• Project objectives
• Work plan
• Status at the Mid-Term-Review
• Description of the performed work and results
• Publications
• Plan for the second year
Project objectives

➢ Scientific objectives
  • **Systematic monitoring** of forested areas
  • Change detection for **deforestation** mapping
  • **Early warning system** for deforestation activities
Project objectives

- **Scientific objectives**
  - **Systematic monitoring** of forested areas
  - Change detection for **deforestation** mapping
  - **Early warning system** for deforestation activities

- **Challenges**
  - Measurement availability over the year
  - Provide **time-tagged** maps
  - Mapping at **regular intervals**
Project objectives

- **Scientific objectives**
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  - Change detection for **deforestation** mapping
  - **Early warning system** for deforestation activities

- **Challenges**
  - Measurement availability over the year
  - Provide **time-tagged** maps
  - Mapping at **regular intervals**

- **Sentinel-1 mission**
  - Weather independent **Synthetic Aperture Radar** (SAR) acquisitions
  - **Global Coverage**
  - Systematic acquisition with **low revisit time**
Project objectives

- **Target**
  - Sentinel-1 interferometric capabilities
  - Combined use of InSAR coherence and backscatter
  - Propose an algorithm for the processing and the classification

- Spatial baseline
- Temporal baseline
Project objectives

➢ Target
  • Sentinel-1 interferometric capabilities
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- Spatial baseline
- Temporal baseline

InSAR coherence: similarity
Project objectives

➢ Target
  • Sentinel-1 interferometric capabilities
  • Combined use of InSAR coherence and backscatter
  • Propose an algorithm for the processing and the classification

  - Spatial baseline
  - Temporal baseline

InSAR coherence: similarity
Project objectives

- Exploit interferometric time series: **temporal decorrelation**
  - interferometric coherence decomposition

$$\rho = \rho_{\text{SNR}} \rho_{\text{quant}} \rho_{\text{amb}} \rho_{\text{az}} \rho_{\text{rg}} \rho_{\text{vol}} \rho_{\text{temp}}$$

- **Correlation factors**
  - Signal to noise ratio
  - Quantization errors
  - SAR ambiguities
  - Azimuth and range bandwidth shifts
  - Volume scattering
  - Temporal
Project objectives

- Exploit interferometric time series: **temporal decorrelation**
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### Work plan

<table>
<thead>
<tr>
<th>WP</th>
<th>Event</th>
<th>Duration</th>
<th>Start</th>
<th>End</th>
<th>Year</th>
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<td>Sat 05.01.21</td>
<td>12.01</td>
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<td>Thu 10.09.20</td>
<td>Sat 05.01.21</td>
<td>10.09</td>
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</tbody>
</table>
Work plan

Phase I

Input data

- **Sentinel-1a,b**
  - Dual-Pol IW Stack
- **TanDEM-X**
  - Bistatic Stack
- F/NF ground reference

Parameters estimation

- Sentinel-1
- TanDEM-X

X-band modeling

- X-band volume & temporal decorrelation models

Parameters analysis

- Multi-resolution spatial analysis
- Multi-temporal analysis
- Cross-frequency analysis and modeling

Output data base

- Sentinel-1 InSAR Statistics
- Sentinel-1 Backscatter Statistics
- Cross-frequency correlations
- Forest Map generation By k-means classification
Work plan

Phase I
- Input data
  - Sentinel-1a,b Dual-Pol IW Stack
  - TanDEM-X Bistatic Stack
  - F/NF ground reference

Parameters Estimation

Parameters estimation block
- Nonlocal InSAR estimation
- Database of nonlocal weights distributions
- Spatial backscatter statistics and Texture measures
- Temporal backscatter statistics

Geocoding

Cross-frequency analysis and modeling

Forest Map generation by k-means classification

Output database

Sentinel-1 cross-frequency statistics
Sentinel-1 cross-frequency correlations
Sentinel-1 InSAR Statistics
Cross-frequency relations
• Project objectives
• Work plan
• **Status at the Mid-Term-Review**
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Status at the Mid-Term-Review
Status at the Mid-Term-Review

Phase I

Input data

- Sentinel-1a,b
  Dual-Pol IW Stack
- TanDEM-X
  Bistatic Stack
- F/NF ground reference

Parameters Estimation

- Sentinel-1
- TanDEM-X

X-band Modeling

- X-band volume & temporal decorrelation models

Parameters analysis

- Multi-resolution, spatial analysis
- Multi-temporal analysis

Output data base

- Sentinel-1 InSAR Statistics
- Sentinel-1 Backscatter Statistics
- Cross-frequency correlations
- Forest Map generation
  By k-means classification

Fully completed
Partially completed
Status at the Mid-Term-Review

- **CORINE**
- **FROM-GTC**
  - F/NF ground reference

### Phase I

**Input data**
- **Sentinel-1a,b**
  - Dual-Pol IW Stack
- **TanDEM-X**
  - Bistatic Stack

**Parameters Estimation**
- Sentinel-1
- TanDEM-X

**X-band Modeling**
- X-band volume & temporal decorrelation models

**Parameters analysis**
- Multi-resolution spatial analysis
- Multi-temporal analysis

**Output data base**
- Sentinel-1 InSAR Statistics
- Sentinel-1 Backscatter Statistics
- Cross-frequency correlations
- Forest Map generation By k-means classification

- **Fully completed**
- **Partially completed**
- **Random Forest classifier**
Status at the Mid-Term-Review

Parameters estimation block

- Nonlocal InSAR estimation
- Database of nonlocal weights distributions
- Spatial backscatter statistics and Texture measures
- Temporal backscatter statistics
- Geocoding
Parameters estimation block

- Nonlocal InSAR estimation
- Database of nonlocal weights distributions
- Spatial backscatter statistics and Texture measures
- Temporal backscatter statistics

Geocoding
Status at the Mid-Term-Review

- **Nonlocal InSAR estimation**
  - Computational cost
  - Coverage versus full resolution mapping trade-off
  - Faster deep learning solutions

- **X-band modeling**
  - Higher temporal decorrelation w.r.t. C-band
  - Need of shorter revisit-time
  - Joint analysis with PAZ data
Status at the Mid-Term-Review

- **Nonlocal InSAR estimation**
  - Computational cost
  - Coverage versus full resolution mapping trade-off
    - Faster deep learning solutions

- **X-band modeling**
  - Higher temporal decorrelation w.r.t. C-band
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  - Joint analysis with PAZ data
• Project objectives
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• **Description of the performed work and results**
• Publications
• Plan for the second year
Main achieved milestones

- Development and implementation of the **framework for land cover classification** by exploiting Sentinel-1 interferometric wide-swath time-series
- Investigation of **backscatter, multi-temporal coherence** and **texture-derived features**
- Application of the classification methodology to two data sets over **Europe** and **Brazil**.
- Publication of the results in the **Remote Sensing of Environment** peer-reviewed journal
Results

- Analysis over Europe: Germany
- Histograms of the computed features
- Random Forest classification
- CORINE land cover map used as reference
- Feature importance defined by means of ablation studies
Results

(a)

(b)

(c)
## Classification accuracy

<table>
<thead>
<tr>
<th>Input parameters</th>
<th>patch (a)</th>
<th>patch (b)</th>
<th>patch (c)</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{\gamma}^0 \theta_{inc}$</td>
<td>76.02%</td>
<td>79.93%</td>
<td>76.86%</td>
<td>88.73</td>
</tr>
<tr>
<td>$\hat{\tau} \rho_{LT} \theta_{inc}$</td>
<td>79.30%</td>
<td>77.98%</td>
<td>71.43%</td>
<td>78.77%</td>
</tr>
<tr>
<td>$\hat{\gamma}^0 \hat{\tau} \rho_{LT} \theta_{inc}$</td>
<td>83.28%</td>
<td>86.84%</td>
<td>82.90%</td>
<td>91.85%</td>
</tr>
</tbody>
</table>
Results

- Analysis over the Rondonia state
- Random Forest classification
- Finer Resolution Observation and Monitoring of Global Land Cover (FROM-GLC, 2017) used as reference
- Use of backscatter, interferometric parameters and textures
## Classification accuracy

<table>
<thead>
<tr>
<th>No-texture</th>
<th>patch 1</th>
<th>patch 2</th>
<th>patch 3</th>
<th>patch 4</th>
<th>patch 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.12%</td>
<td>80.34%</td>
<td>95.40%</td>
<td>92.36%</td>
<td>91.42%</td>
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</tr>
<tr>
<td>texture</td>
<td>72.88%</td>
<td>81.46%</td>
<td>96.10%</td>
<td>95.66%</td>
<td>93.54%</td>
</tr>
</tbody>
</table>
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The project has produced the following publications:


• Project objectives
• Work plan
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• Plan for the second year
Plan for the second year

- Follow on from Phase I:
  - Resolution improvement and class definition
  - Deep learning solution for the estimation of the coherence
  - X-band modeling

- Phase II:
  - Investigate deep learning solutions for high-resolution forest mapping and deforestation
  - Investigate the use of synthetic data for the training of the network
  - Validate the results by means of Sentinel-2 and -3 data
Plan for the second year

Phase II

Input Data

- **Sentinel-1a,b**
  - Dual-Pol IW Stack
- Database of correlations
- F/NF ground reference

Deep Learning classification

- Parameters Estimation
- Change detection

Validation

Data Fusion

Output data

- Forest coverage
- Forest change map
- Validation map
- Forest coverage from fused data

DLR 

EOSA
Thank you for your attention!

francescopaolo.sica@dlr.de
Thank you for your attention!

francescopaolo.sica@dlr.de
Method

• Combine backscatter and coherence
• Interferometric Wide-Swath data
• M acquisition for each scene

For the single target (resolution cell)
• SLC processing

\[ \hat{\gamma}_m^0 = K \hat{A}_m \tan(\theta_{inc}) \]

\[ \hat{\gamma}^0 \]

average over \( m \)

\( K \) calibration factor
\( A \) amplitude
\( \theta_{inc} \) incidence angle
Method

- Combine backscatter and coherence
- Interferometric Wide-Swath data
- M acquisition for each scene

For the single target (resolution cell)
- InSAR processing

\[ \Delta = nT \]
- \( T \) – revisit time
- \( n \in [1,N] \)
- \( N \) – number of samples
Method

- Exponential model fitting

\[ \rho_{\text{temp}}(t) = (1 - \rho_{LT}) e^{-\left(\frac{t}{\tau}\right)^2} + \rho_{LT} \]

- Decorrelation constant
- Long term coherence

Least square fitting

\[
(\hat{\tau}, \hat{\rho}_{LT}) = \arg \min_{\tau, \rho_{LT}} \left\{ \sum_{n=1}^{N} \sum_{i=1}^{N-n} \sum_{j \in \Omega(p)} \left( (1 - \rho_{LT}) e^{-\left(\frac{nt}{\tau}\right)^2} + \rho_{LT} - \hat{\rho}_{\text{temp}}[n, i, j] \right)^2 \right\}
\]
Results

Optical (Google)  Reference  no texture  with texture

ART  FOR  NFR
Results

Optical (Google)  Reference  no texture  with texture

ART  FOR  NFR
Results

Optical (Google)  Reference  no texture  with texture

ART  FOR  NFR
Results

Optical (Google)  Reference  no texture  with texture
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