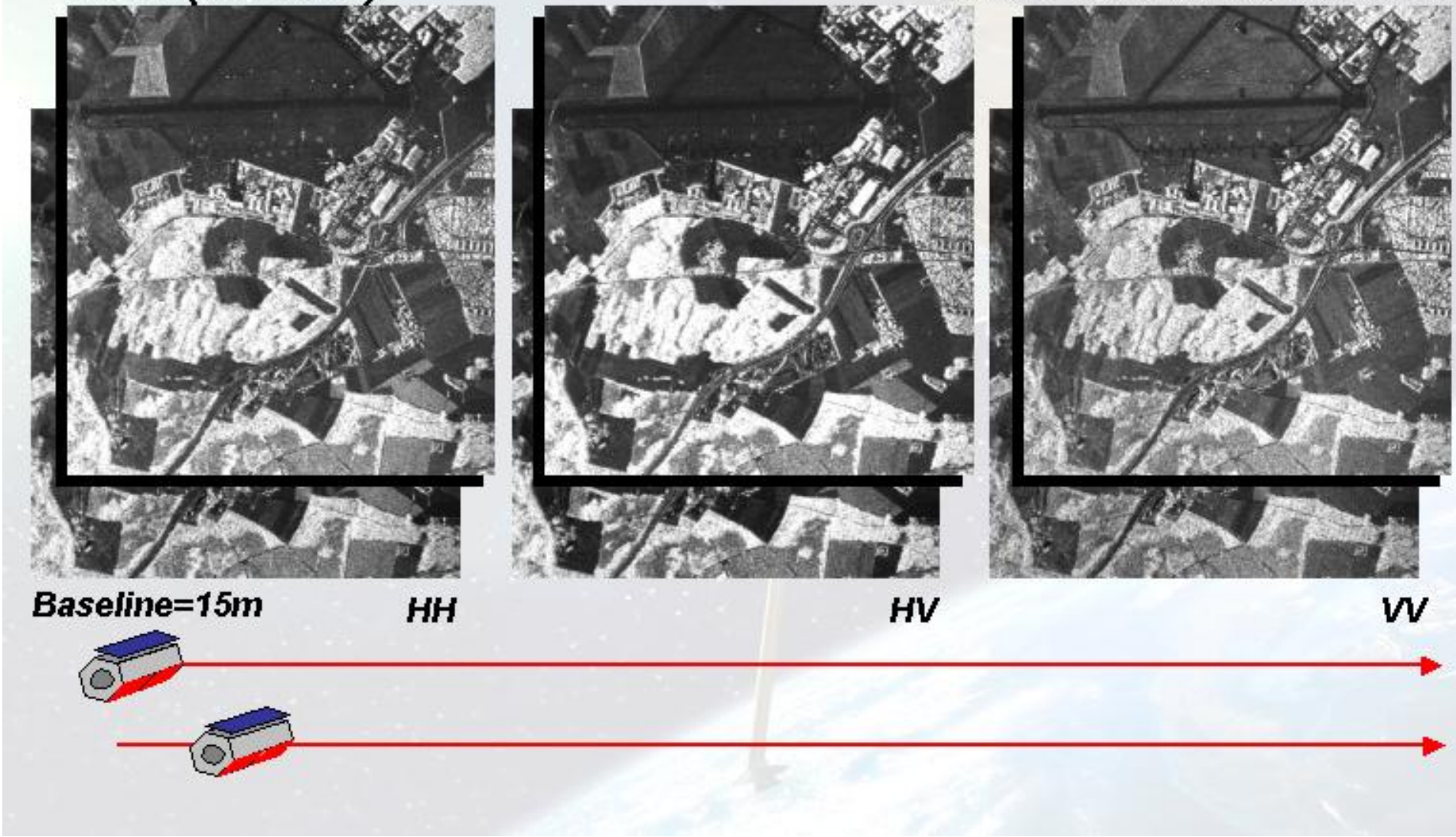
Forest Parameters

Surface Parameters

Agricultural Parameters

Land Ice Parameters

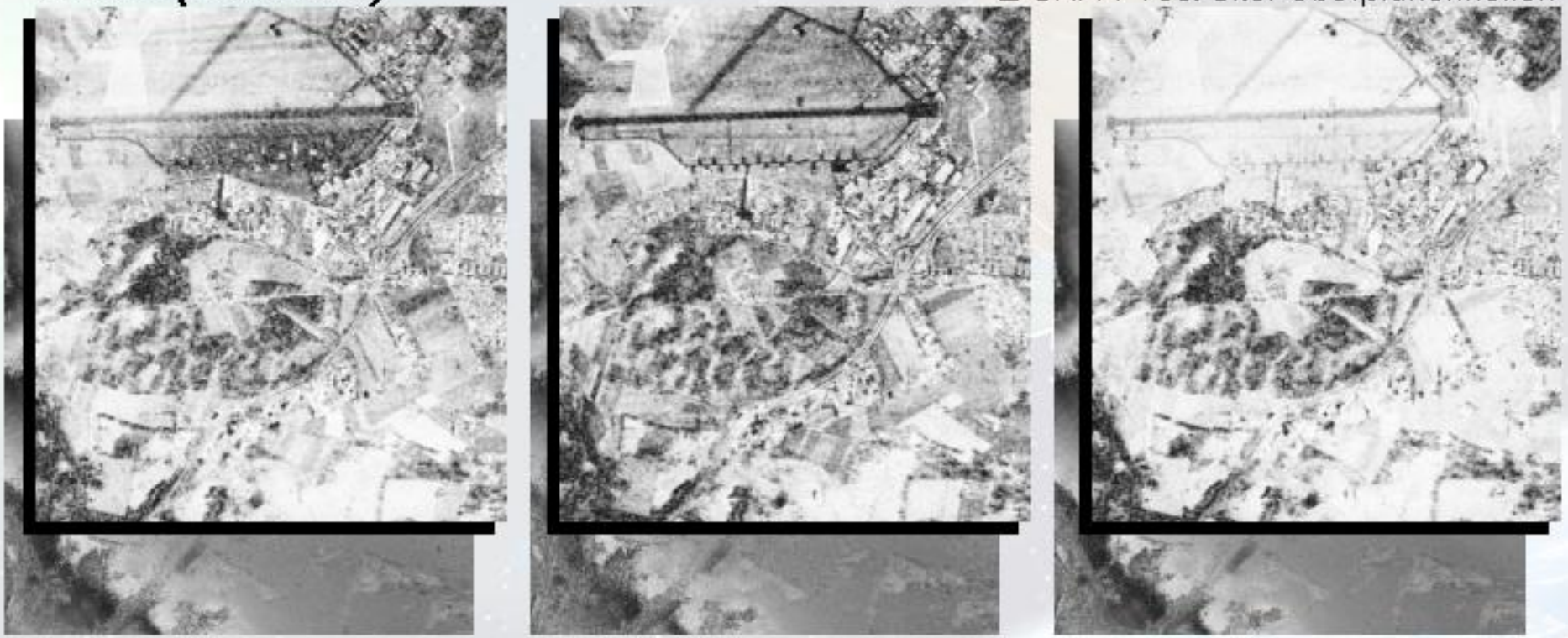
Single Pass
Polarimetric SAR Interferometry



Single Pass
Polarimetric SAR Interferometry

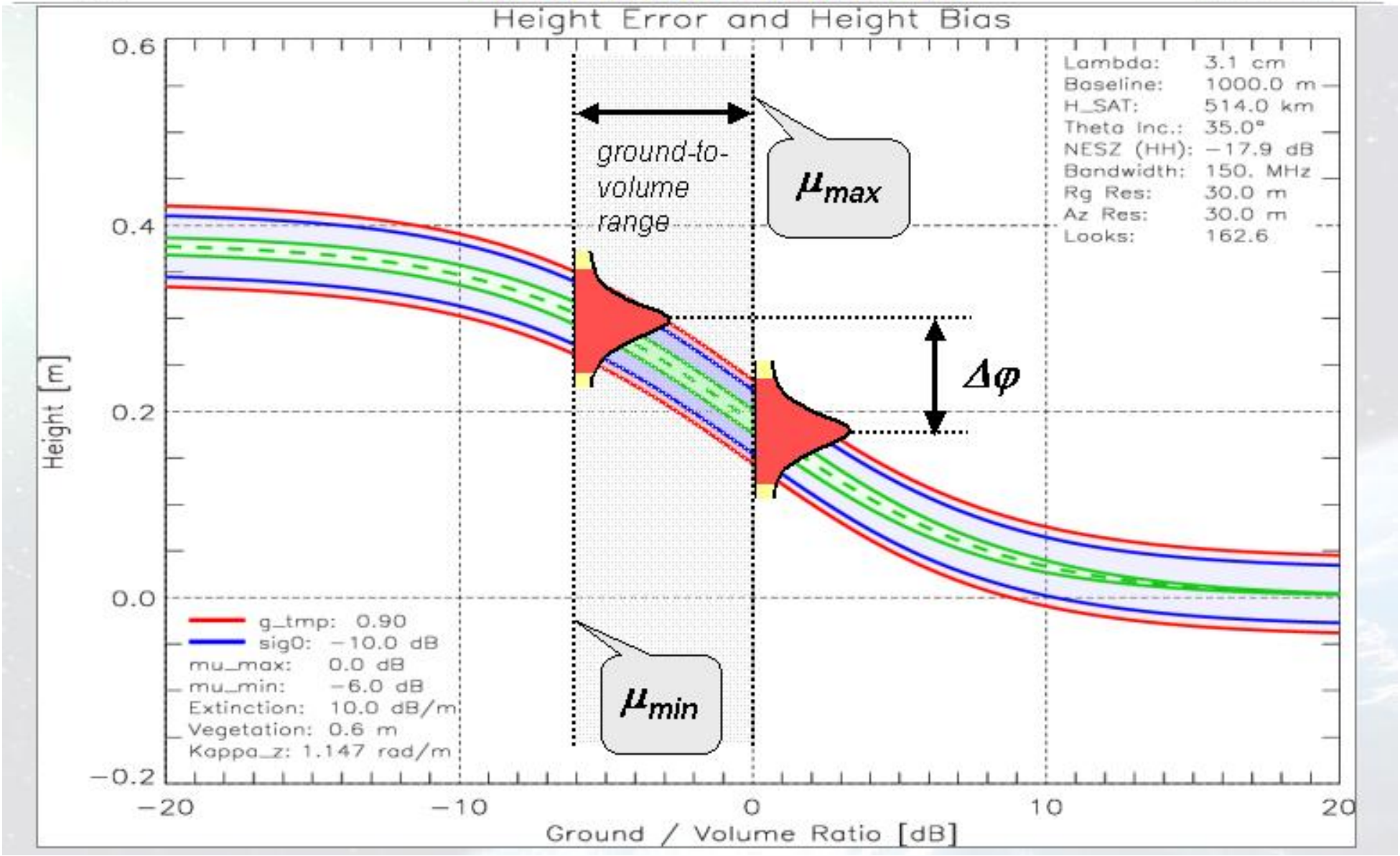
L-band (Pol-InSAR)

E-SAR / Test Site: Oberpfaffenhoffen

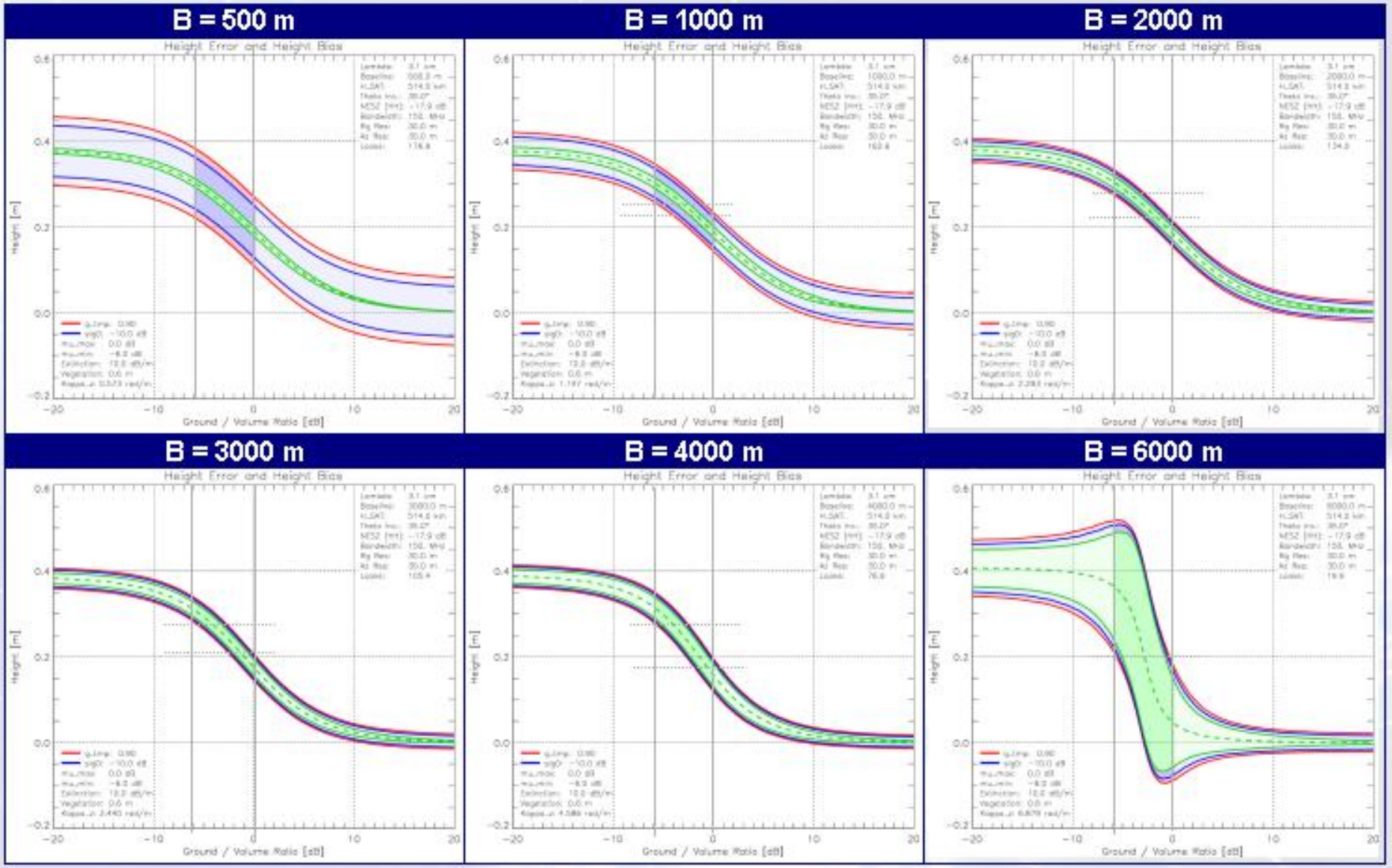


Baseline=15m **HH-HH** **HV-HV** **VV-VV**

Polarimetric Interferometric: Performance Estimation

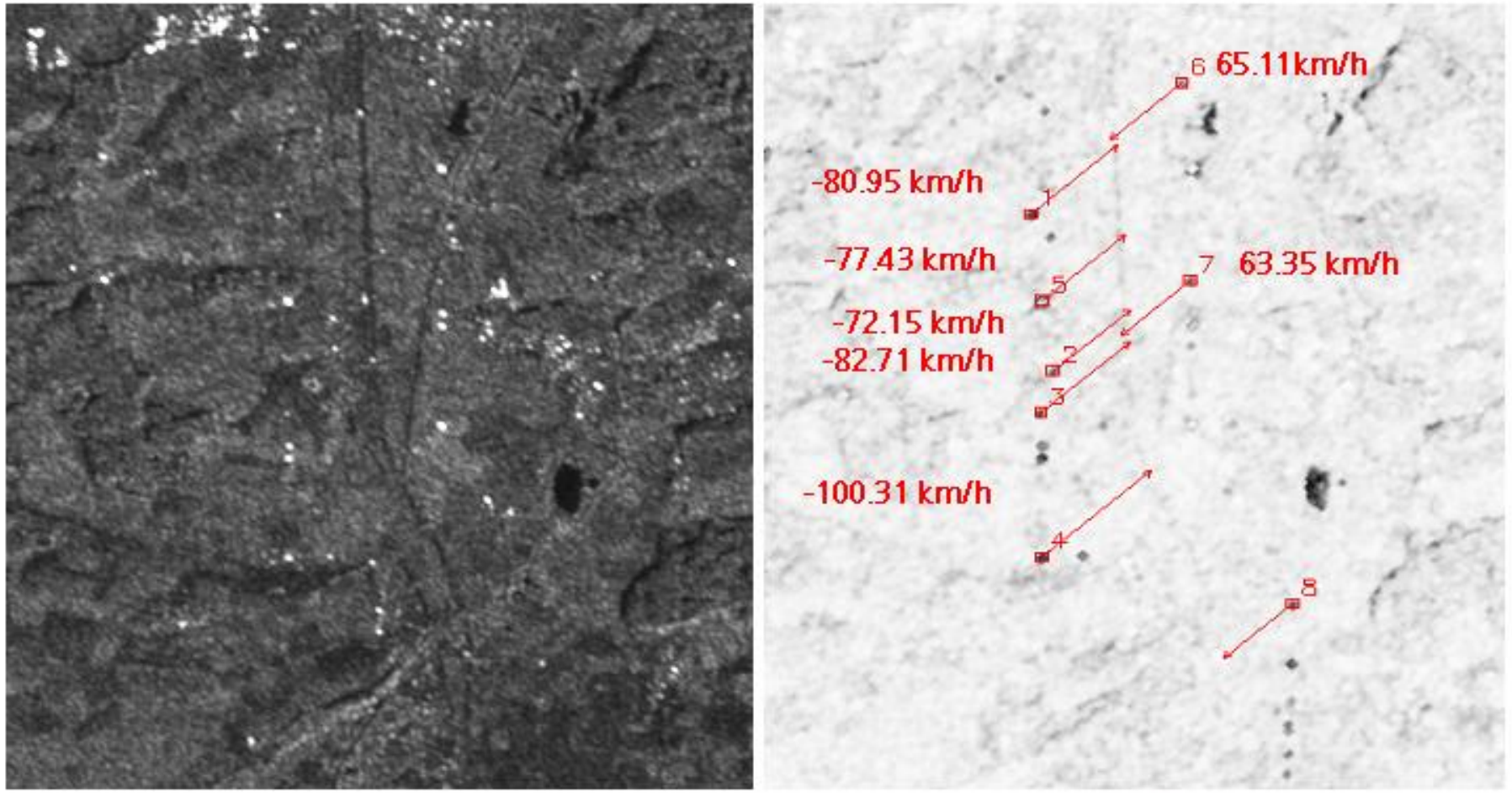


Polarimetric Interferometry: Performance Estimation



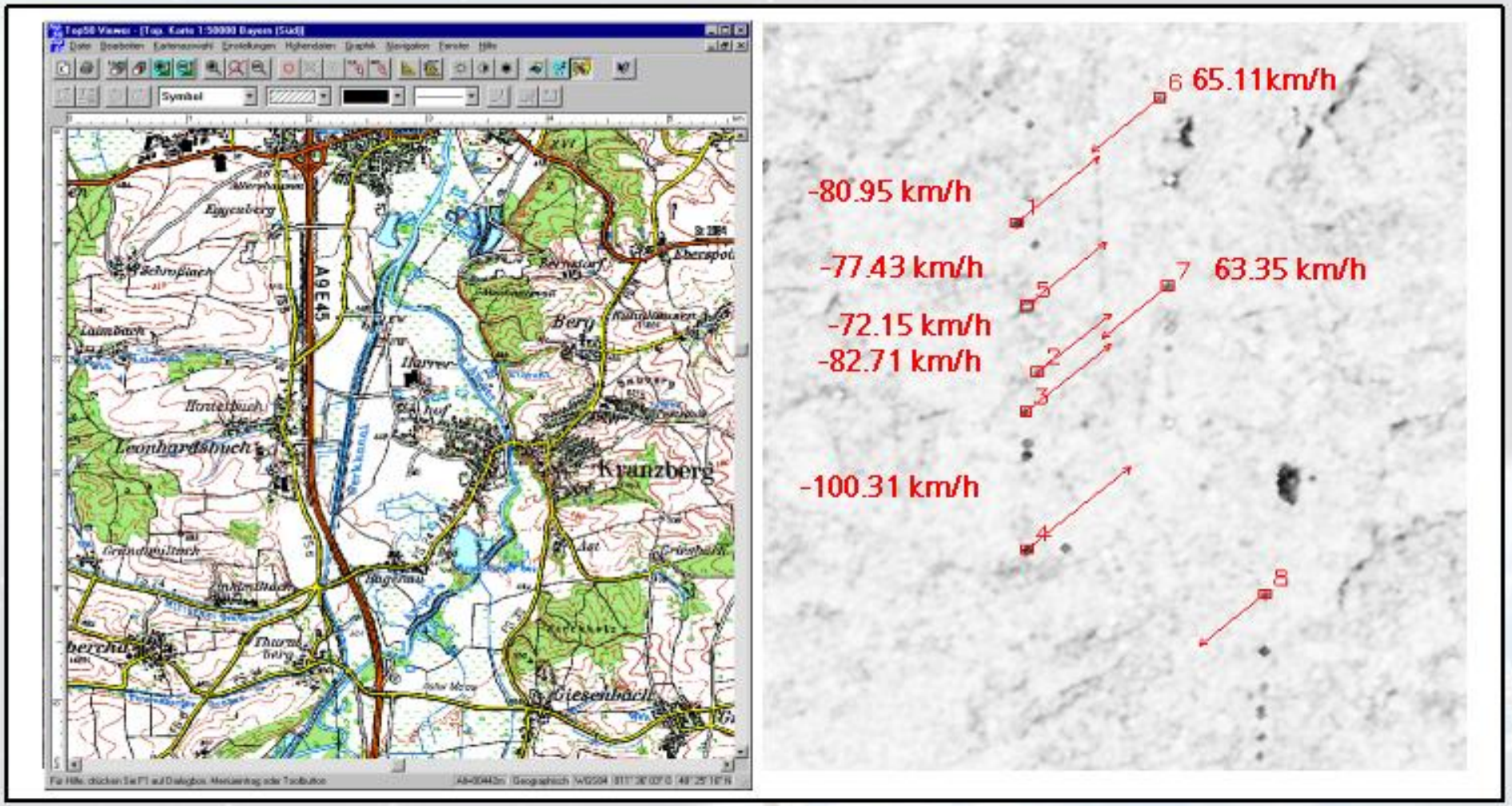
Along-Track Interferometry

Traffic Monitoring with Along Track Interferometry



SRTM/X-SAR data from the highway A-9 (7 meters along-track displacement, DLR-IMF)

Traffic Monitoring with Along Track Interferometry

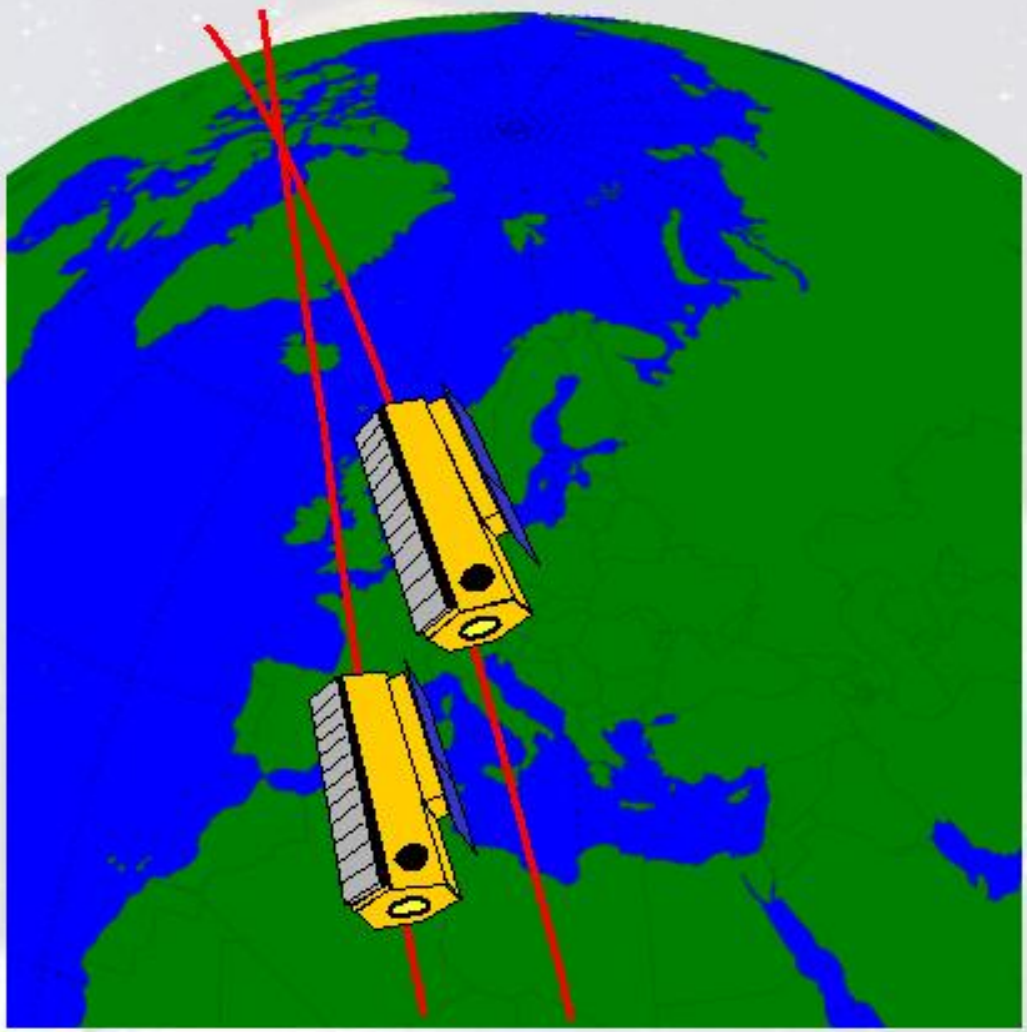


SRTM/X-SAR data from the highway A-9 (7 meters along-track displacement, DLR-IMF)

Summary

Scientific Opportunities

- *DEM-based applications (DTED-3):*
  - *land environment, hydrology, geology, etc.*
- *polarimetric SAR interferometry*
- *along-track interferometry (e.g. mapping of ocean currents, moving target indication)*
- *super-resolution in azimuth and range*
- *Digital beam-forming with 4 phase centers*
- *multi-angle bistatic observations*
- *bi-static SAR polarimetry*
- *stereogrammetric applications*
- *Formation flying*



Main challenges to be investigated in Phase A:

- PRF and Phase Synchronisation (design upgrade)
- Precise baseline determination using differential GPS and phase measurements
- Close formation flying capability
- Bi-static and interferometric data processing (DTED-3)
- Spotlight SAR interferometry
- Interferometric calibration (Ocean data takes, tie points)
- Scientific applications and opportunities