HI-FIVE: High-Resolution Forest Coverage with InSAR & Deforestation Surveillance

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LIVING PLANET FELLOWSHIP

BIOSPHERE

Outline

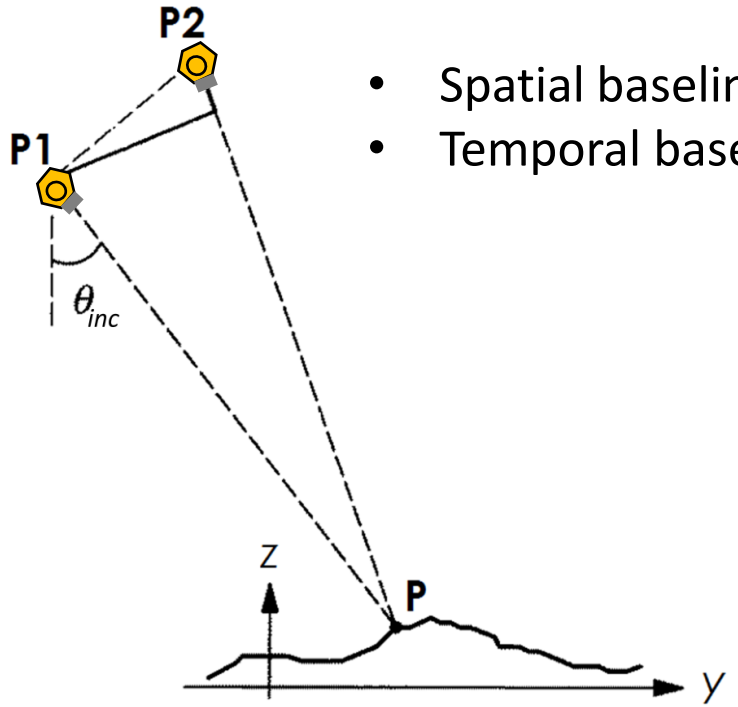
- Project objectives
- Work plan and current status
- Results
- Publications
- Plan for the next 6 months

Project objectives

- Scientific objectives
  - **Systematic monitoring** of forested areas
  - Change detection for **deforestation** mapping
  - **Early warning system** for deforestation activities
- Challenges
  - Provide **time-tagged** maps
  - Mapping at **regular intervals**
  - Product availability **over the year**
- Sentinel-1 SAR constellation
  - Weather independent **Synthetic Aperture Radar** (SAR) acquisitions
  - **Global Coverage**
  - Systematic acquisition with **short 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

Exploit interferometric time series: **temporal decorrelation**

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

Correlation factors

- Signal to noise ratio
- Quantization errors
- SAR ambiguities
- Azimuth and range bandwidth shifts
- Volume scattering
- Temporal

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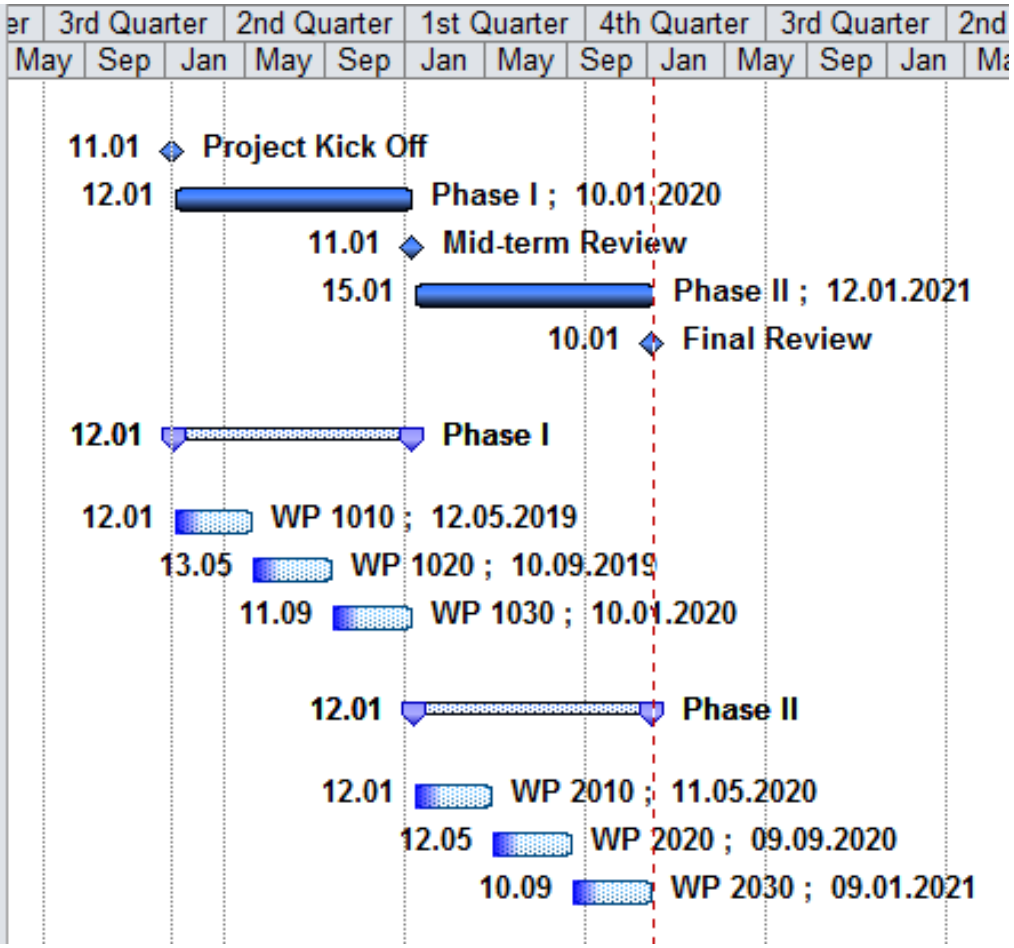
Work plan and current status

	WP	Event	Duration	Start	End	Res
1						
2		Project Kick Off	1 dy	Fri 11.01.19	Fri 11.01.19	
3		Phase I	364 dys	Sat 12.01.19	Fri 10.01.20	
4		Mid-term Review	4 dys	Sat 11.01.20	Tue 14.01.20	
5		Phase II	364 dys	Wed 15.01.20	Tue 12.01.21	
6		Final Review	1 dy	Sun 10.01.21	Sun 10.01.21	
7						
8	**1000**	**Phase I: Data Analysis, Modeling, and Classification**	**364 dys**	**Sat 12.01.19**	**Fri 10.01.20**	
9	1010	WP 1010	121 dys	Sat 12.01.19	Sun 12.05.19	
10	1020	WP 1020	121 dys	Mon 13.05.19	Tue 10.09.19	
11	1030	WP 1030	122 dys	Wed 11.09.19	Fri 10.01.20	
12						
13	**2000**	**Phase II: Enhanced Classification, Change detection, and Validation**	**364 dys**	**Sun 12.01.20**	**Sat 09.01.21**	
14	2010	WP 2010	121 dys	Sun 12.01.20	Mon 11.05.20	
15	2020	WP 2020	121 dys	Tue 12.05.20	Wed 09.09.20	
16	2030	WP 2030	122 dys	Thu 10.09.20	Sat 09.01.21	



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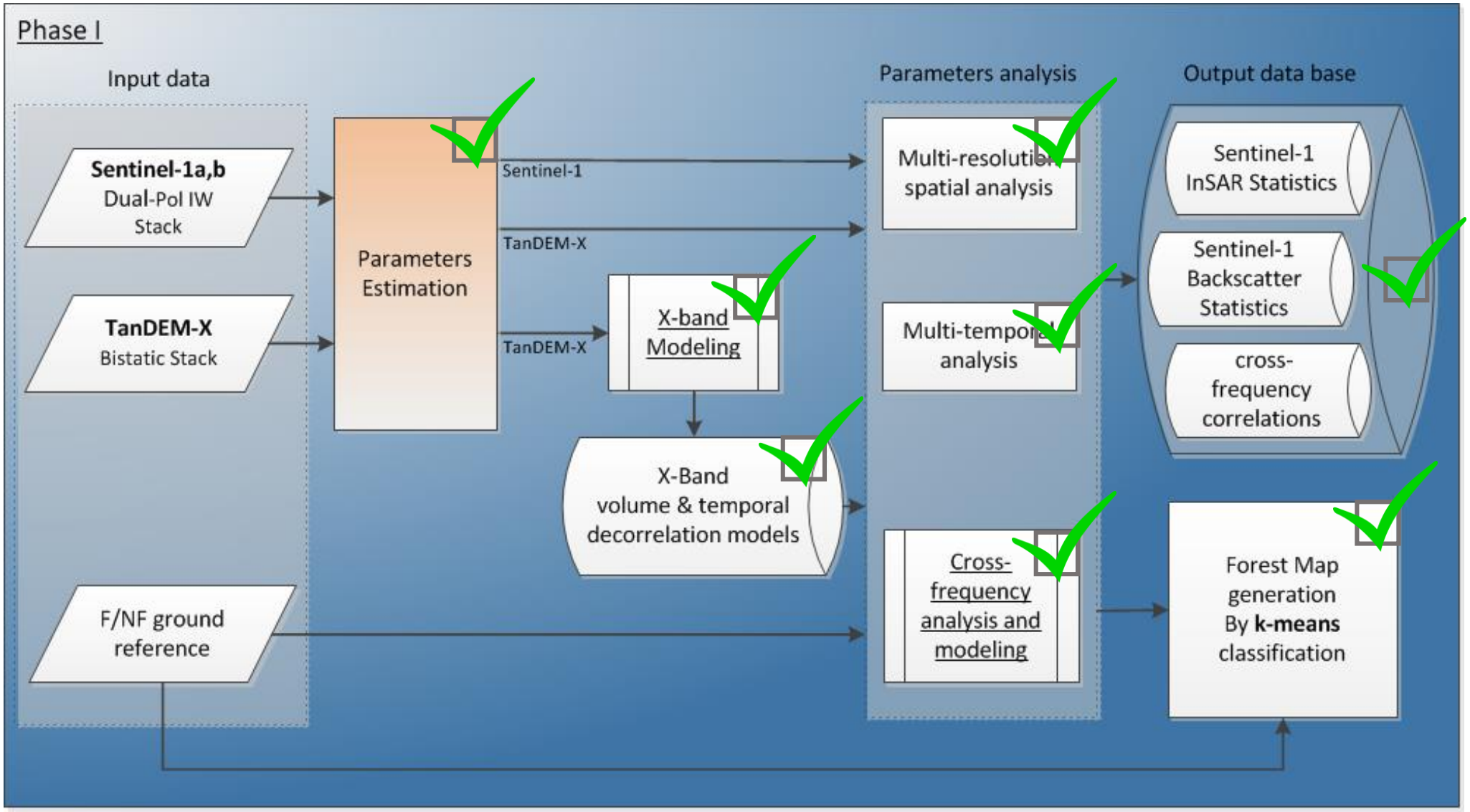
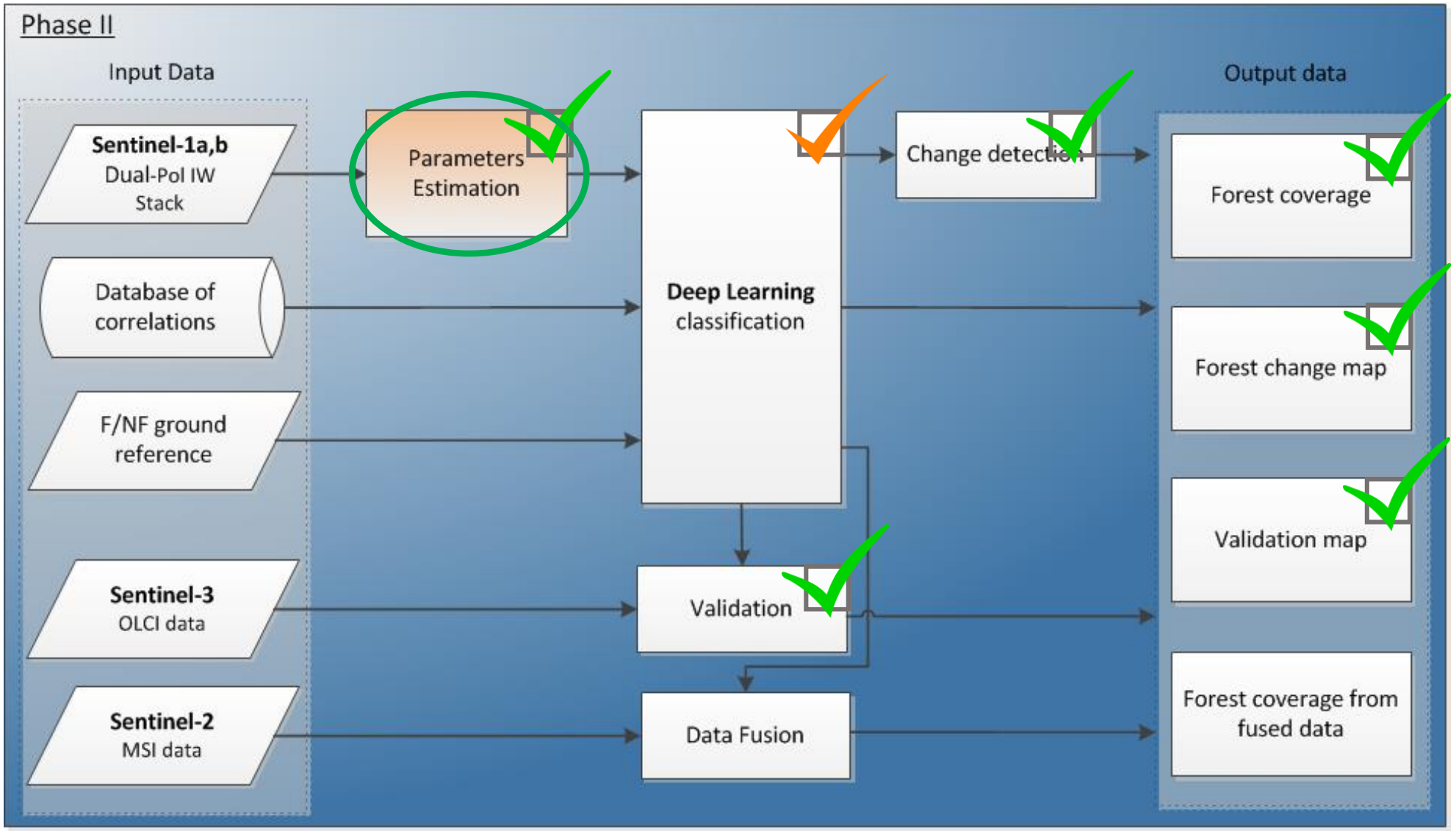


Fully completed

Partially completed

- Random Forest classifier

Work plan and current status



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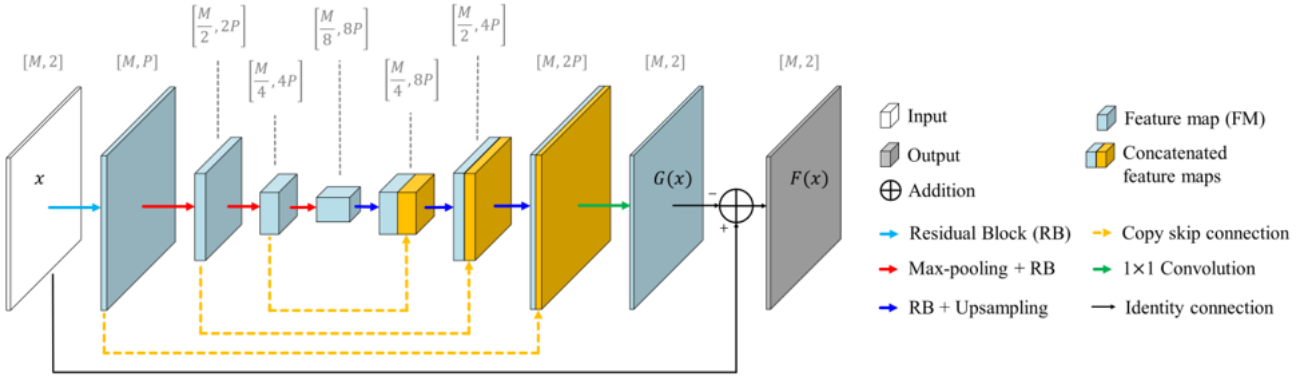
Work plan and current status

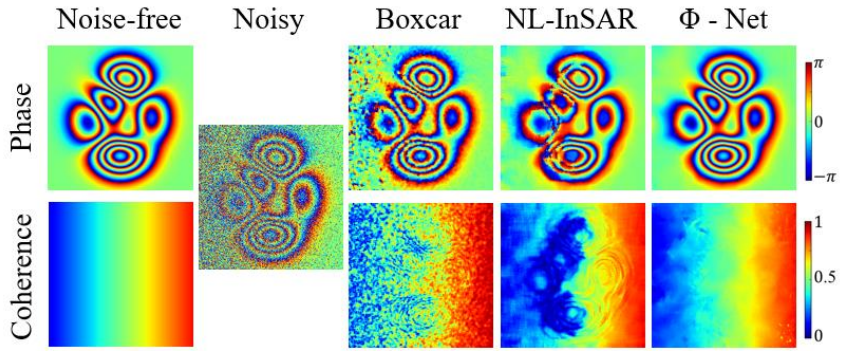
Φ-Net: improved coherence estimation

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING

Φ-Net: Deep Residual Learning for InSAR Parameters Estimation

Francescopaolo Sica, *Member, IEEE*, Giorgia Gobbi, Paola Rizzoli, and Lorenzo Bruzzone, *Fellow, IEEE*





COMPUTATIONAL PERFORMANCE: HARDWARE (HW)/SOFTWARE (SW) SPECIFICATIONS AND COMPUTING TIMES FOR PROCESSING A SINGLE PATCH OF 256 × 256 PIXELS WITH ALL ANALYZED ALGORITHMS

Computational performance and HW/SW specification			
Algorithm	HW	SW	Time [s]
boxcar	4x Intel(R) Xeon(R) CPU E5-4650Q @ 2.70GHz, 512 GB RAM	Python	0.06
SpInPhase	1x Intel(R) Core(TM) CPU i7-7700HQ @ 2.80GHz, 16 GB RAM	C	155.10
NL-InSAR	1x Intel(R) Core(TM) CPU i7-7700HQ @ 2.80GHz, 16 GB RAM	C	84.22
OC-InSAR-BM3D	1x Intel(R) Core(TM) CPU i7-7700HQ @ 2.80GHz, 16 GB RAM	C	11.10
Φ-Net	1x Tesla V100 GPUs 32GB RAM 2x Intel(R) Xeon(R) CPU E5-2698 v4 @ 2.20GHz , 512 GB RAM	Python	0.32

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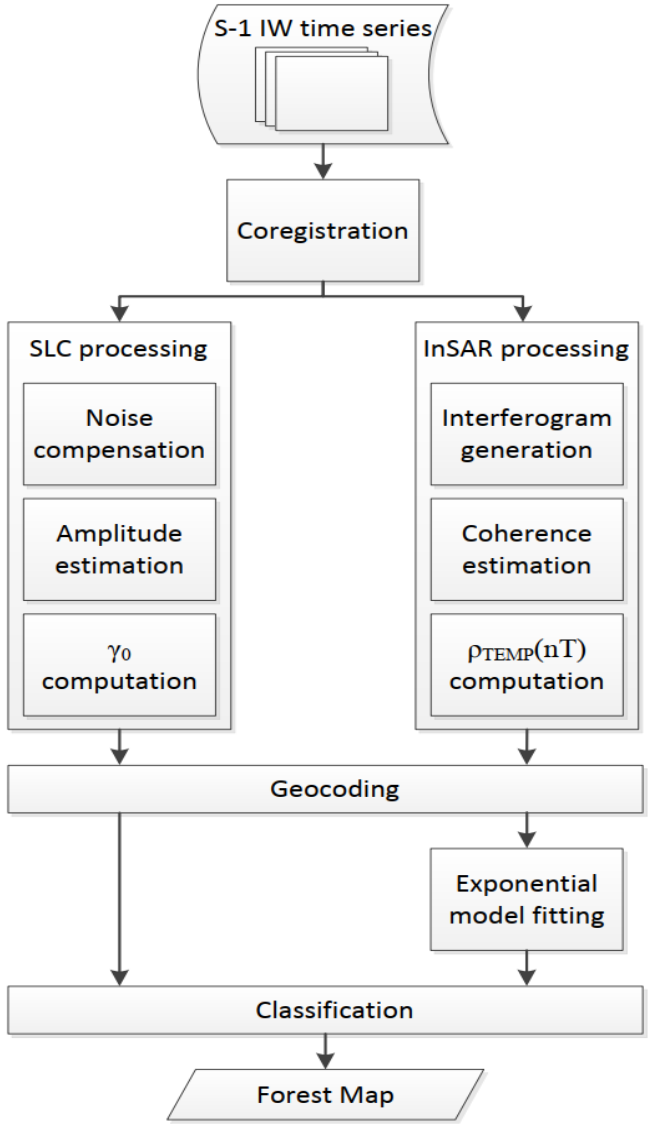
Sentinel-1 interferometric processing

- framework for **land cover classification** from **Sentinel-1 interferometric wide-swath** time-series
- **multi-temporal backscatter**, **coherence** and **texture-derived features**
- Observation interval: **1 month**
- Revisit time: **6 days**
- Application to **forest** and **deforestation** mapping over **Brazil**.



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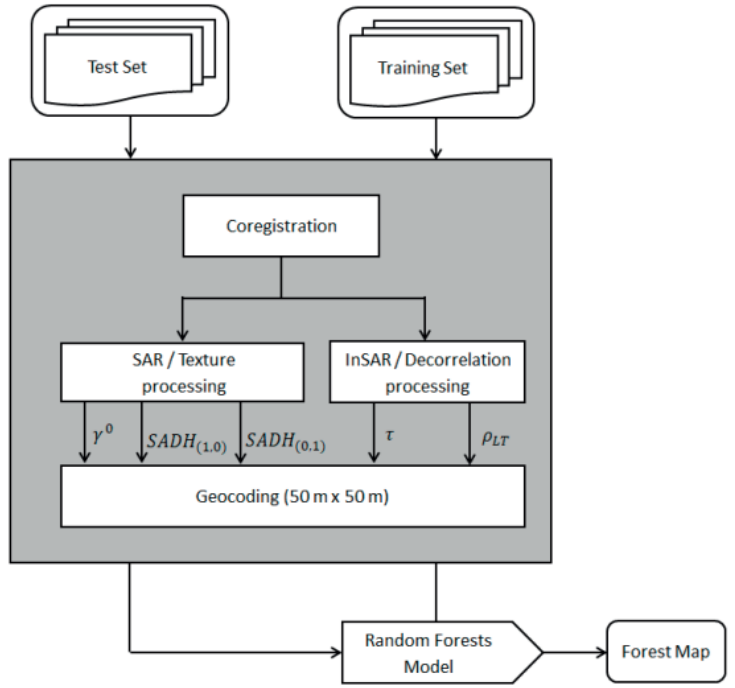
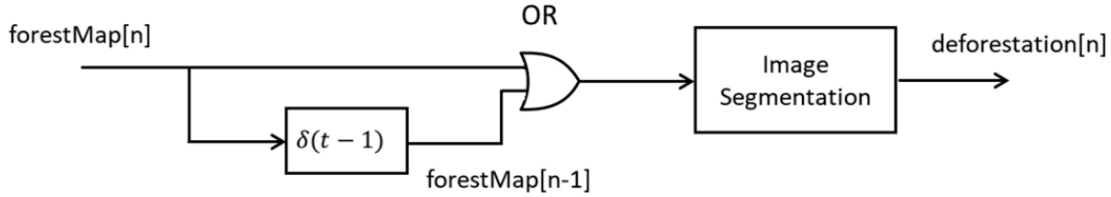
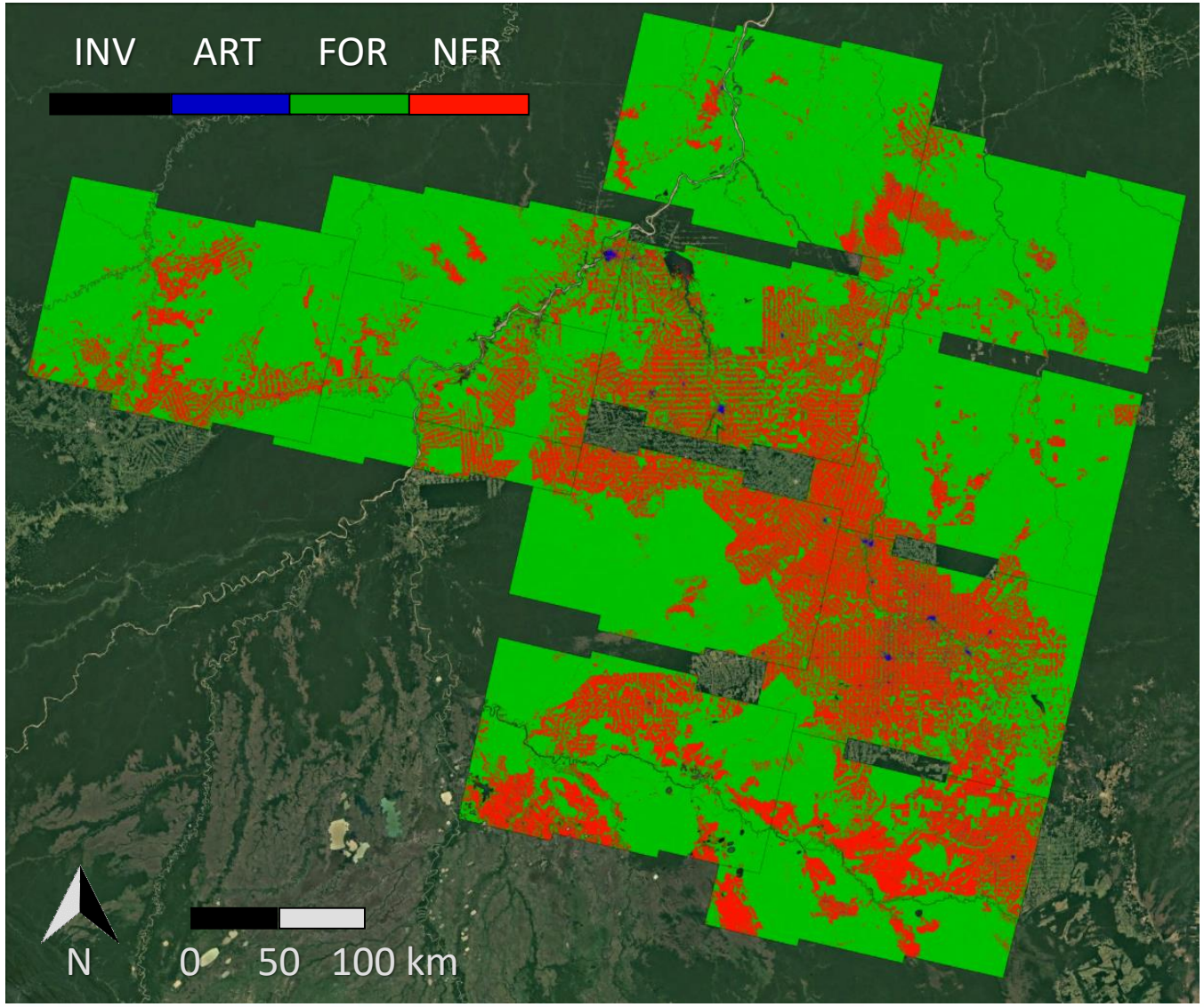




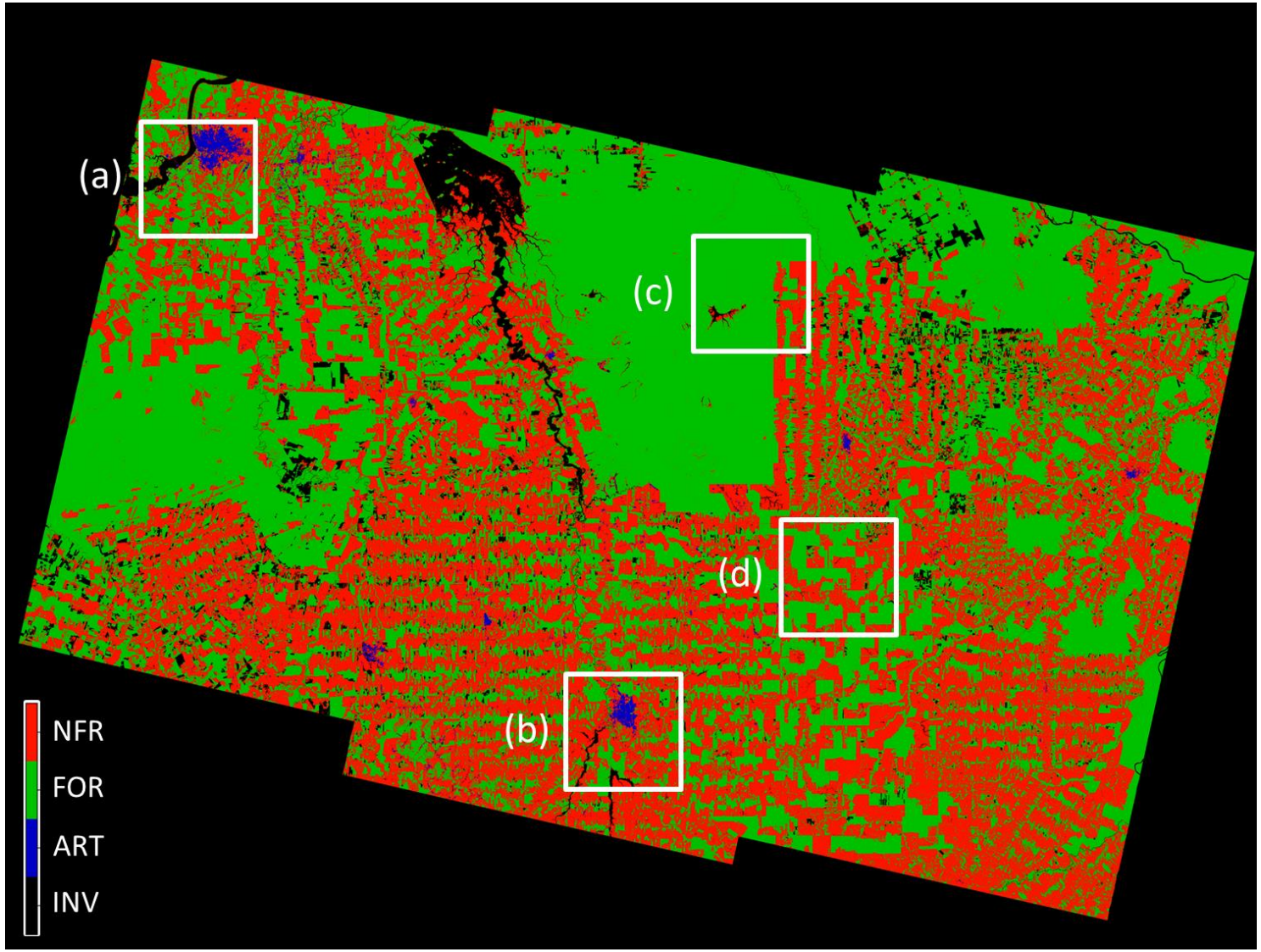
Monthly forest mapping

- Test site: **Rondonia State** (Brazil)
- Observation interval: **1 month**
- Revisit time: **6 days**
- Resolution: **50x50 m²**
- Classes:
  - ART: artificial surfaces
  - FOR: forested areas
  - NFR: non-forested areas
  - INV: invalid pixels



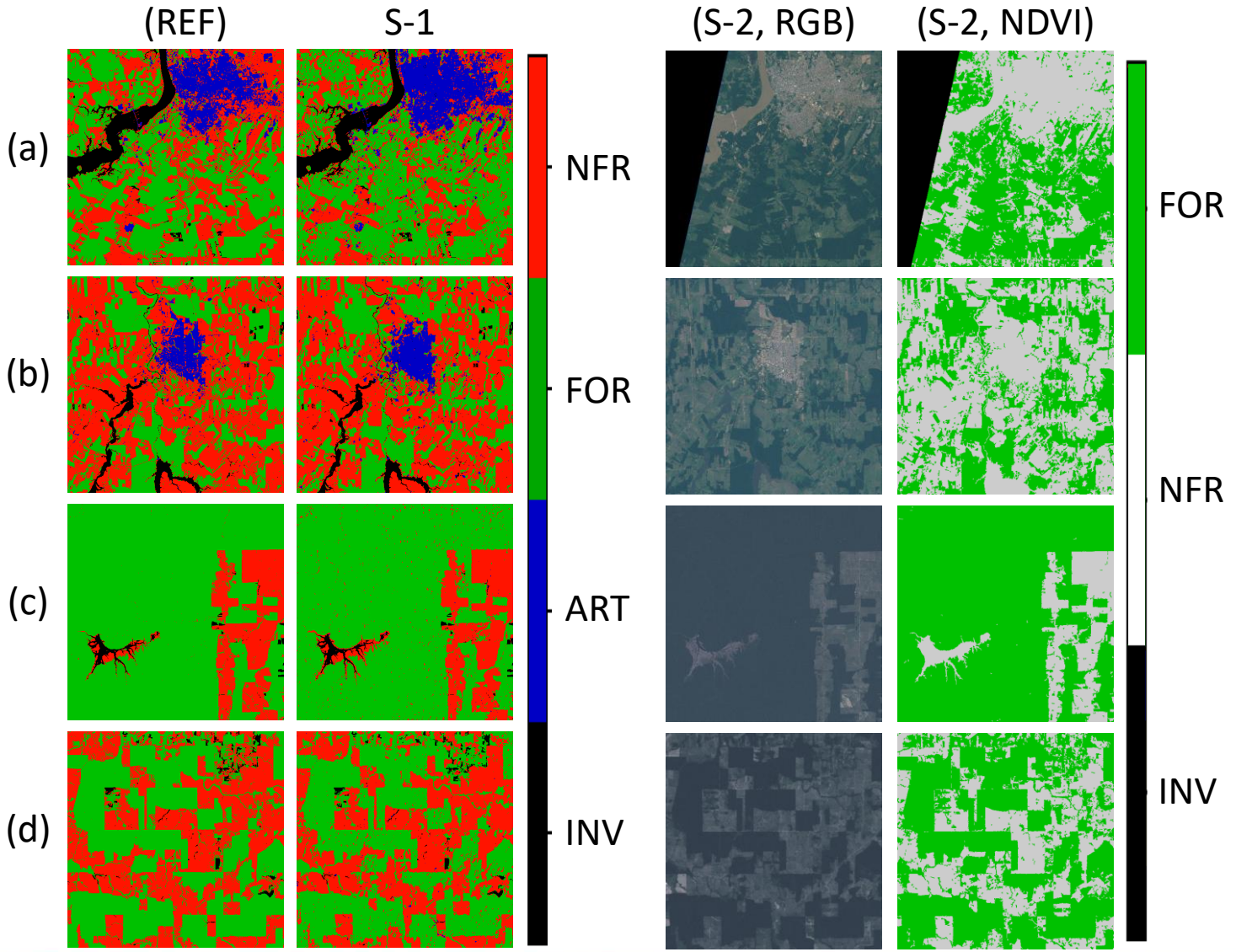
Monthly forest mapping

- Machine learning algorithm: **Random Forest classification**
- Reference: Finer Resolution Observation and Monitoring of Global Land Cover (**FROM-GLC, 2017**)



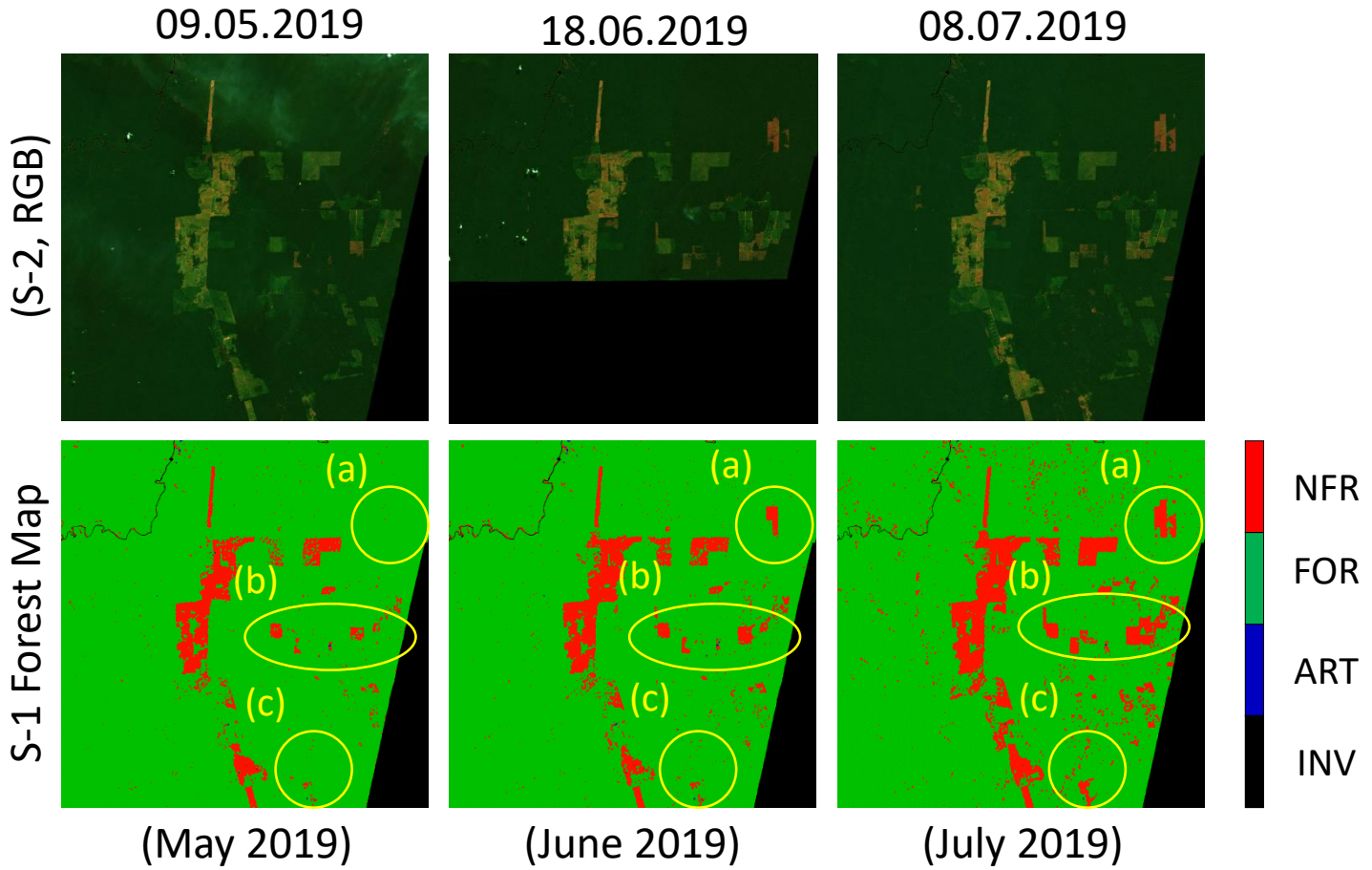
Monthly forest mapping

- S-1 forest maps can be generated monthly
- Identification of deforestation phenomena on a monthly scale
- S-2 is used as reference: only cloud-free acquisitions are considered
- Achieved accuracies levels are over **90%**



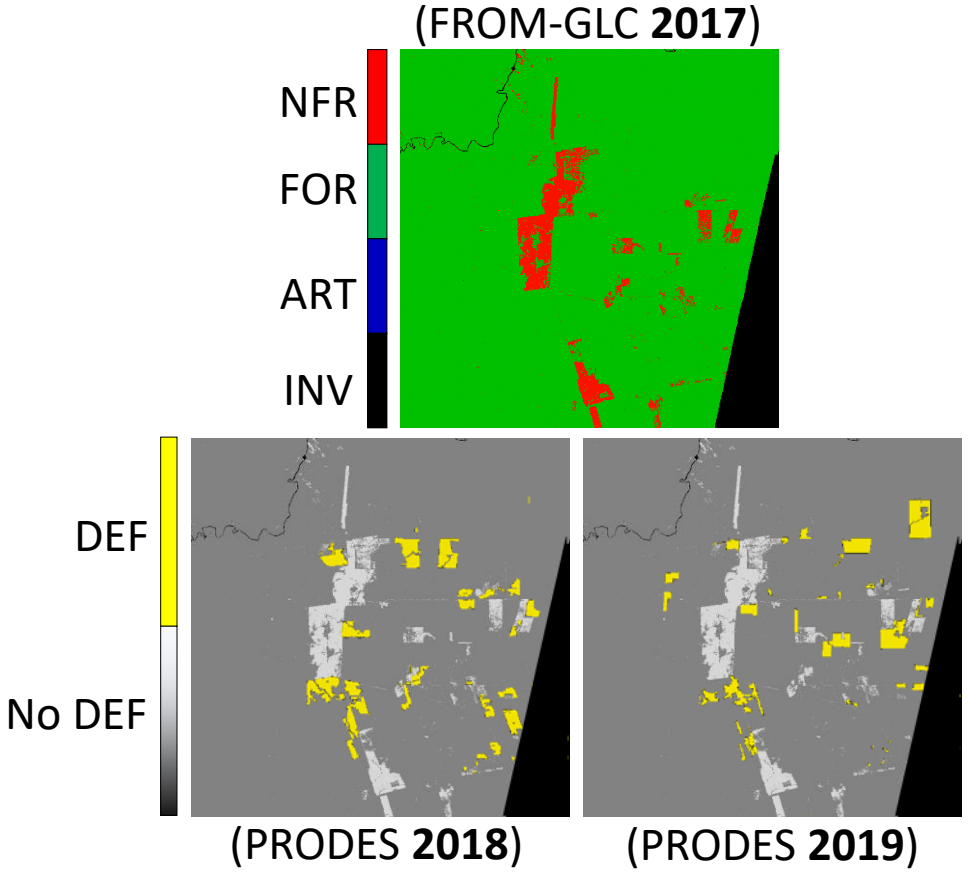
Monthly deforestation mapping

- Test site: **Boca do Acre** (Brazil)
- Observation interval: **May to July 2019**.
- Reference: **Sentinel-2** and **PRODES**
- 3 main on-going deforestation activities have been identified
- We used “Polygons” to indicate deforestation activity **clusters** (DEF).

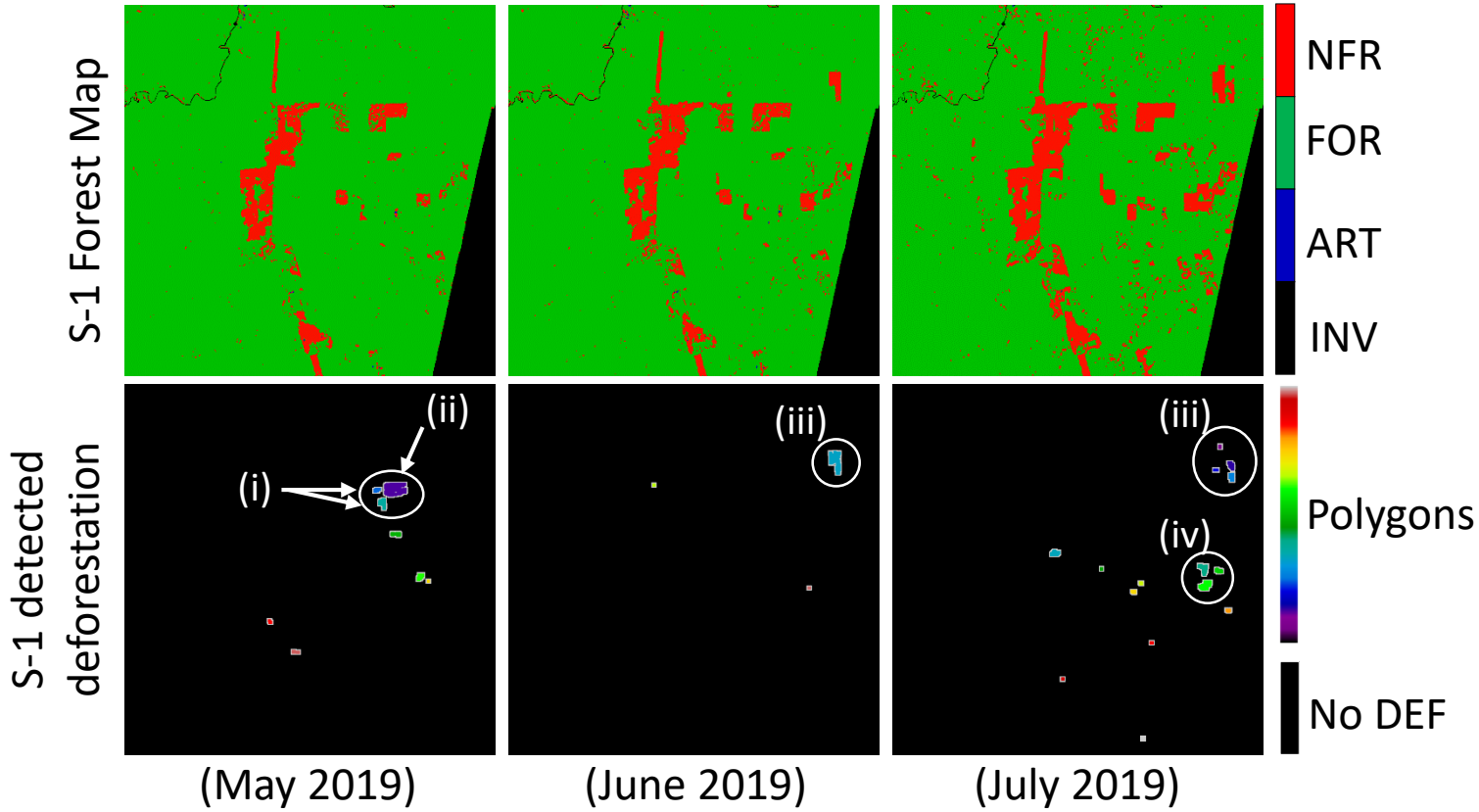


Monthly deforestation mapping

References



Forest and deforestation maps



Φ-Net: improved coherence estimation

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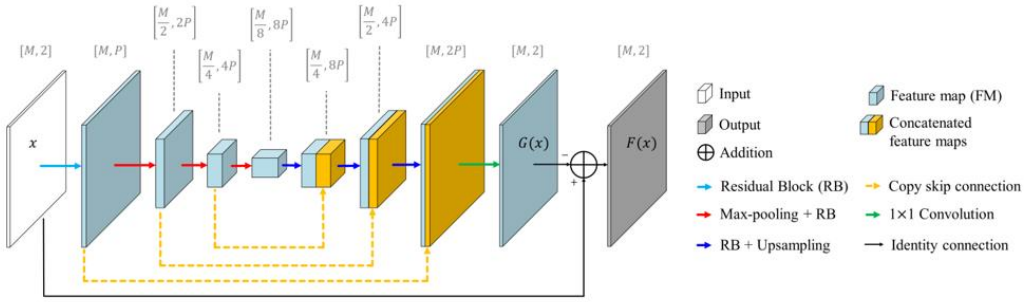
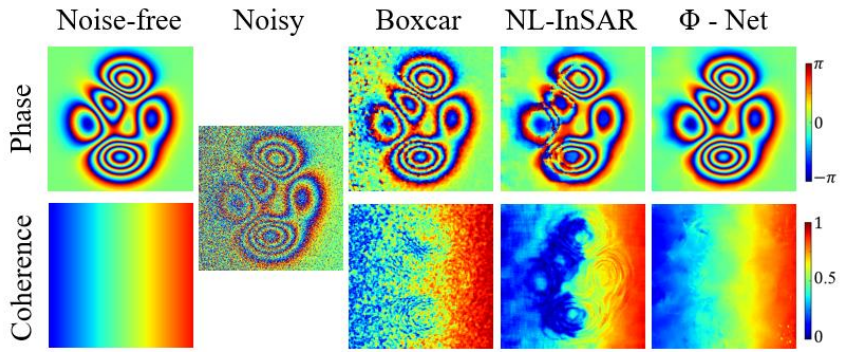
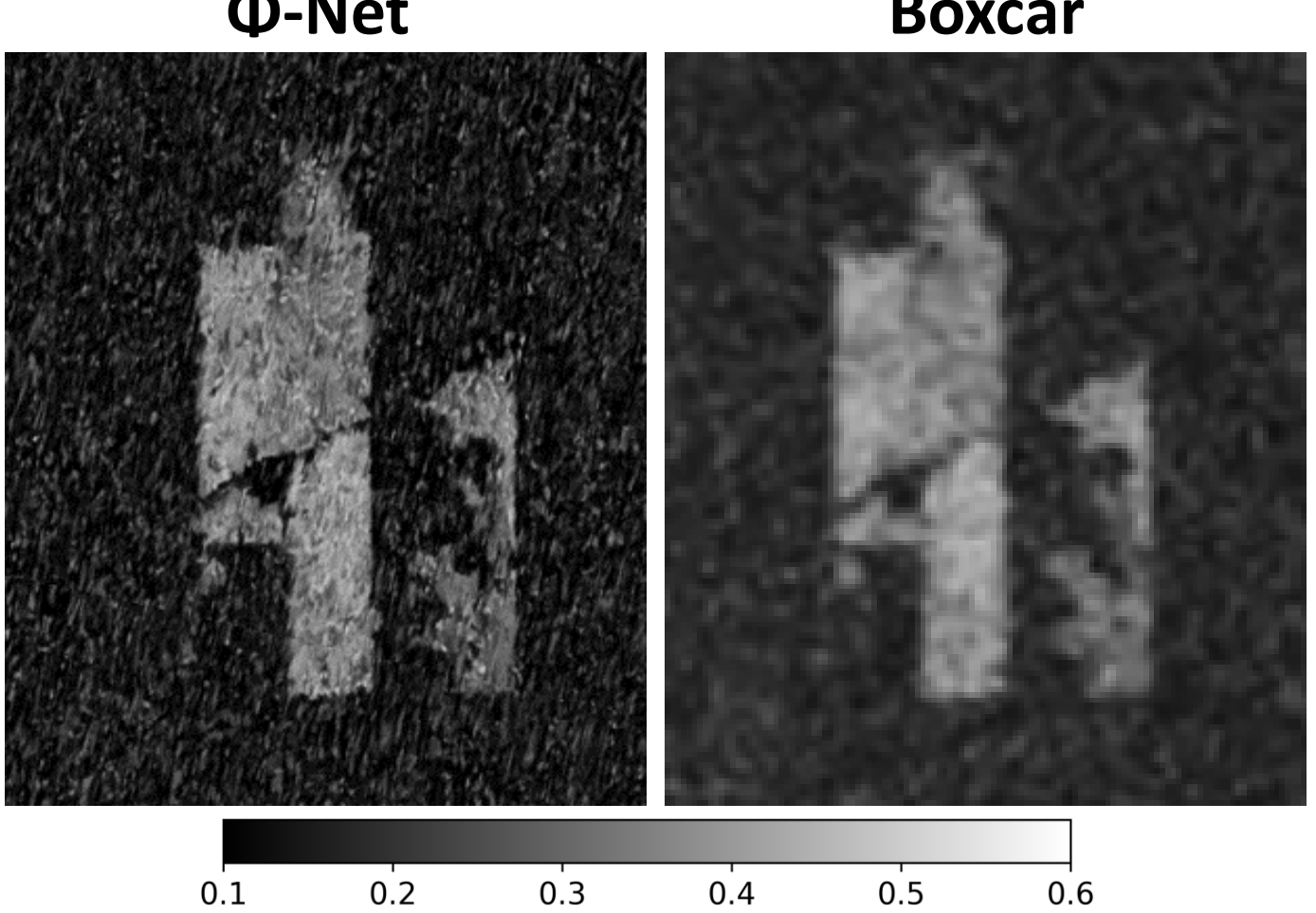




Coherence maps at 10x10 m² resolution



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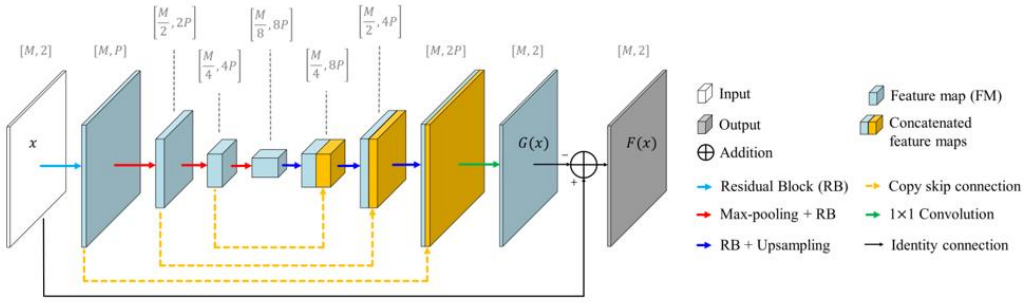

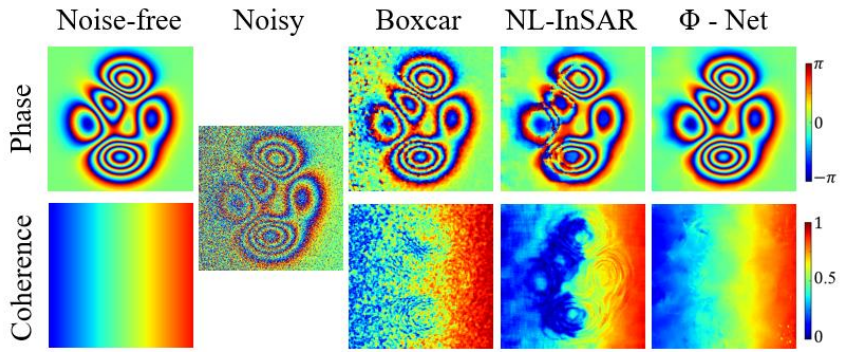

Code available here

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Publications

- Journal publications:
  - Sica, F., Pulella, A., Nannini, M., Pinheiro, M., Rizzoli, P. (2019). Repeat-pass SAR interferometry for land cover classification: A methodology using Sentinel-1 Short-Time-Series. Remote Sensing of Environment, 232, 111277.
  - Sica, F. et al., "InSAR Decorrelation at X-Band From the Joint TanDEM-X/PAZ Constellation," in IEEE Geoscience and Remote Sensing Letters, doi: 10.1109/LGRS.2020.3014809.
  - Pulella, A.; Aragão Santos, R.; Sica, F.; Posovszky, P.; Rizzoli, P. Multi-Temporal Sentinel-1 Backscatter and Coherence for Rainforest Mapping. Remote Sens. 2020, 12, 847.
  - Pulella, A.; Sica, F.; Rizzoli, P. Monthly Deforestation Monitoring with Sentinel-1 Multi-temporal Signatures and InSAR Coherences. Revista de Teledetección, [S.l.], n. 56, p. 1-22, nov. 2020. ISSN 1988-8740.

Publications

- Selected conference publications:
  - Sica, F., Pulella, A., Rizzoli, P. (2019, July). Forest Classification and Deforestation Mapping by Means of Sentinel-1 InSAR Stacks. In *IGARSS 2019 IEEE International Geoscience and Remote Sensing Symposium* (pp. 2635-2638). IEEE.
  - Bueso Bello, J. L., Rizzoli, P., Sica, F. (2019). Estimating the Deforestation Rate in the Amazon Rainforest from Sentinel-1 and TanDEM-X Multi-Temporal Stacks. In *International Geoscience and Remote Sensing Symposium* (IGARSS).
  - Rizzoli, P., Bello, J. L. B., Pulella, A., Sica, F., Zink, M. (2018, July). A Novel Approach to Monitor Deforestation in the Amazon Rainforest by Means of Sentinel-1 and Tandem-X Data. In *IGARSS 2018 IEEE International Geoscience and Remote Sensing Symposium* (pp. 192-195). IEEE.
- Other publications:
  - Sica F., Gobbi G., Rizzoli P. and Bruzzone L., "Φ-Net: Deep Residual Learning for InSAR Parameters Estimation," in *IEEE Transactions on Geoscience and Remote Sensing*, doi: 10.1109/TGRS.2020.3020427.

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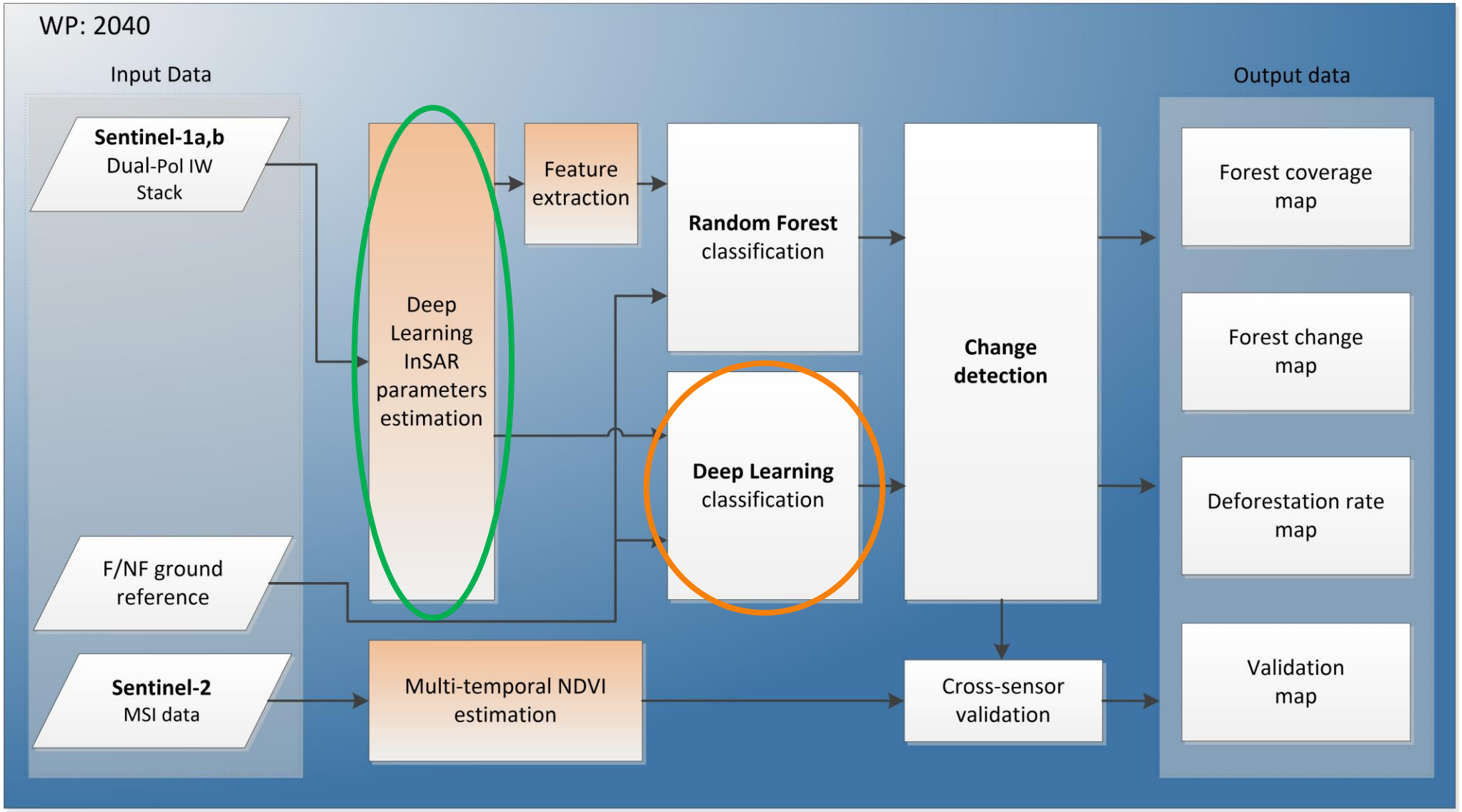
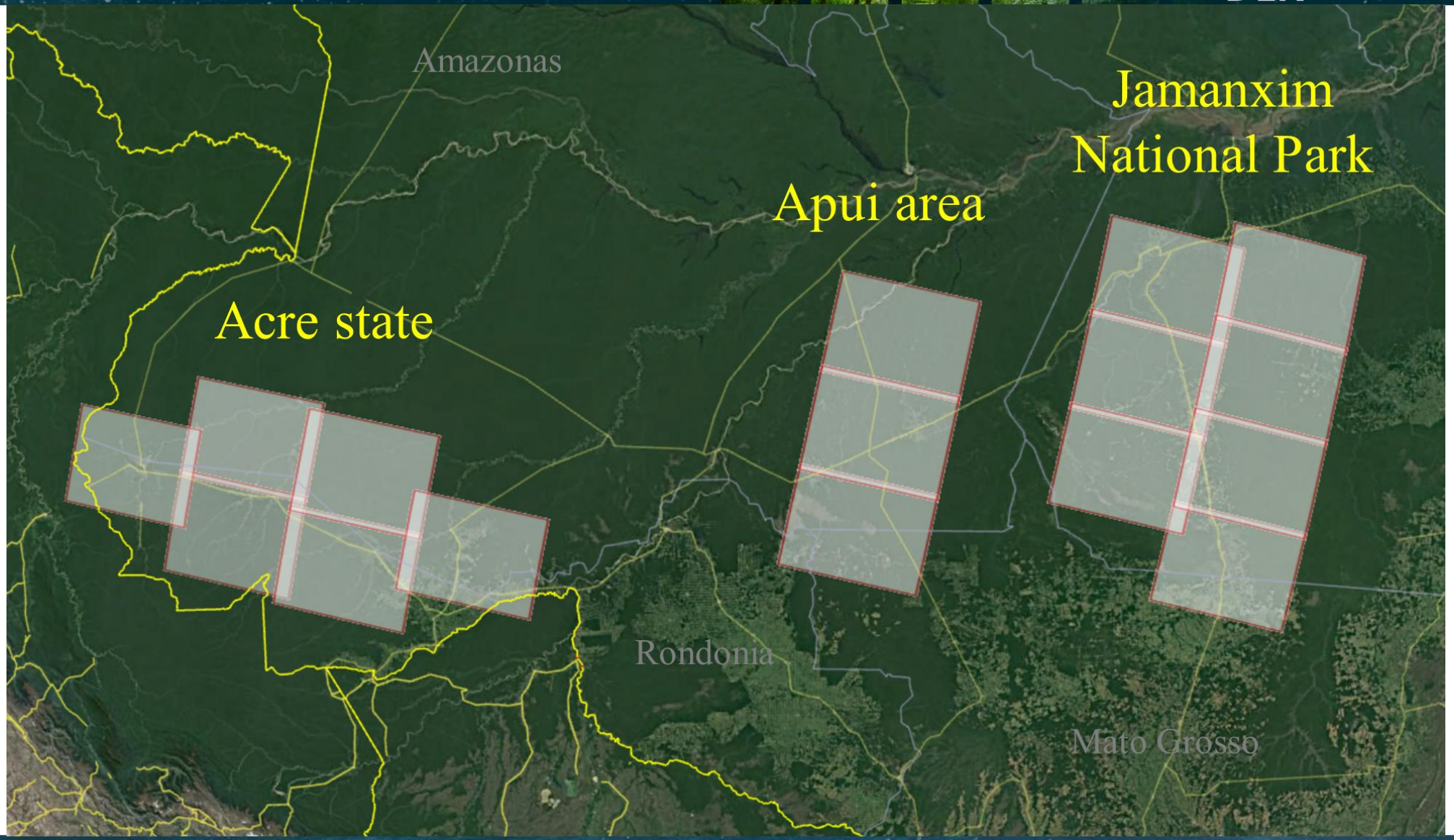


Hot spot areas



Conclusions

- Sentinel-1 interferometric time series allow for the accurate **mapping of forested areas** and for the identification of **deforestation activity**.
- Importance of the **coherence parameter** and the **6 days** revisit time.
- The proposed framework is based on a **monthly observation scenario** allowing to promptly follow deforestation activities.
- Future development foresee the use of **Deep Learning** algorithms in order to improve **spatial and temporal resolution** of deforestation products.
- Enable **Near-Real-Time** deforestation activity mapping.

Thank you for your attention!

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