Global Maps from Interferometric TanDEM-X Data: Applications and Potentials

Paola Rizzoli, Michele Martone, Benjamin Bräutigam, and Manfred Zink

DLR - Microwaves and Radar Institute
Outline

TanDEM-X Mission

✓ About 500,000 scenes of 30x50 Km² are available
  ✓ 2 global coverages
  ✓ Addtionally dedicated acquisitions
  ✓ 4.5 years of mission operation
  ✓ Interferometric dataset of bistatic acquisitions
Outline

TanDEM-X Mission

✔ About 500,000 scenes of 30x50 Km² are available
  ✔ 2 global coverages
  ✔ Additionally dedicated acquisitions
  ✔ 4.5 years of mission operation
  ✔ Interferometric dataset of bistatic acquisitions

Global TanDEM-X Quicklook mosaics

✔ Derived by composing Quicklook images
✔ Achievable ground resolution: 25x25 m²
✔ Multiple coverages available
Outline

TanDEM-X Mission

- About 500,000 scenes of 30x50 Km² are available
  - 2 global coverages
  - Additionally dedicated acquisitions
  - 4.5 years of mission operation
  - Interferometric dataset of bistatic acquisitions

Global TanDEM-X Quicklook mosaics

- Derived by composing Quicklook images
- Achievable ground resolution: 25x25 m²
- Multiple coverages available
Outline

TanDEM-X Mission

✓ About 500,000 scenes of 30x50 Km² are available
  ✓ 2 global coverages
  ✓ Additionnally dedicated acquisitions
  ✓ 4.5 years of mission operation
  ✓ Interferometric dataset of bistatic acquisitions

Global TanDEM-X Quicklook mosaics

✓ Derived by composing Quicklook images
✓ Achievable ground resolution: 25x25 m²
✓ Multiple coverages available
Outline

How can we use this **Global interferometric dataset?**
Outline

How can we use this **Global interferometric dataset**?

- Starting Point: Global dataset of the interferometric coherence

- First coverage Acquisitions
Outline

How can we use this **Global interferometric dataset**?

1. Interferometric Performance Analysis
2. Ice classification
3. Forest Discrimination
TanDEM-X Interferometric Performance Analysis

Objective
Monitor the interferometric performance of the on-going mission, support the optimization of the acquisition strategy, and predict the final TanDEM-X DEM performance.

Ice classification

Forest Discrimination

Interferometric Performance Analysis
TanDEM-X Interferometric Performance Analysis

Objective
Monitor the interferometric performance of the on-going mission, support the optimization of the acquisition strategy, and predict the final TanDEM-X DEM performance.

Quicklook mosaics can be quickly generated and are easy to manage!
TanDEM-X Interferometric Performance Analysis

✓ Global mosaic of the relative height error standard deviation
✓ Ground resolution 300x300 m²
✓ All available TanDEM-X coverages
TanDEM-X Interferometric Performance Analysis

✓ Support for acquisition planning optimization
TanDEM-X Interferometric Performance Analysis

✓ Support for acquisition planning optimization

Difficult terrain (mountains) → reacquired using crossing orbits

First + second coverage

Crossing orbits

First + second + crossing

The Alps
TanDEM-X Interferometric Performance Analysis

- Support for acquisition planning optimization

Difficult terrain (mountains) → reacquired using crossing orbits

- First + second coverage
- Crossing orbits
- First + second + crossing

The Alps
TanDEM-X Interferometric Performance Analysis

- Support for acquisition planning optimization

Deserts reacquired using steeper incidence angles to improve SNR
TanDEM-X Interferometric Performance Analysis

✓ Estimation of the final DEM performance by evaluating the relative height error confidence level within the mission specification for tiles of 1°x1° lat/lon

- rel. Height Error < 2 m for flat terrain (predominant slope < 20%)
- rel. Height Error < 4 m for mountaineous terrain (predominant slope > 20%)
TanDEM-X Interferometric Performance Analysis

- Estimation of the final DEM performance by evaluating the relative height error confidence level within the mission specification for tiles of 1°x1° lat/lon
  - rel. Height Error < 2 m for flat terrain (predominant slope < 20%)
  - rel. Height Error < 4 m for mountaineous terrain (predominant slope > 20%)

![Map of tiles with height error distribution]

- Rel. HE > 93%: 13673 Tiles (83.88 %)
- Rel. HE ∈ [90%, 93%]: 1038 Tiles (6.36 %)
- Rel. HE < 90% but Forest: 818 Tiles (5.01 %)
- Rel. HE < 90% but Ice: 95 Tiles (0.58 %)
- Rel. HE ∈ [85%, 90%]: 336 Tiles (2.06 %)
- Rel. HE < 85%: 339 Tiles (2.07 %)
TanDEM-X Interferometric Performance Analysis

✓ Estimation of the final DEM performance by evaluating the relative height error confidence level within the mission specification for tiles of 1°x1° lat/lon

Quicklook Mosaic

Final TanDEM-X full-resolution DEM

Rel. HE > 93%: 13673 Tiles (83.88 %)
Rel. HE ∈ [90%, 93%]: 1038 Tiles (6.36 %)
Rel. HE < 90% but Forest: 818 Tiles (5.01 %)
Rel. HE < 90% but Ice: 95 Tiles (0.58 %)
Rel. HE ∈ [85%, 90%]: 336 Tiles (2.06 %)
Rel. HE < 85%: 339 Tiles (2.07 %)
Estimation of the final DEM performance by evaluating the relative height error confidence level within the mission specification for tiles of $1^\circ \times 1^\circ$ lat/lon

Tiles with Land mass $> 1%$

$E[(1)-(2)] = -0.3\%$

$\text{stdDev}[(1)-(2)] = 2.6\%$

- Rel. HE $> 93\%$: 13673 Tiles (83.88 \%) 
- Rel. HE $\in [90\%, 93\%]$: 1038 Tiles (6.36 \%)
- Rel. HE $< 90\%$ but Forest: 818 Tiles (5.01 \%)
- Rel. HE $< 90\%$ but Ice: 95 Tiles (0.58 \%)
- Rel. HE $\in [85\%, 90\%]$: 336 Tiles (2.06 \%)
- Rel. HE $< 85\%$: 339 Tiles (2.07 \%)
Classification of the Greenland Ice Sheet

**Objective**

discriminate snow facies over the Greenland ice sheet by exploiting interferometric acquisitions

1. Interferometric Performance Analysis
2. Ice classification
3. Forest Discrimination
Classification of the Greenland Ice Sheet

**Objective**

discriminate snow facies over the Greenland ice sheet by exploiting interferometric acquisitions

TanDEM-X data acquired during Winter 2011 only
Mosaics ground resolution ~ 50 m
Classification of the Greenland Ice Sheet
Classification of the Greenland Ice Sheet

Coherence

SNR

Backscatter ($\gamma^0$)
Classification of the Greenland Ice Sheet

Coherence

SNR

SNR Decorrelation

[Image showing coherence, SNR, SNR decorrelation maps of the Greenland Ice Sheet]
Classification of the Greenland Ice Sheet

Coherence

Volume Decorrelation

SNR Decorrelation

+ Height of ambiguity dependency

+ Other decorrelation sources (quantization, ambiguities, …)
Classification of the Greenland Ice Sheet

Discrimination of different facies by combining the information coming from backscatter and volume decorrelation.
Classification of the Greenland Ice Sheet

Discrimination of different facies by combining the information coming from backscatter and volume decorrelation

Fuzzy $c$-Means Clustering

Iterative algorithm for finding $c$ optimal fuzzy partitions of the input observations set, by minimizing the Euclidean norm between observations and cluster centers.
Classification of the Greenland Ice Sheet

Discrimination of different facies by combining the information coming from backscatter and volume decorrelation

**Fuzzy $c$-Means Clustering**

Iterative algorithm for finding $c$ optimal fuzzy partitions of the input observations set, by minimizing the Euclidean norm between observations and cluster centers.

- Number of clusters: $c = 4$
- Features per observation:
  - Volume decorrelation
  - Backscatter
- Fuzzy membership matrix:
  - probability of an observation to belong to a specific cluster ($\epsilon [0,1]$)
Classification of the Greenland Ice Sheet

Cluster 1

Membership Matrix
Classification of the Greenland Ice Sheet

Cluster 1

Cluster 2

Membership Matrix
Classification of the Greenland Ice Sheet

Cluster 1

Cluster 2

Cluster 3

Membership Matrix
Classification of the Greenland Ice Sheet

Cluster 1

Cluster 2

Cluster 3

Cluster 4

Membership Matrix

[Image of membership matrix scale]
Classification of the Greenland Ice Sheet

Cluster 1

Cluster 2

Cluster 3

Cluster 4

Membership Matrix
Classification of the Greenland Ice Sheet
Classification of the Greenland Ice Sheet

Cluster 1

Cluster 2

Cluster 3

Cluster 4

Classification performed by selecting the most likely cluster
Classification of the Greenland Ice Sheet
Classification of the Greenland Ice Sheet

Classification of the Greenland Ice Sheet

Classification of the Greenland Ice Sheet

Classification of the Greenland Ice Sheet

Forest/Non-Forest Map

Objective
Generation of a global forest/non-forest map by exploiting the volume decorrelation intensity over vegetated areas.
Forest/Non-Forest Map

Objective
Generation of a global forest/non-forest map by exploiting the volume decorrelation intensity over vegetated areas.

Amazona Clear cuts
Cape York Peninsula
Objective

Generation of a global forest/non-forest map by exploiting the volume decorrelation intensity over vegetated areas.
Coherence (and therefore volume decorrelation) is influenced by the height of ambiguity. Such dependency has to be properly taken into account when mosaicking images.

- First coverage
  (Height of Amb. ~ 45 m)
- Second coverage
  (Height of Amb. ~ 35 m)
- Additional acquisitions
  (Height of Amb. ~ 60 m)
Forest/Non-Forest Map

✔ Discrimination of volume decorrelation intensity within a single image:
Forest/Non-Forest Map

✓ Discrimination of volume decorrelation intensity within a single image:

✓ Volume Decorrelation

Russia
Forest/Non-Forest Map

- Discrimination of volume decorrelation intensity within a single image:
  - Volume Decorrelation
  - Apply adaptive thresholds
    - High vol. decorrelation
    - Medium vol. decorrelation
    - Low vol. decorrelation

Russia
Forest/Non-Forest Map

✓ Discrimination of volume decorrelation intensity within a single image:

✓ Volume Decorrelation

✓ Desert areas can be easily recognized

✓ Example over the Namibia Desert:

Russia
Forest/Non-Forest Map

✓ Discrimination of volume decorrelation intensity within a single image:

✓ Volume Decorrelation

✓ Desert areas can be easy recognized
  ✓ Example over the Namibia Desert:

Russia
Forest/Non-Forest Map

✓ Discrimination of volume decorrelation intensity within a single image:

✓ Volume Decorrelation

✓ Desert areas can be easily recognized
  ✓ Example over the Namibia Desert:

Russia
Forest/Non-Forest Map

✓ Discrimination of volume decorrelation intensity within a single image:
  ✓ Volume Decorrelation
  ✓ Desert areas can be easily recognized
    ✓ Example over the Namibia Desert:

Volume Decorrelation

Russia
Forest/Non-Forest Map

✓ Discrimination of volume decorrelation intensity within a single image:
  ✓ Volume Decorrelation
  ✓ Desert areas can be easily recognized
    ✓ Example over the Namibian Desert:

High
Medium
Low

Russia
Forest/Non-Forest Map

✓ Discrimination of volume decorrelation intensity within a single image:

✓ Volume Decorrelation
✓ Desert areas can be easily recognized
  ✓ Example over the Namibia Desert:

✓ High
✓ Medium
✓ Low

Geometric distortions

Russia
Forest/Non-Forest Map

Example: Amazon Rainforest – First coverage acquisitions
Forest/Non-Forest Map

Example: Amazon Rainforest – First coverage acquisitions

- Water Bodies filtered out using GLOBCOVER.
Forest/Non-Forest Map

Example: Amazon Rainforest – First coverage acquisitions

- Optical image
- Volume Decorrelation
- Volume Decorrelation Intensity
Forest/Non-Forest Map

Combine multiple coverages to improve quality and perform classification

- Example over Russia
Forest/Non-Forest Map

Combine multiple coverages to improve quality and perform classification

- Example over Russia

Resolution: 100x100 m²

- Dense forest
- Sparse forest
- No forest
- Water

(GLOBCOVER)
Forest/Non-Forest Map

Combine multiple coverages to improve quality and perform classification

- Example over Russia

Clustering Algorithms could also be useful...
...work in progress...

Resolution: 100x100 m²

- Dense forest
- Sparse forest
- No forest
- Water (GLOBCOVER)
Summary

TanDEM-X is not „just“ a DEM

- A unique interferometric data set in X-band which can be used for scientific purposes on a global scale
  - Ice classification
  - Forest/non-forest map
  - Mission performance monitoring and optimization
Summary

TanDEM-X is not „just“ a DEM

✔ A unique interferometric data set in X-band which can be used for scientific purposes on a global scale
  ✔ Ice classification
  ✔ Forest/non-forest map
  ✔ Mission performance monitoring and optimization

✔ Working with Quicklook images is fast and reduces the computing effort
Summary

TanDEM-X is not „just“ a DEM

✓ A unique interferometric data set in X-band which can be used for scientific purposes on a global scale
  ✓ Ice classification
  ✓ Forest/non-forest map
  ✓ Mission performance monitoring and optimization

✓ Working with Quicklook images is fast and reduces the computing effort

✓ Multiple coverages and present/future acquisitions allows to analyze seasonal changes of significant aspects, i.e.:
  ✓ Greenland Ice Sheet melting monitoring
  ✓ Deforestation
Summary

TanDEM-X is not „just“ a DEM

✓ A unique interferometric data set in X-band which can be used for scientific purposes on a global scale
  ✓ Ice classification
  ✓ Forest/non-forest map
  ✓ Mission performance monitoring and optimization

✓ Working with Quicklook images is fast and reduces the computing effort

✓ Multiple coverages and present/future acquisitions allows to analyze seasonal changes of significant aspects, i.e.:
  ✓ Greenland Ice Sheet melting monitoring
  ✓ Deforestation

✓ The development of algorithms and products is still a work in progress.
  ✓ Further updates at IGARSS 2015.
Thank you for your attention.

Italy's Interferometric coherence from TanDEM-X data.