Joint PAZ and TanDEM-X Mission Interferometric Performance

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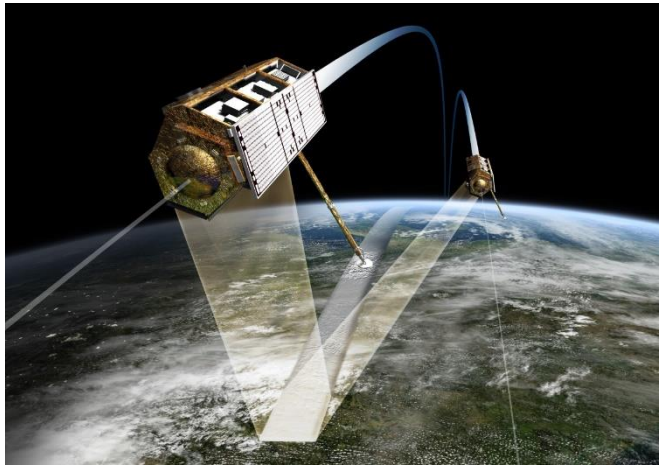
[3]Institute of Environmental Engineering, ETH Zurich

Introduction & Motivation

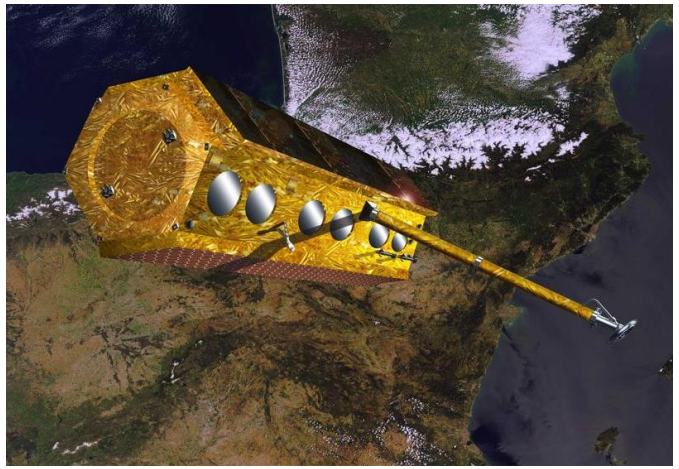
- TerraSAR-X and TanDEM-X satellites were launched in 2007 and 2010
  - Both satellites flying in close formation with a repeat cycle of 11 days



- PAZ satellite was launched in 2018 in the same orbit plane, with a 98.18° offset
  - Same repeat cycle of 11 days
  - If it could be combined with TSX/TDX, repeat cycles of 4 and 7 days could be possible

Objectives:

- The objective is to analyze the PAZ & TSX/TDX joint exploitation for interferometry
- Give some guidance on coherence levels expected depending on the land cover type



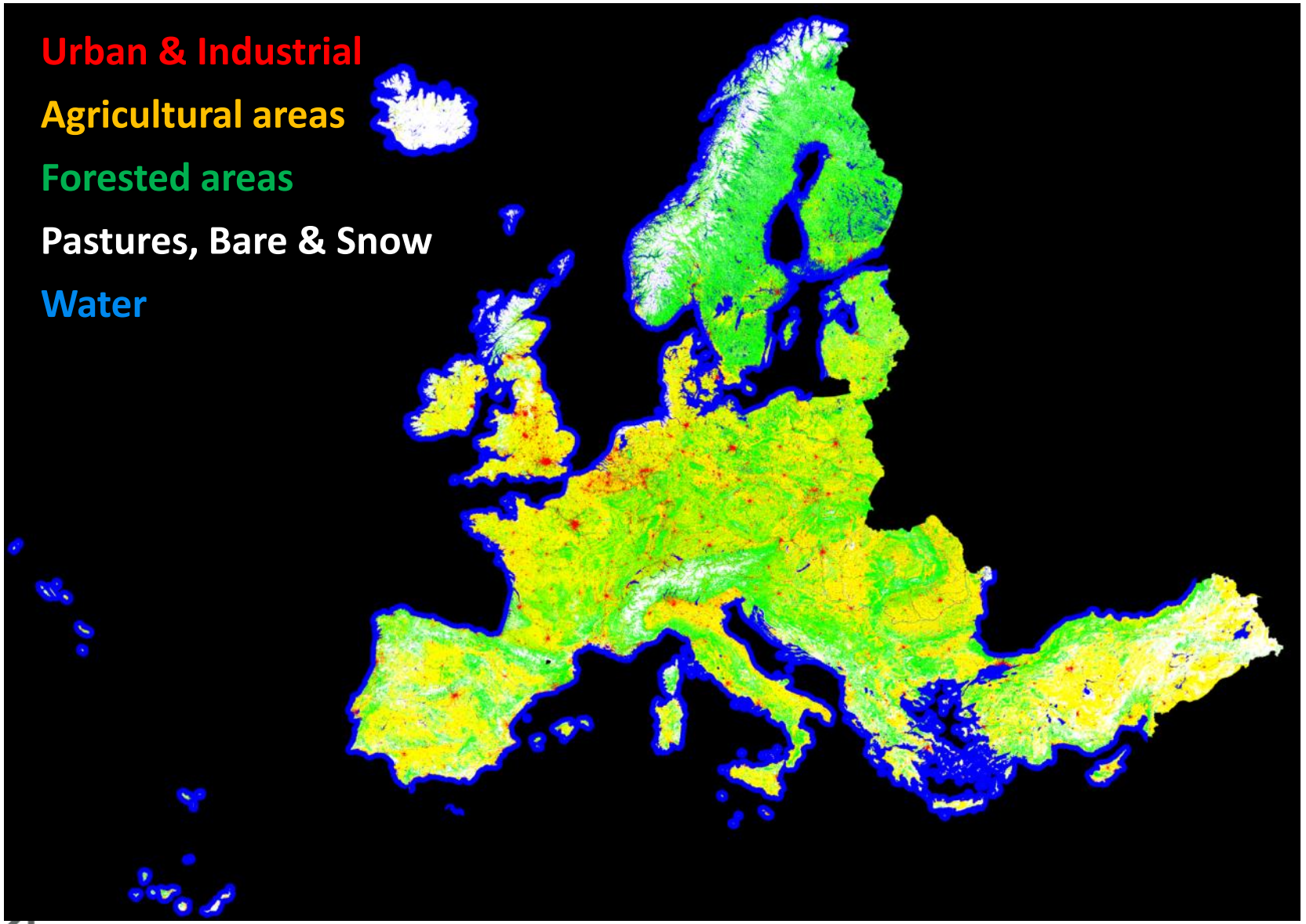
Datasets – Neustrelitz strip 11

- Datasets acquired over DLR and INTA calibration fields with TSX/TDX and PAZ acquisitions at different polarizations

Neustrelitz,
northern Germany.
Main DLR
calibration test site

Madrid, Spain
Albacete, Spain
INTA calibration test
sites

CORINE Land Cover Map - 2018



100m Resolution,

Several land cover classes (44)

⇩

Land cover classes grouped into 5 main classes

Datasets – Neustrelitz strip 11

- Acquisitions performed over the Neustrelitz area by TSX/TDX and PAZ satellites

Satellite	Acq. Time	Pol.	Perp. Baseline [m]
PAZ	2019.12.07	VV	-163
TSX	**2019.12.14**	**VV**	**-**
PAZ	2019.12.18	VV	-6
PAZ	2020.01.20	VV	-141
TSX	2019.11.22	HH	-67
PAZ	2019.11.26	HH	33
TSX	2019.12.25	HH	60
PAZ	2019.12.29	HH	130
PAZ	2020.01.09	HH	25
TSX	**2020.01.27**	**HH**	**-**
PAZ	2020.01.31	HH	1
TSX-TDX	2020.01.16	VV	108

150 MHz bandwidth, single-pol
Range x azimuth res.: 1.8m x 3.3m
Inc. angle: ~39° (ground-range res. 2.8m)

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TSX	2019.12.25	HH	60
PAZ	2019.12.29	HH	130
PAZ	2020.01.09	HH	25
TSX	**2020.01.27**	**HH**	**-**
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150 MHz bandwidth, single-pol
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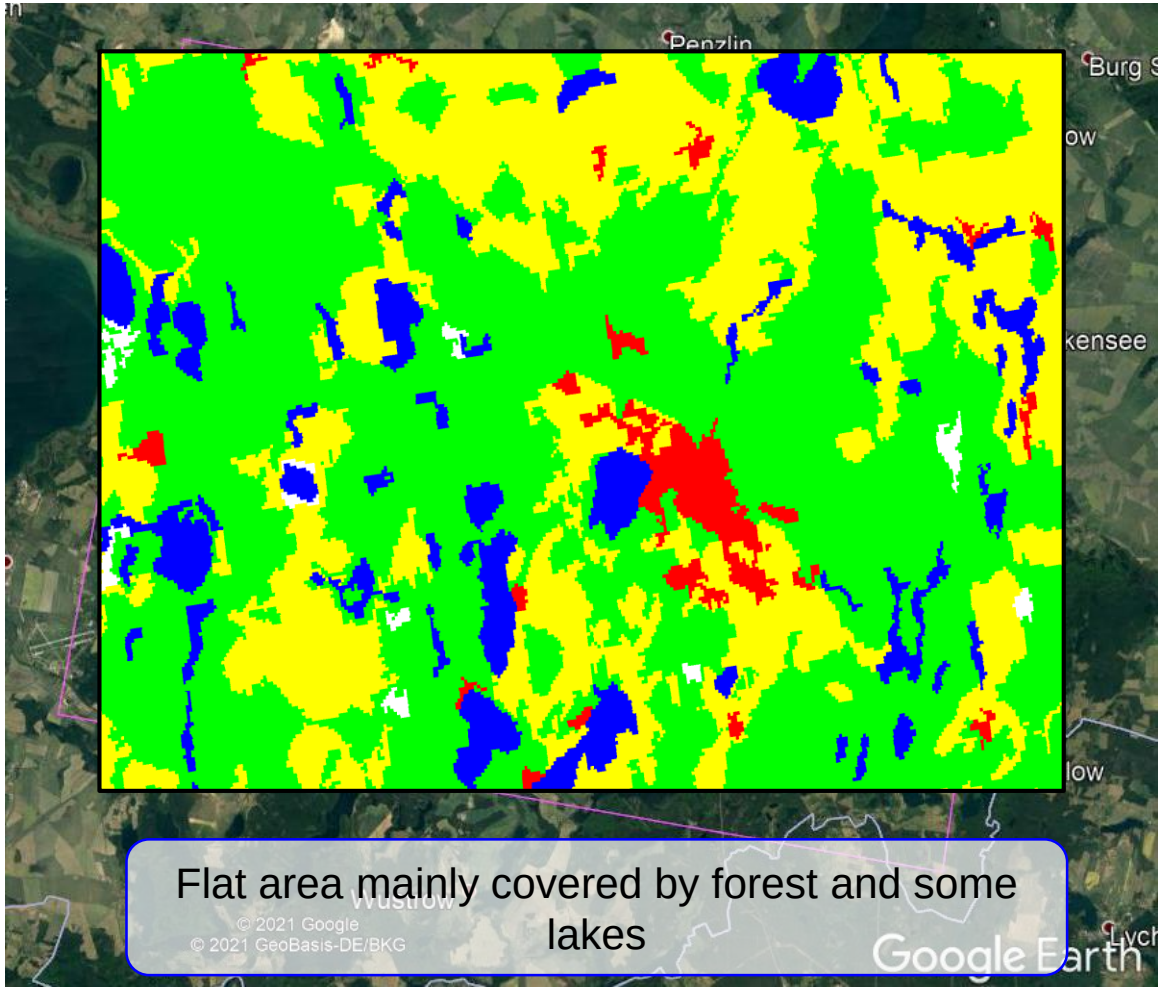
Urban & Industrial **Forested areas**

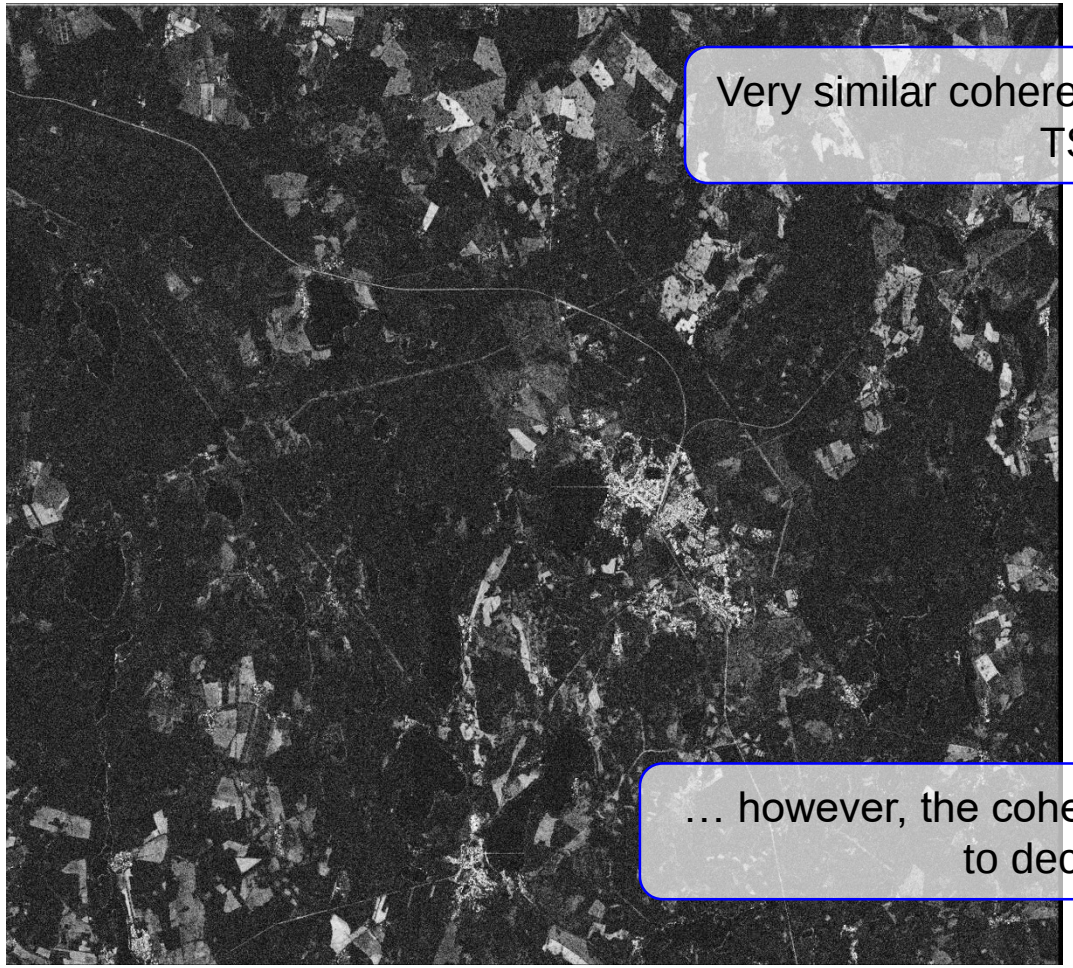
Agricultural areas **Water**

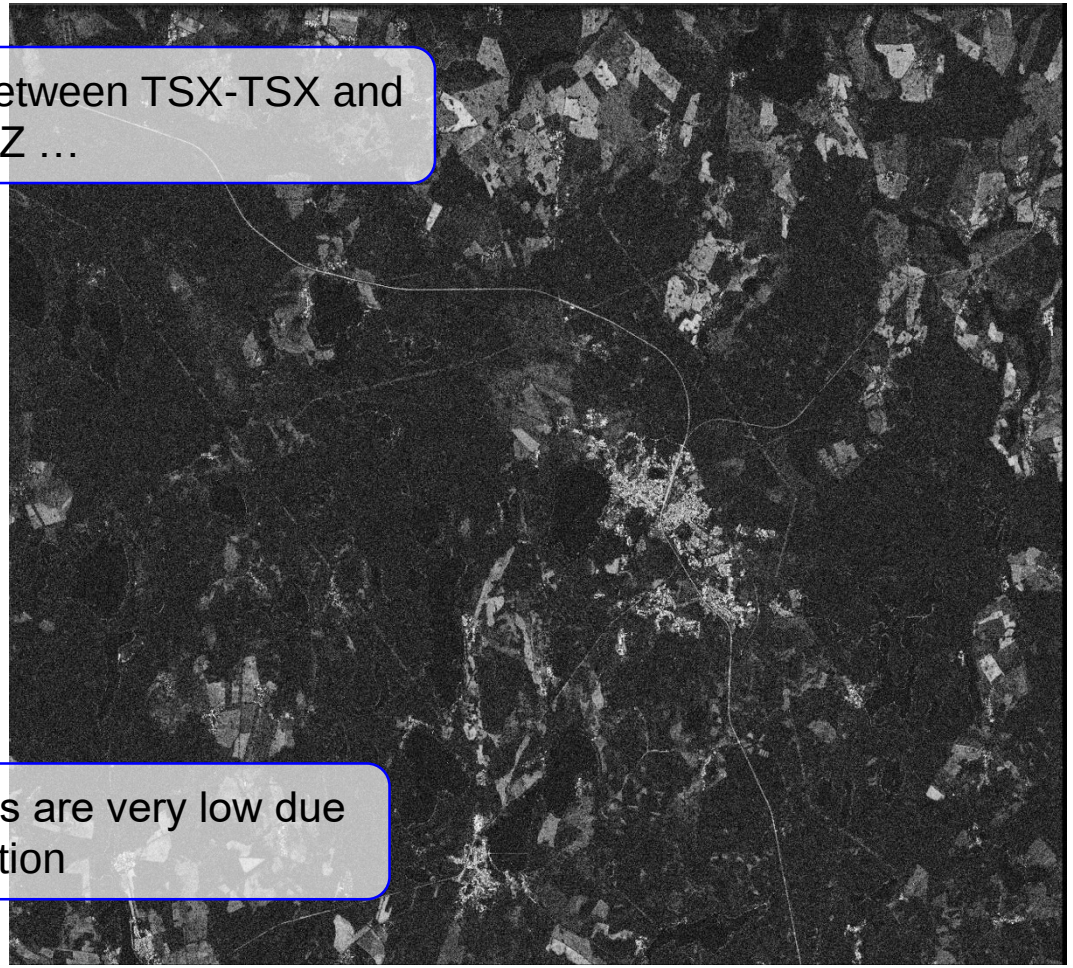


Flat area mainly covered by forest and some lakes

Neustrelitz strip 11 – Coherence between TSX and PAZ

- Comparing two interferograms (HH pol.) with similar temporal separation (33 and 29 days):





Very similar coherence between TSX-TSX and TSX-PAZ …

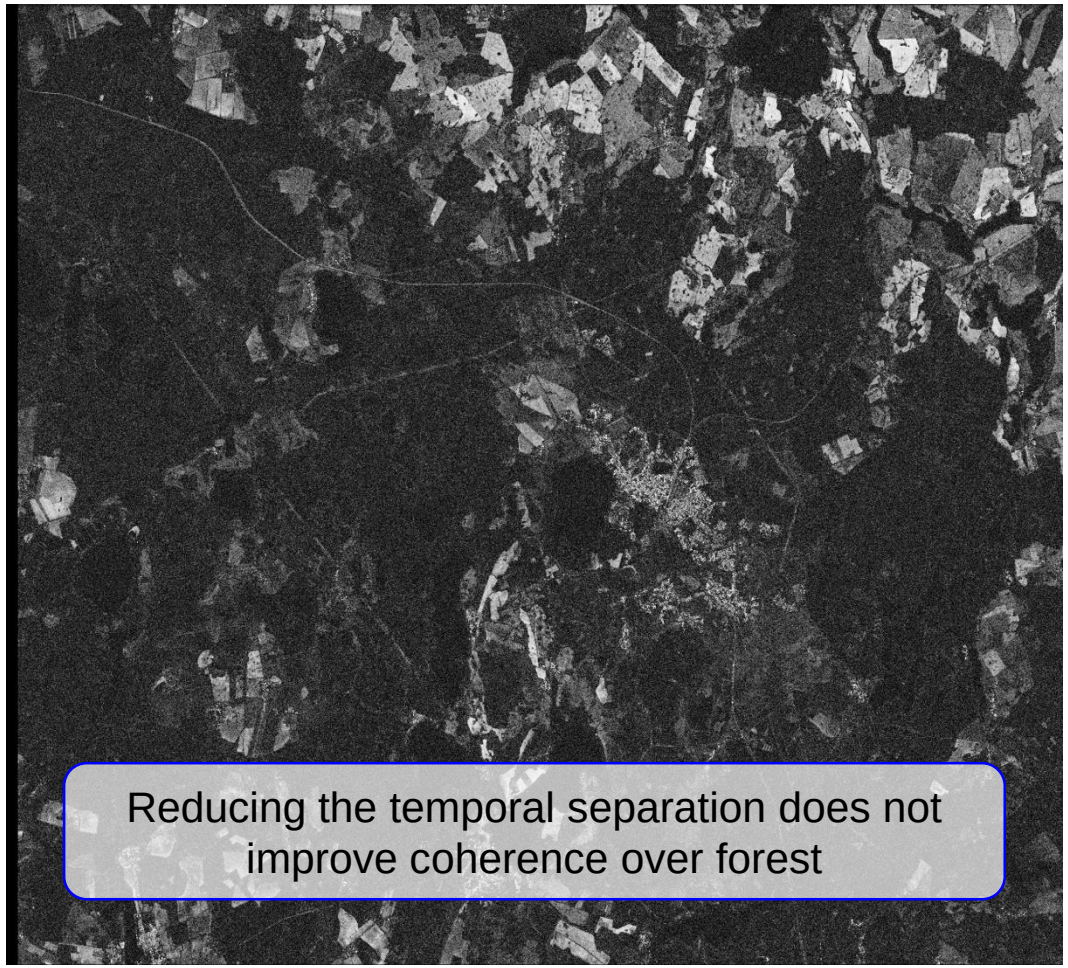
… however, the coherences are very low due to decorrelation

Coherence TSX 2019.12.25 – TSX 2020.01.27 (60m)

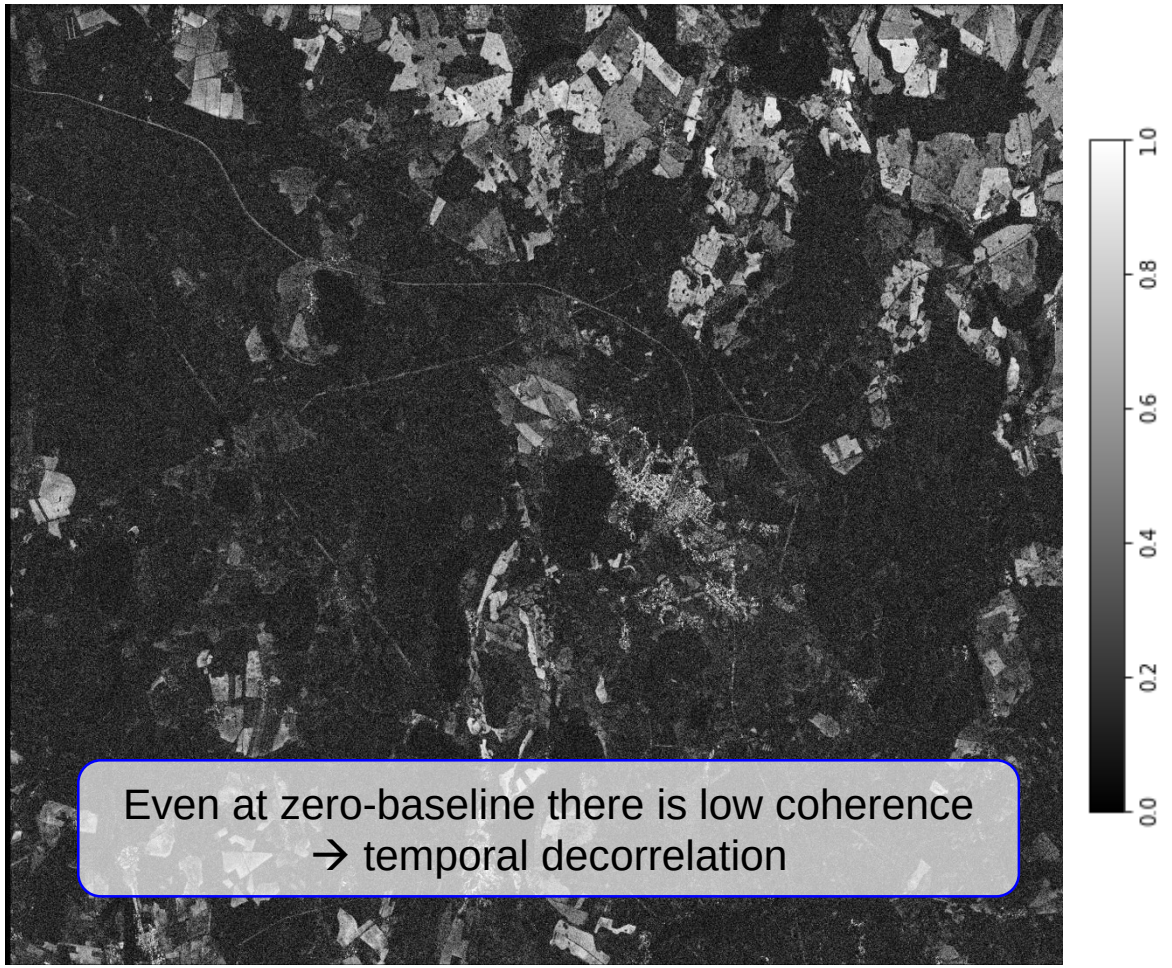
Coherence PAZ 2019.12.29 – TSX 2020.01.27 (130m)

Neustrelitz strip 11 – Coherence between TSX and PAZ

- Comparing two TSX-PAZ interferograms (VV pol.) with shorter temporal separation (7 and 4 days) and zero-baseline:



Coherence PAZ 2019.12.07 – TSX 2019.12.14 (-163m)



Coherence TSX 2019.12.14 – PAZ 2019.12.18 (-6m)

Datasets – Madrid strip 4 and 13

- Two different datasets were acquired over the are near Madrid city, with different land cover

Madrid strip 4

Satellite	Acq. Time	Pol.	Perp. Baseline [m]
TDX	2019.12.05	VV	97
TDX	**2020.01.18**	**VV**	**-**
PAZ	2020.01.22	VV	292
TDX	2019.11.24	HH	11
PAZ	2019.11.28	HH	448
PAZ	2019.12.09	HH	340
TDX	**2019.12.16**	**HH**	**-**
PAZ	2020.01.11	HH	468
TSX-TDX	2019.12.27	VV	116
TSX-TDX	2020.01.07	HH	109

150 MHz bandwidth, single-pol
Range x azimuth res.: 1.8m x 3.3m
Inc. angle: ~29° (ground-range res. 3.6m)

Madrid strip 11

Satellite	Acq. Time	Pol.	Perp. Baseline [m]
TSX	**2019.12.11**	**VV**	**-**
PAZ	2019.12.26	VV	51
PAZ	2020.01.17	VV	-74
PAZ	2019.11.23	HH	-85
PAZ	2019.12.04	HH	-2
TSX	2019.12.22	HH	50
PAZ	2020.01.06	HH	8
TSX	**2020.01.24**	**HH**	**-**
PAZ	2020.01.28	HH	176
TDX	2020.02.04	HH	-115
TDX	2020.02.15	HH	-296
TSX	2020.03.08	HH	-59
TSX	2020.03.19	HH	-71
TSX-TDX	2020.01.02	VV	119
TSX-TDX	2020.01.13	HH	115

150 MHz bandwidth, single-pol
Range x azimuth res.: 1.8m x 3.3m
Inc. angle: ~39° (ground-range res. 2.8m)

Datasets – Madrid strip 4 and 13

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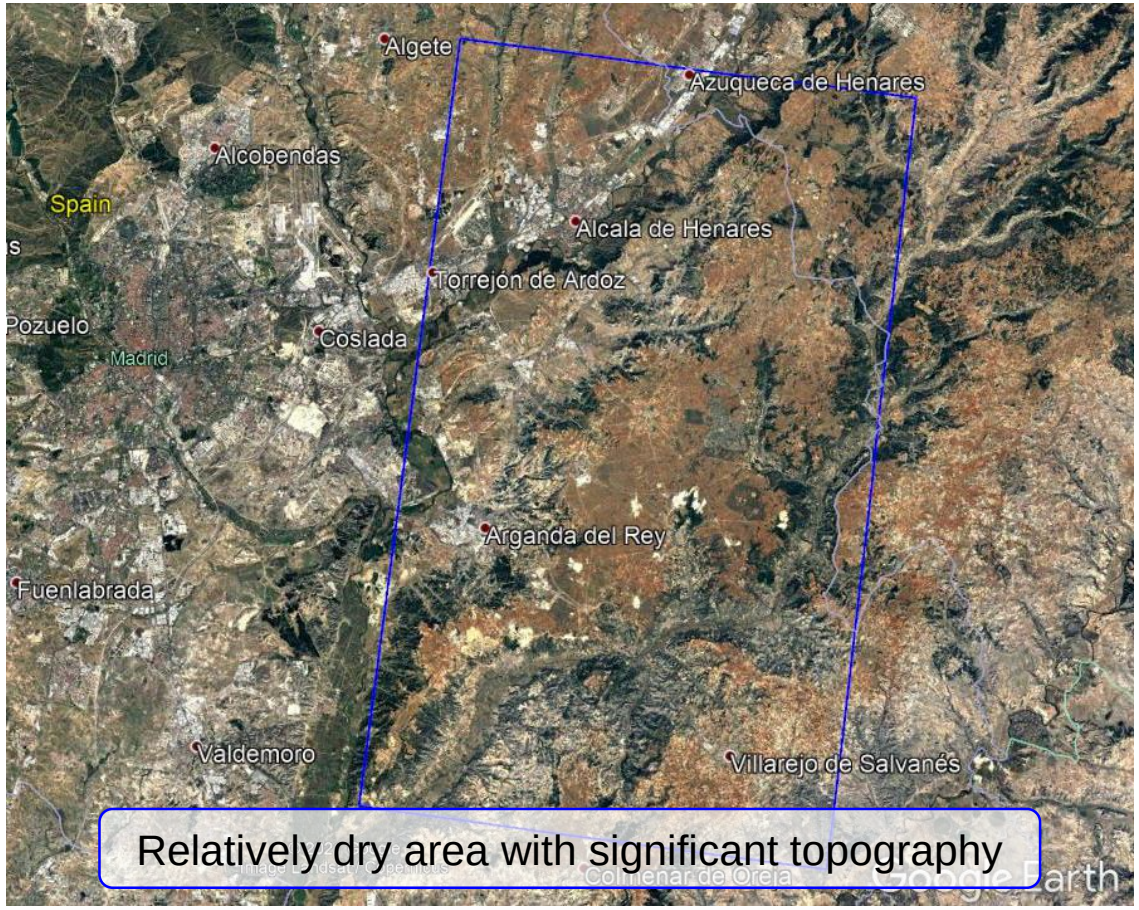
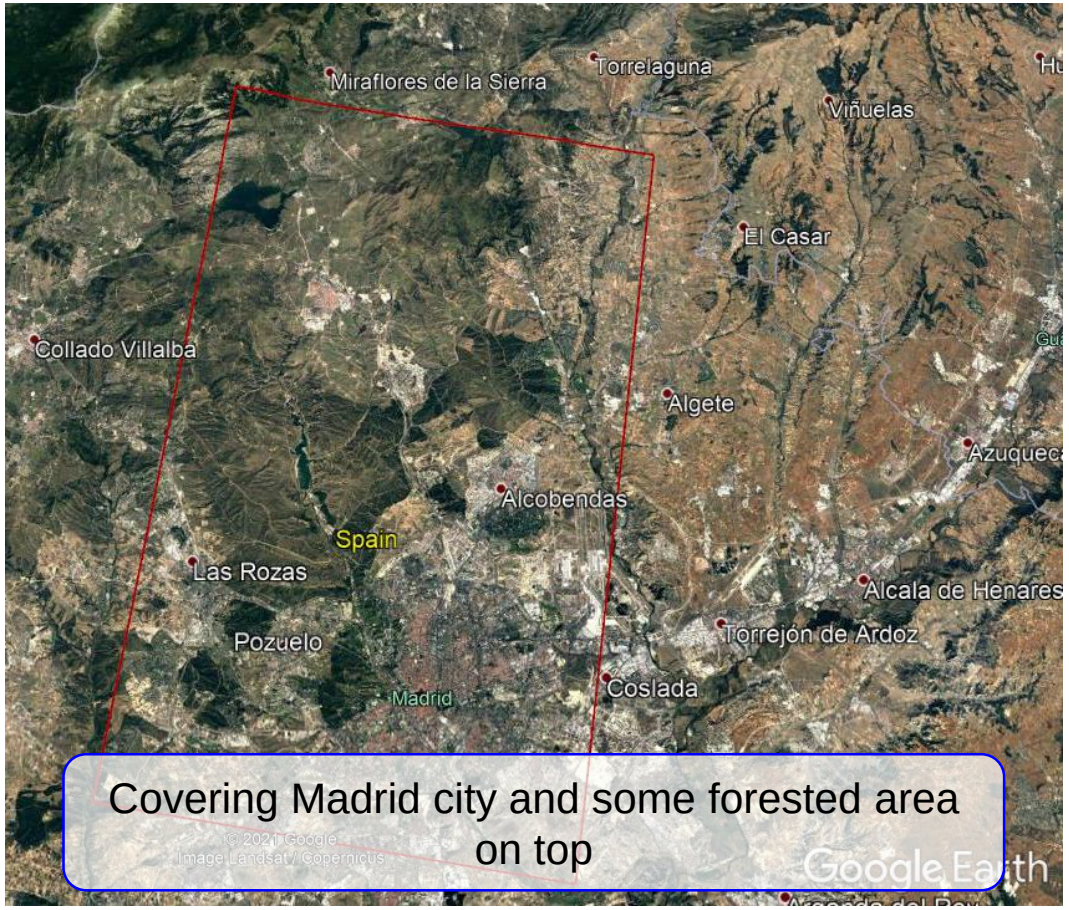
Madrid strip 4



Madrid strip 11



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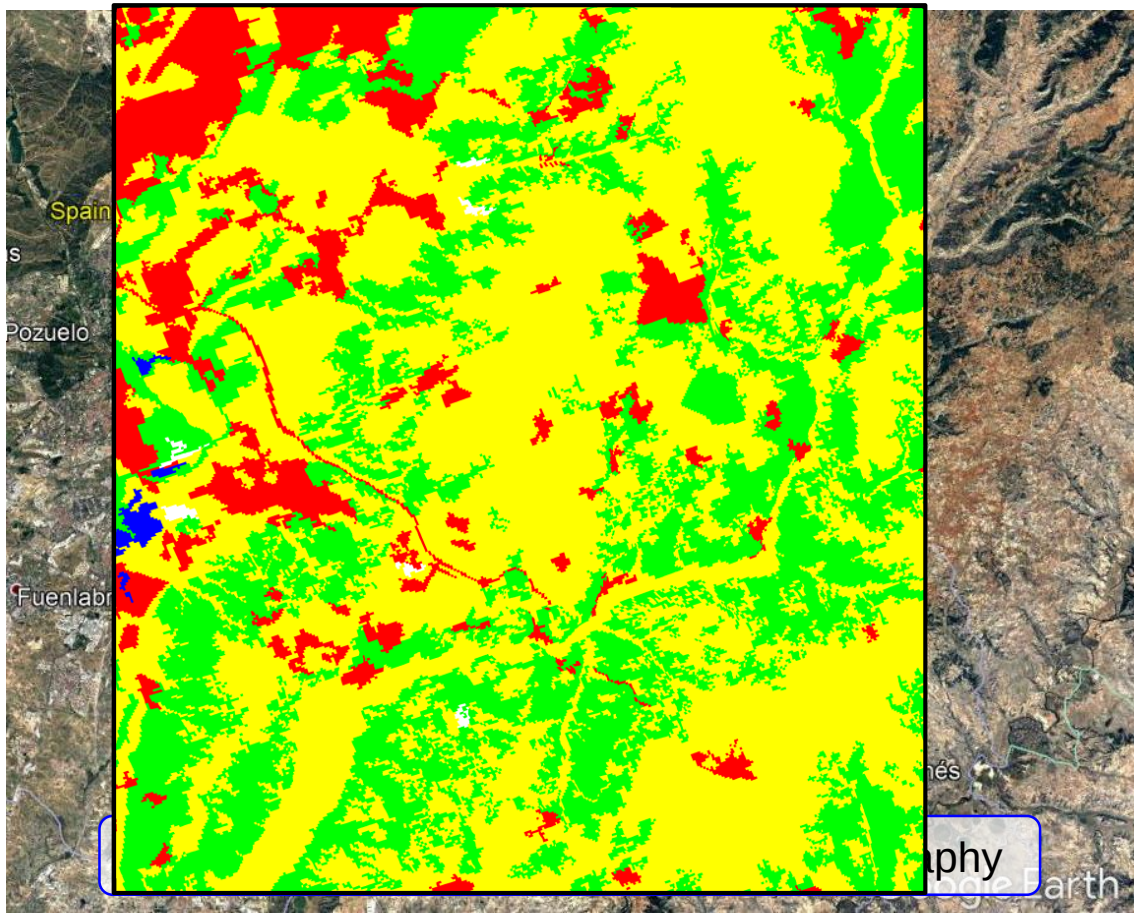
Urban & Industrial **Forested areas**

Agricultural areas **Water**

Madrid strip 4



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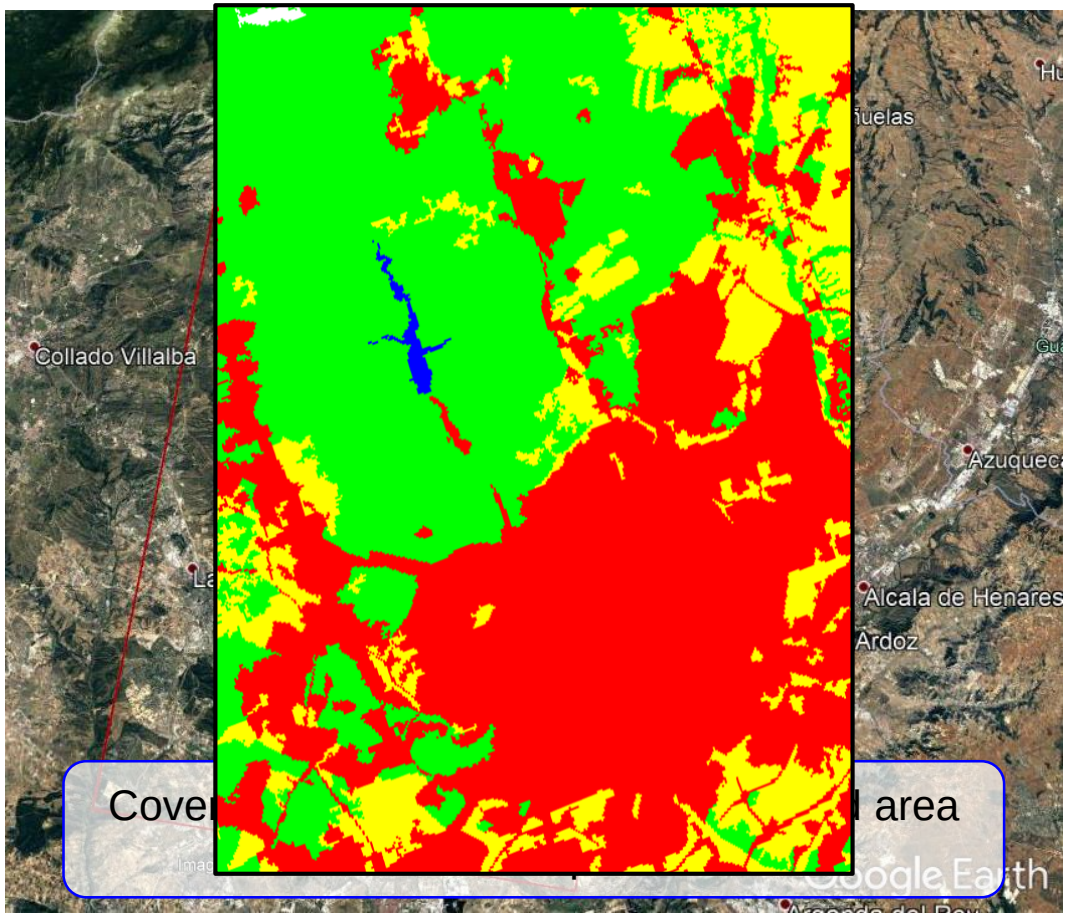
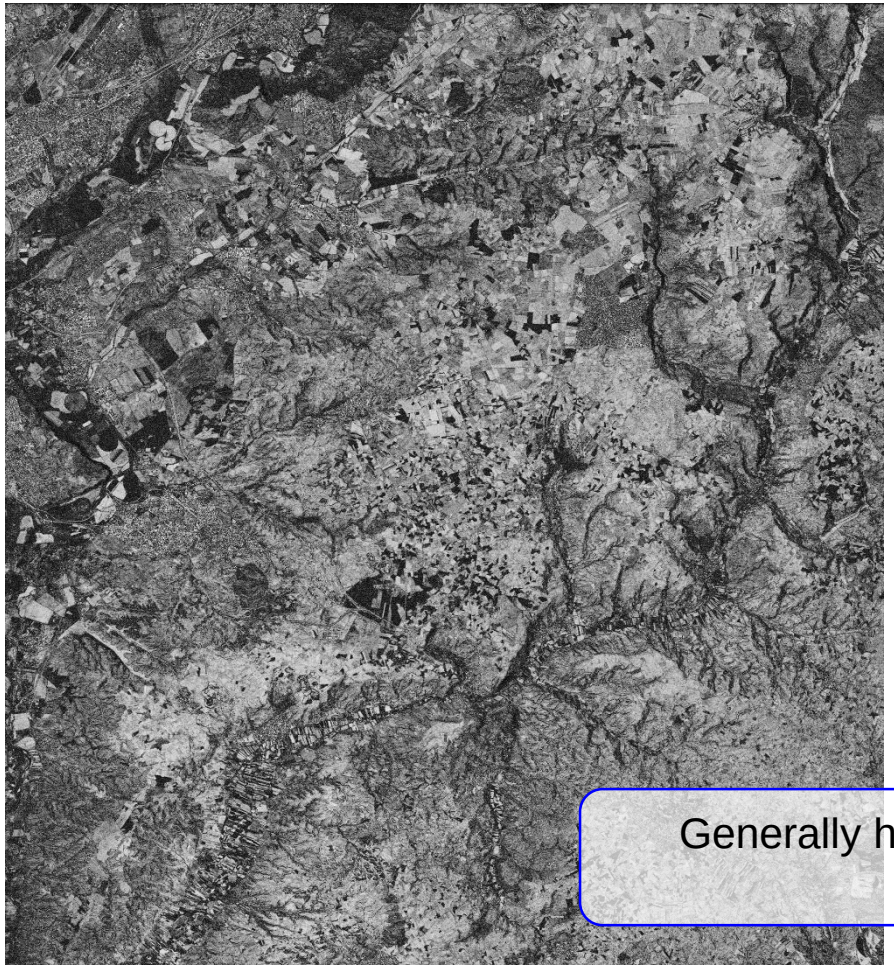
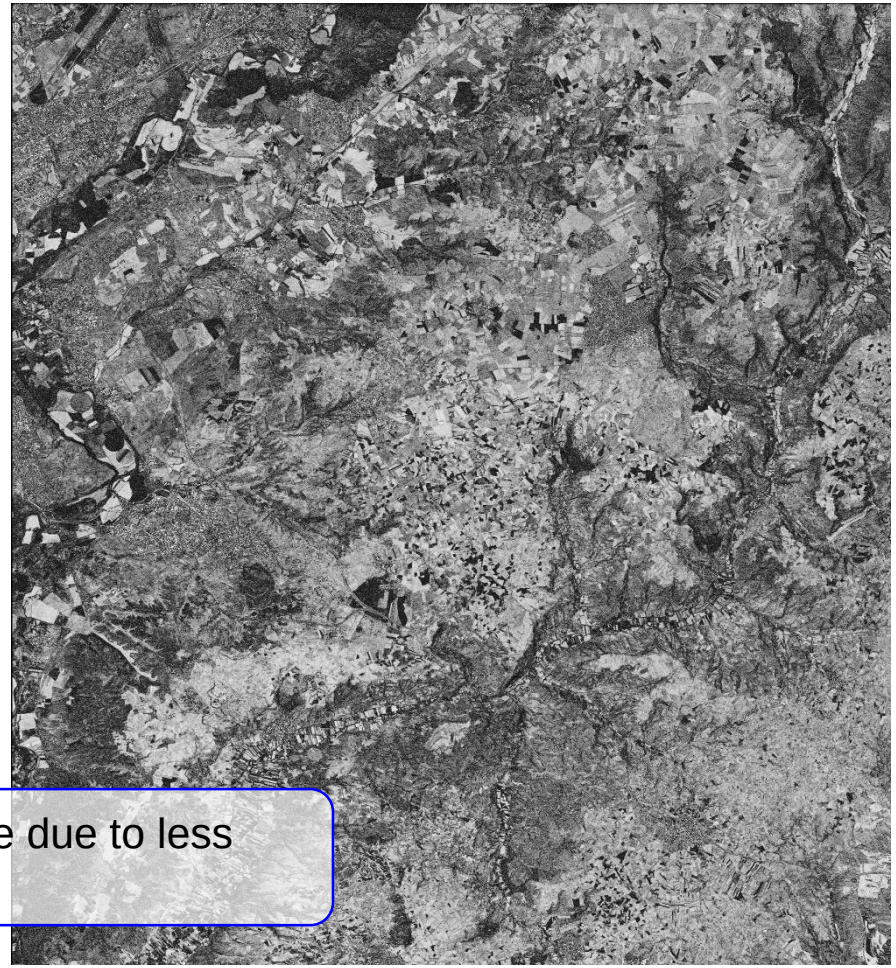


Madrid strip 4 – Coherence between TSX and PAZ

- Comparing two TSX-PAZ interferograms (HH pol.) with 18 and 7 days temporal separation:





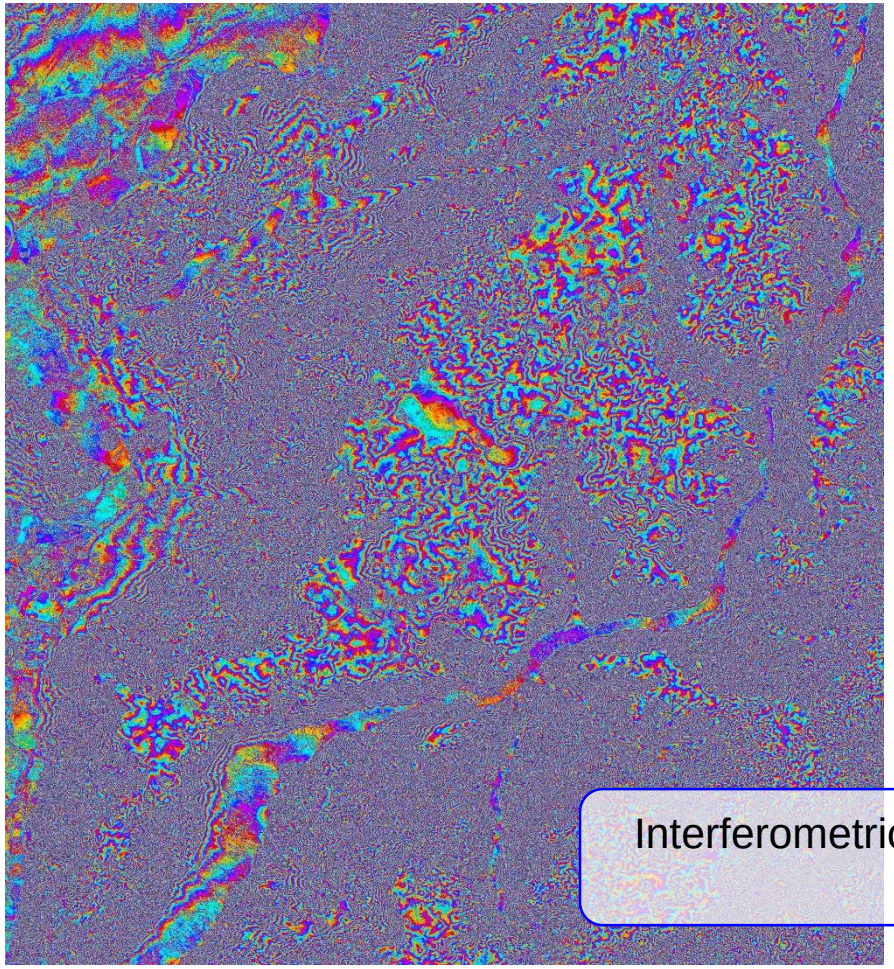
Generally higher coherence due to less vegetation

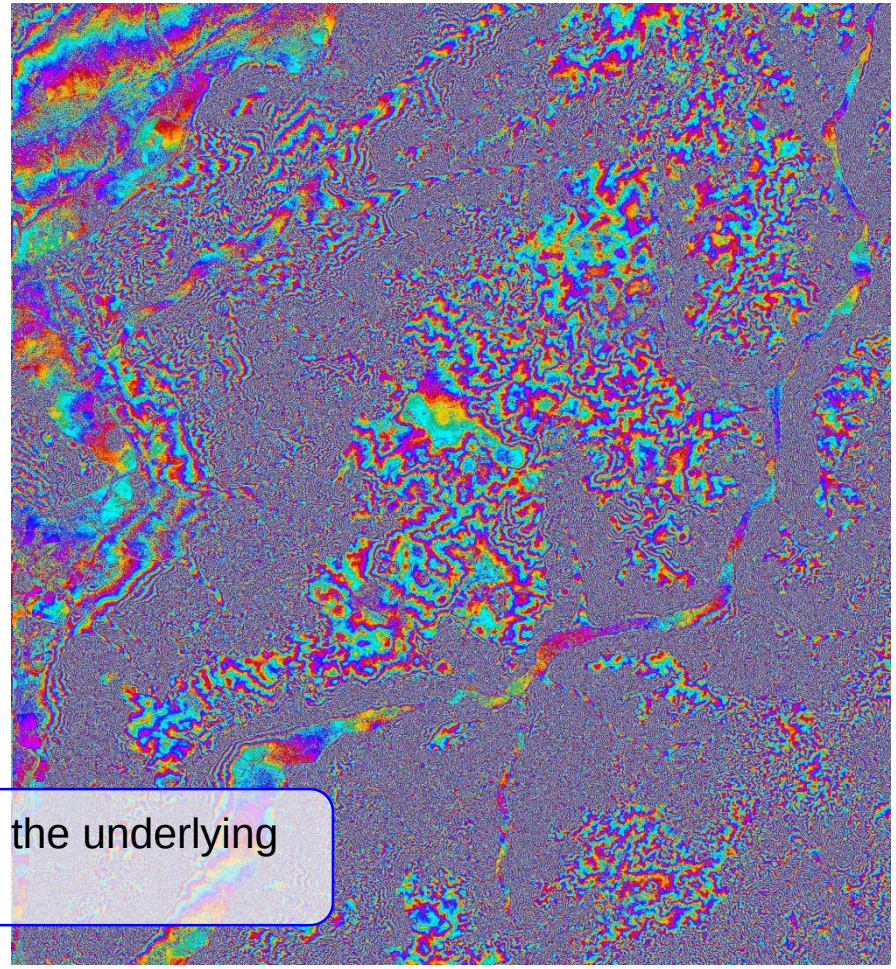
Coherence PAZ 2019.11.28 – TDX 2019.12.16 (448m)

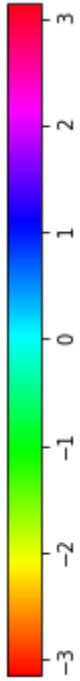
Coherence PAZ 2019.12.09 – TDX 2019.12.16 (340m)

Madrid strip 4 – Interferometric phase between TSX and PAZ

- Comparing two TSX-PAZ interferograms (HH pol.) with 18 and 7 days temporal separation:







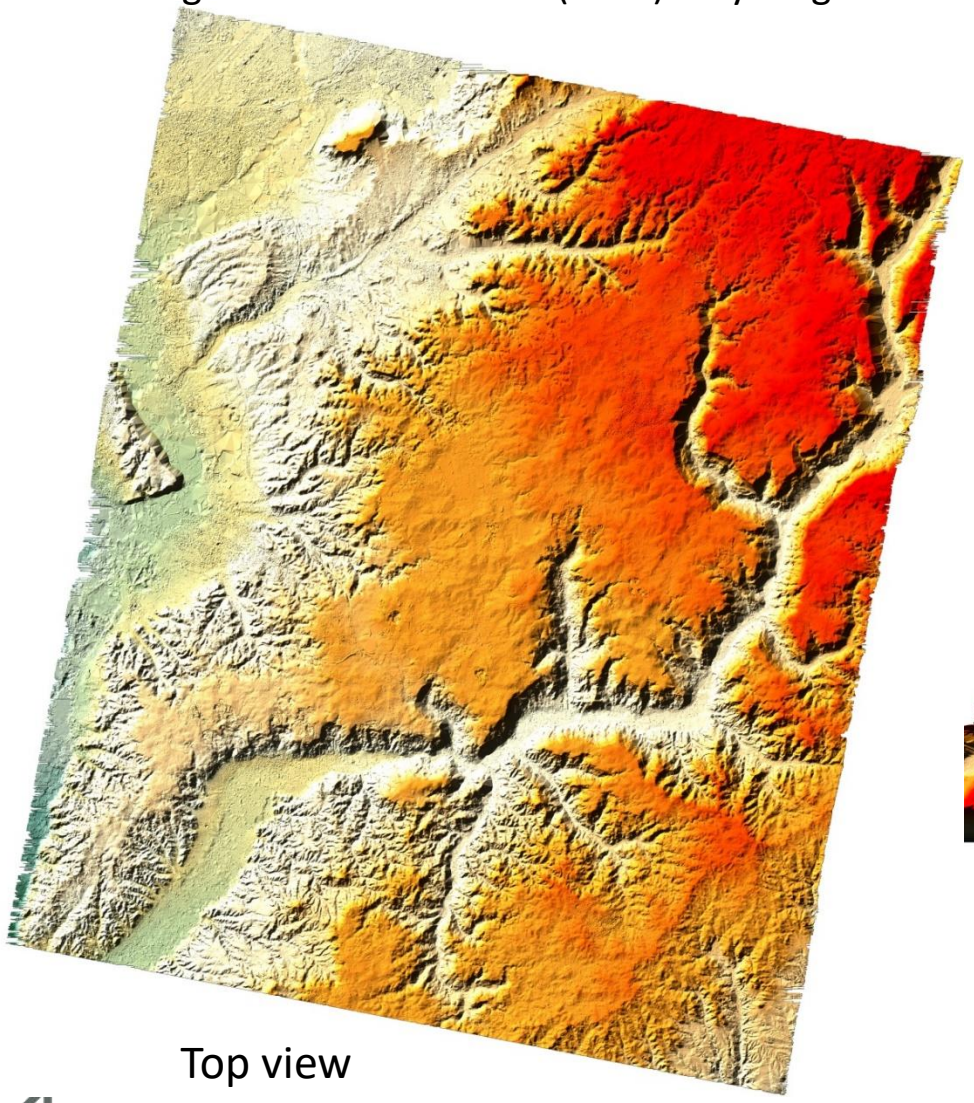
Interferometric phase reveals the underlying topography

Int. phase PAZ 2019.11.28 – TDX 2019.12.16 (448m)

Int. phase PAZ 2019.12.09 – TDX 2019.12.16 (340m)

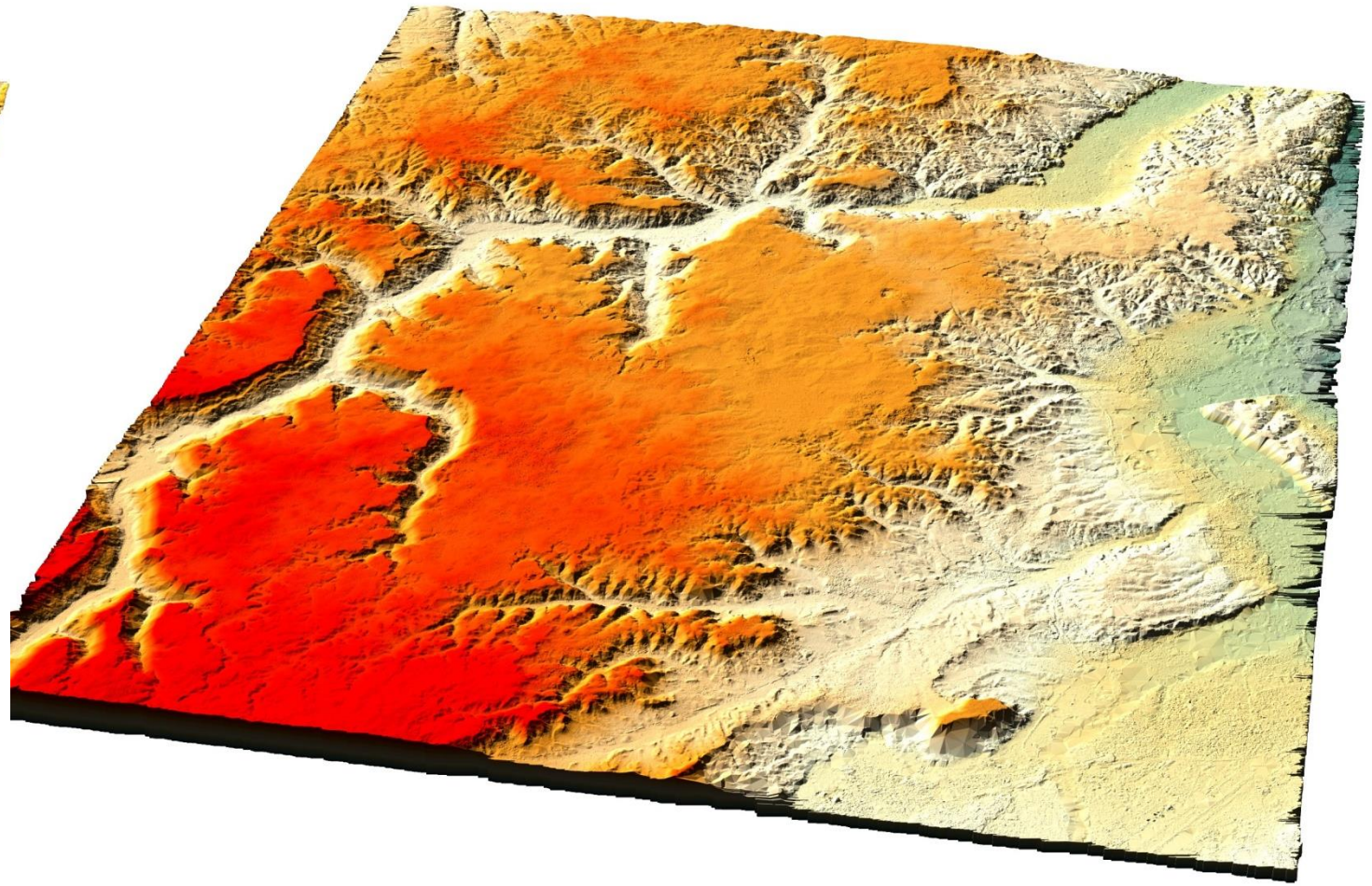
Madrid strip 4 – DEM between TSX and PAZ

- A Digital Elevation Model (DEM) may be generated from the TDX – PAZ acquisition pairs:



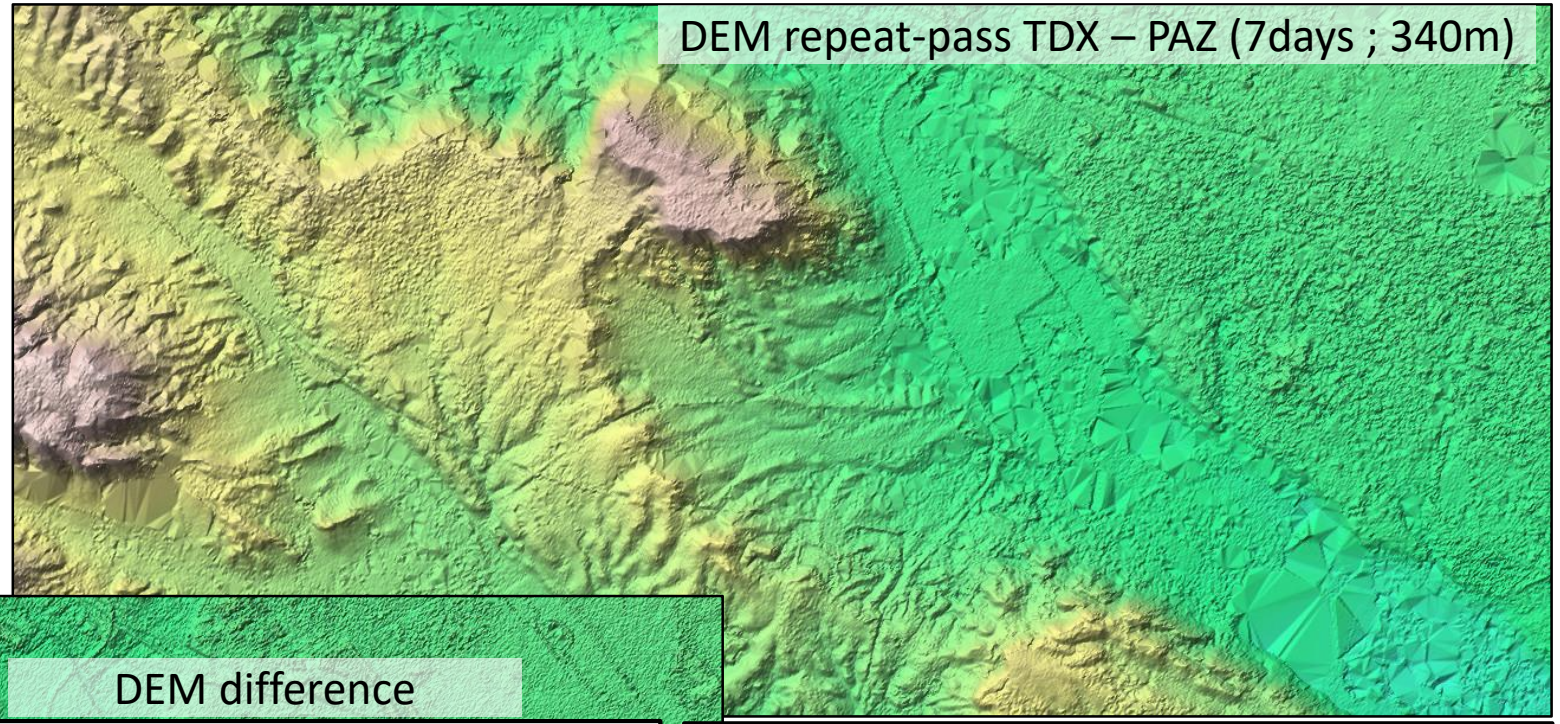
Top view

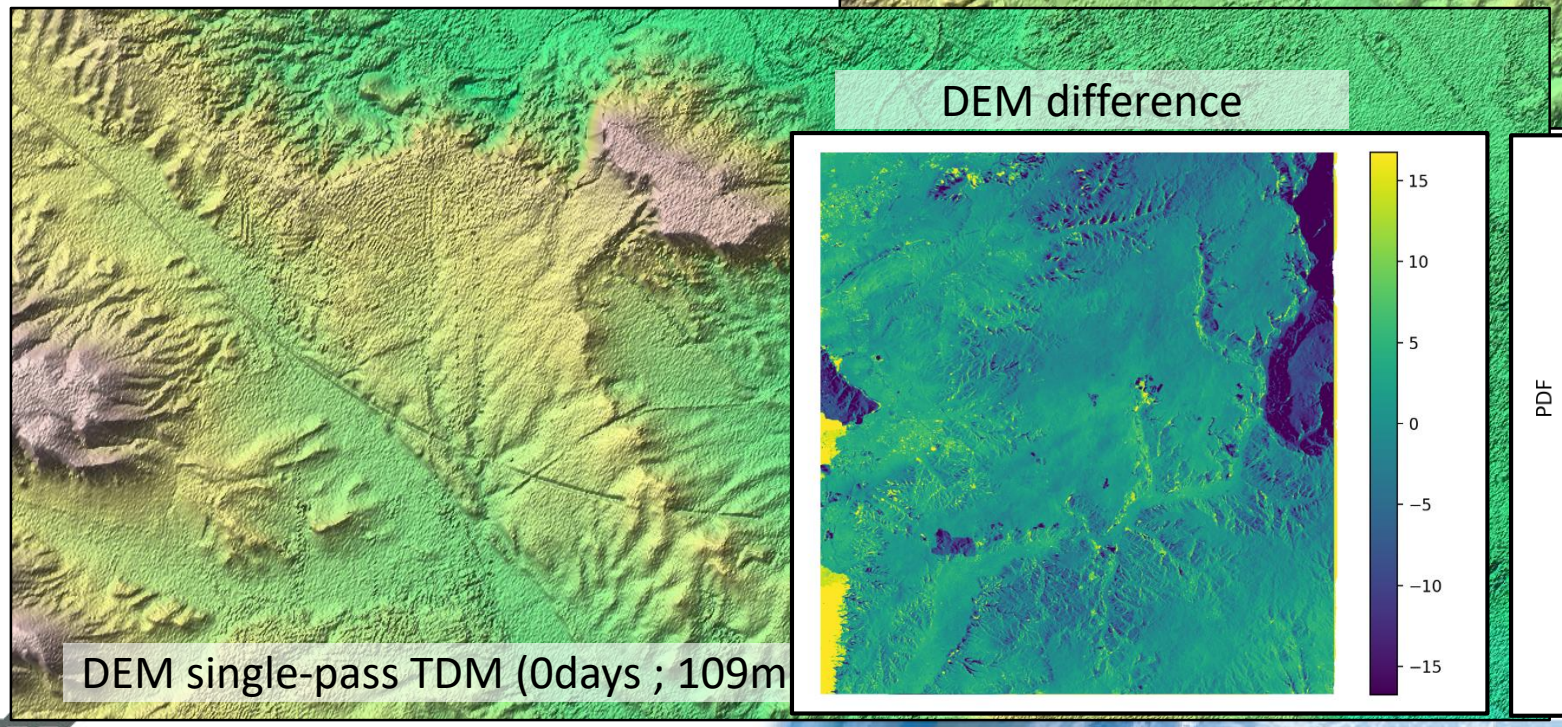
North view

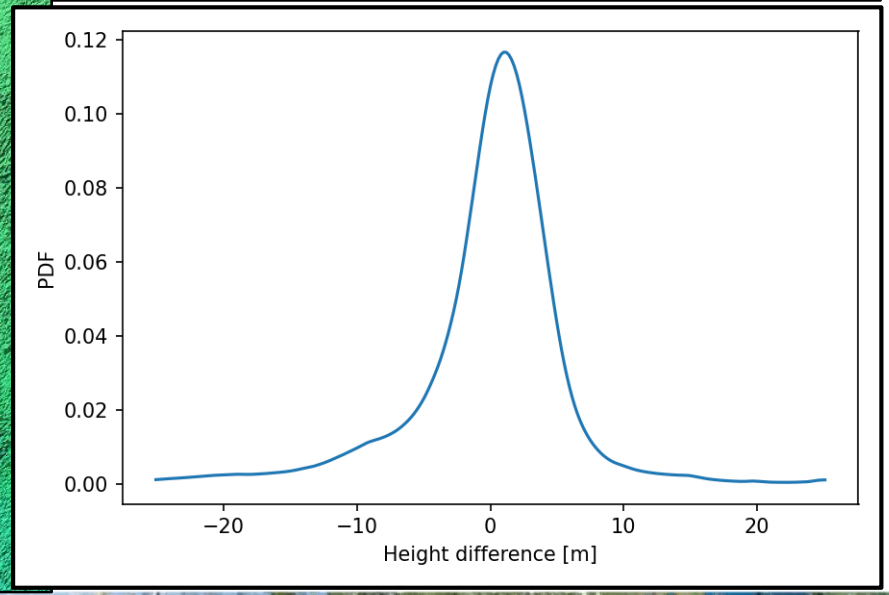


DEM generated TDX – PAZ (7days ; 340m)

Madrid strip 4 – Single & repeat-pass DEM comparison





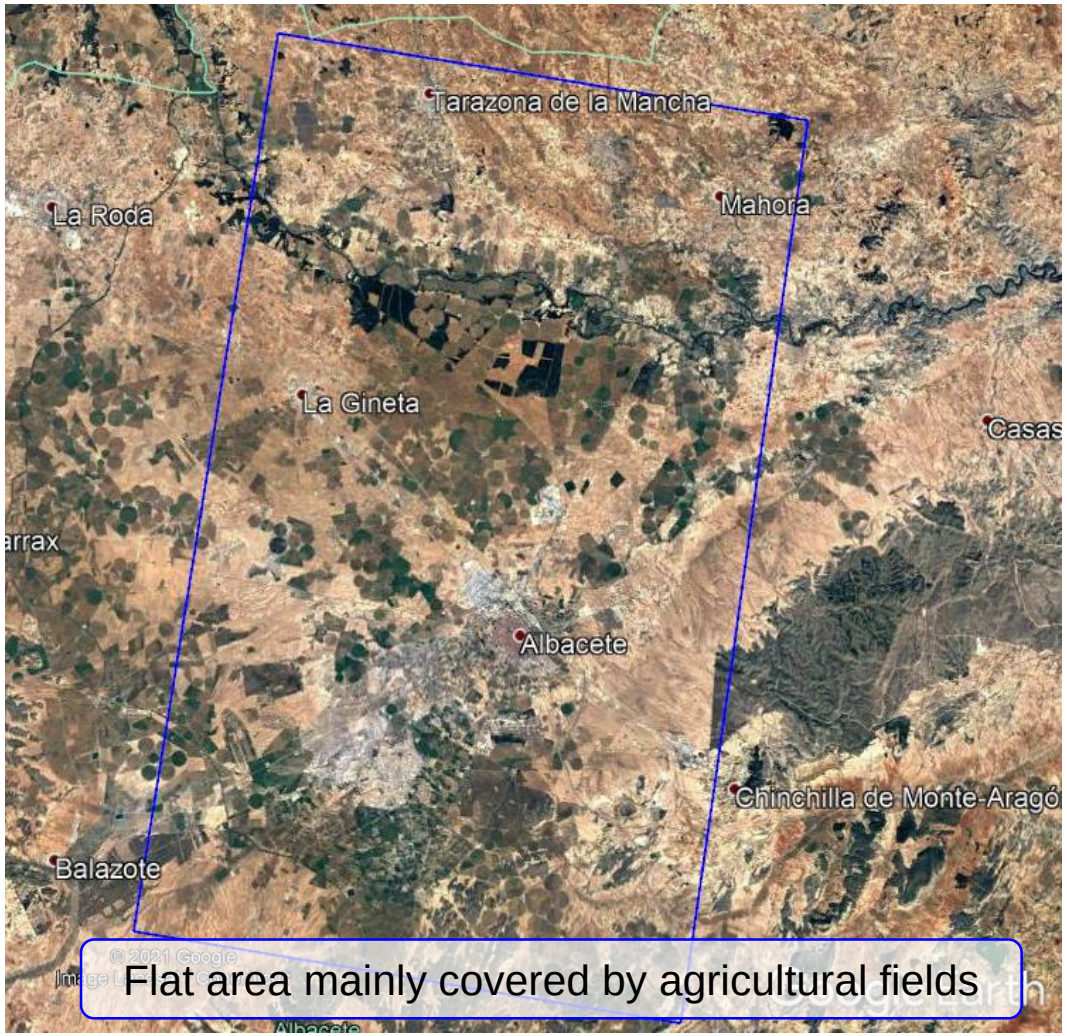


Datasets – Albacete strip 13

- TSX/TDX and PAZ Acquisitions over the Albacete agricultural test-site

Satellite	Acq. Time	Pol.	Perp. Baseline [m]
TDX	2019.12.06	VV	58
PAZ	2019.12.21	VV	282
PAZ	2020.01.01	VV	422
TDX	**2020.01.19**	**VV**	**-**
PAZ	2020.01.23	VV	338
TDX	**2019.11.25**	**HH**	**-**
PAZ	2019.11.29	HH	379
PAZ	2019.12.10	HH	337
TSX	2019.12.17	HH	183
PAZ	2020.01.12	HH	405
TSX-TDX	2019.12.28	VV	123
TSX-TDX	2020.01.08	HH	117

150 MHz bandwidth, single-pol
Range x azimuth res.: 1.8m x 3.3m
Inc. angle: ~42° (ground-range res. 2.6m)



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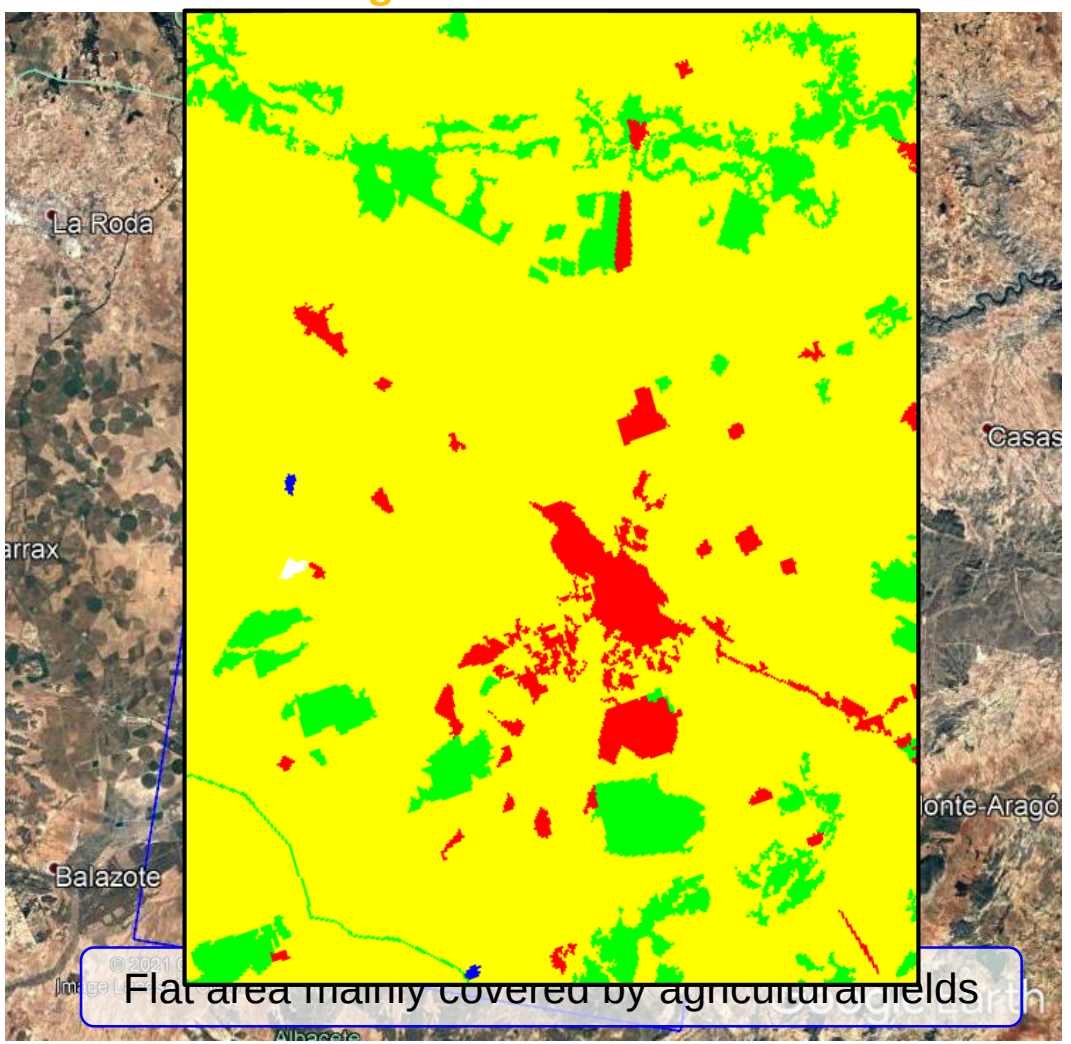
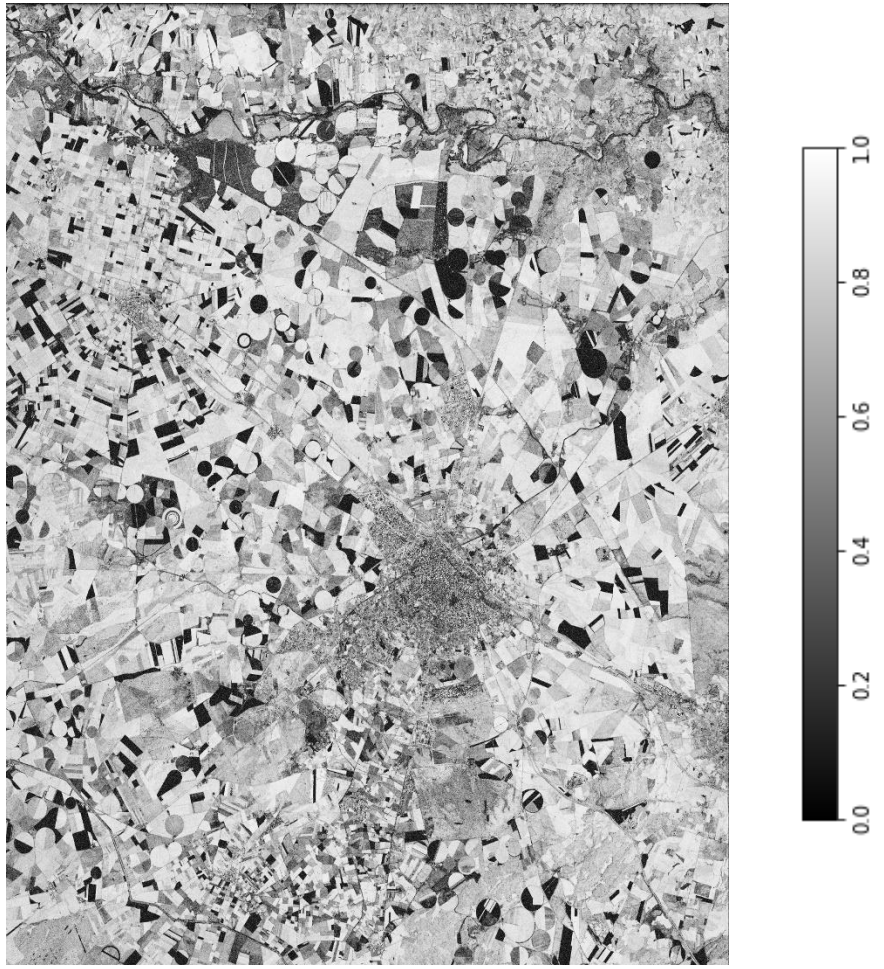
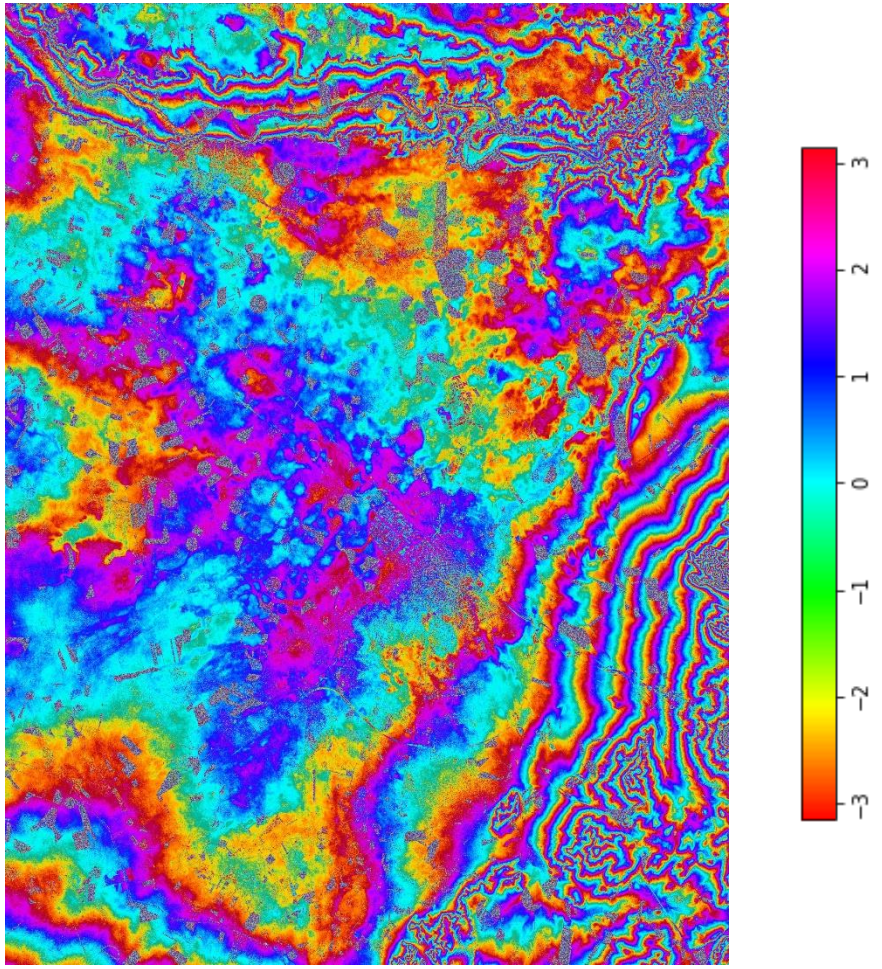


Albacete strip 4 – Coherence between TSX and PAZ

- Coherence between TDX and PAZ over the Albacete test site with 4 days temporal difference:



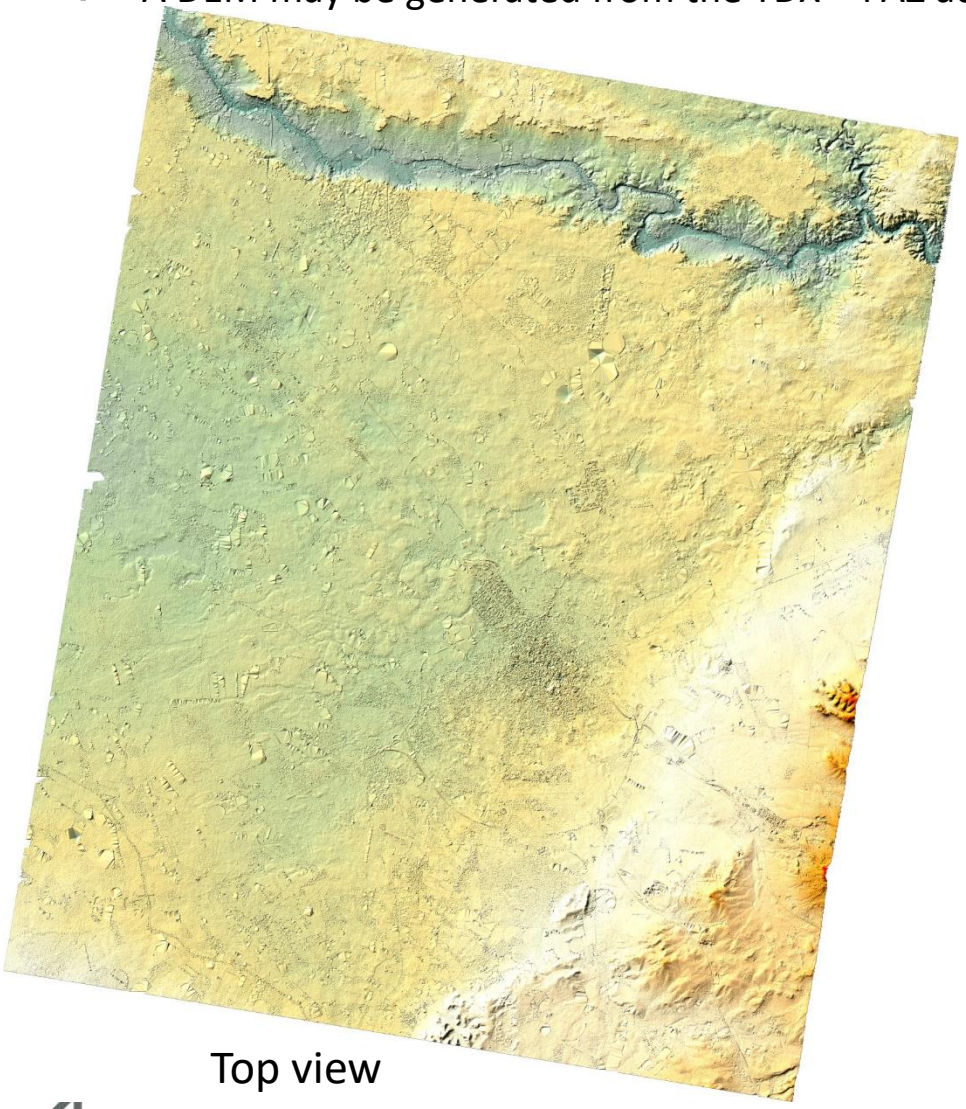
Coherence TDX 2019.11.25 – PAZ 2019.11.29 (379m)



Int. phase TDX 2019.11.25 – PAZ 2019.11.29 (379m)

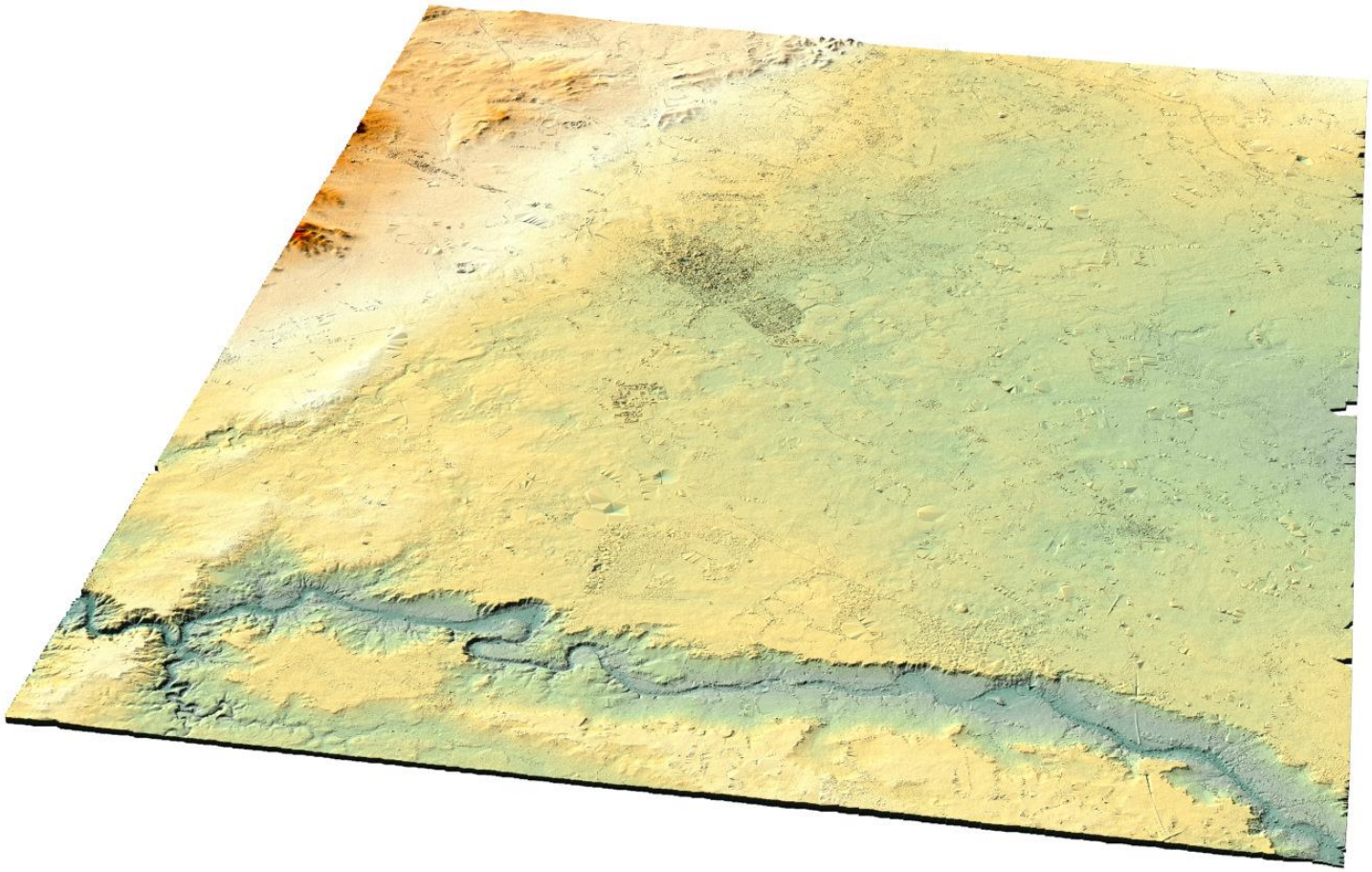
Albacete strip 11 – DEM between TSX and PAZ

- A DEM may be generated from the TDX – PAZ acquisition pairs:



Top view

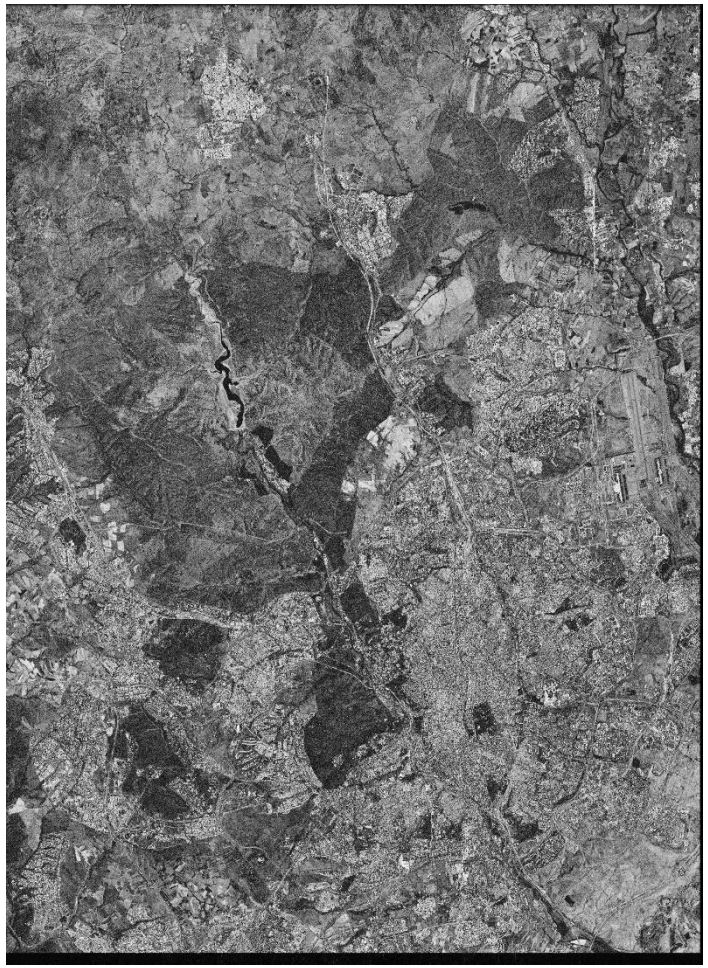
North view



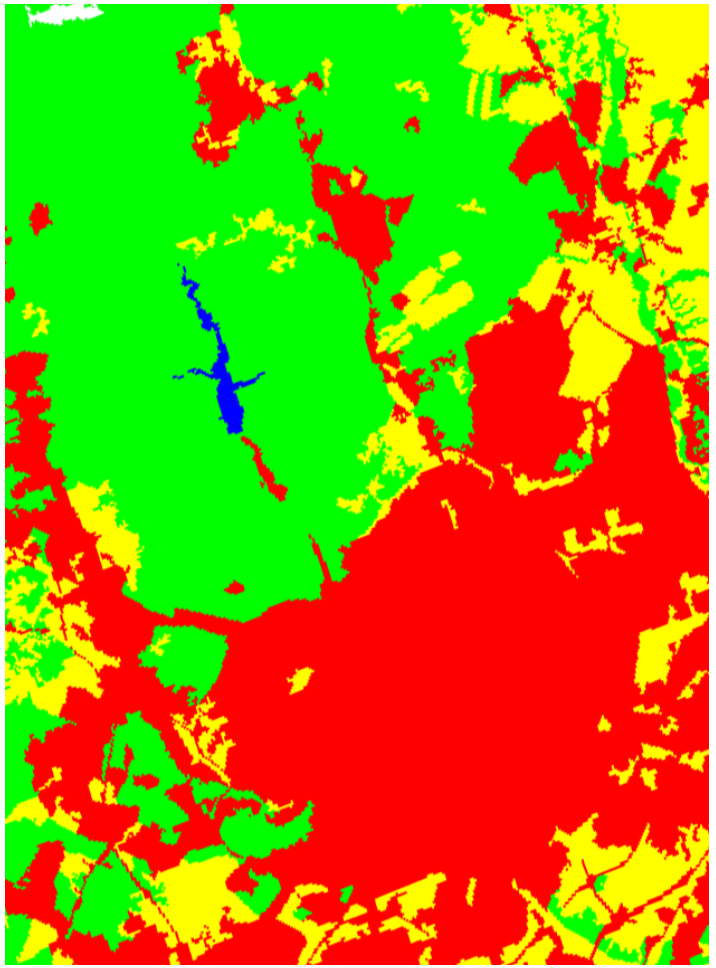
DEM generated TDX – PAZ (4days ; 379m)

Time series: Madrid strip 13 – HH

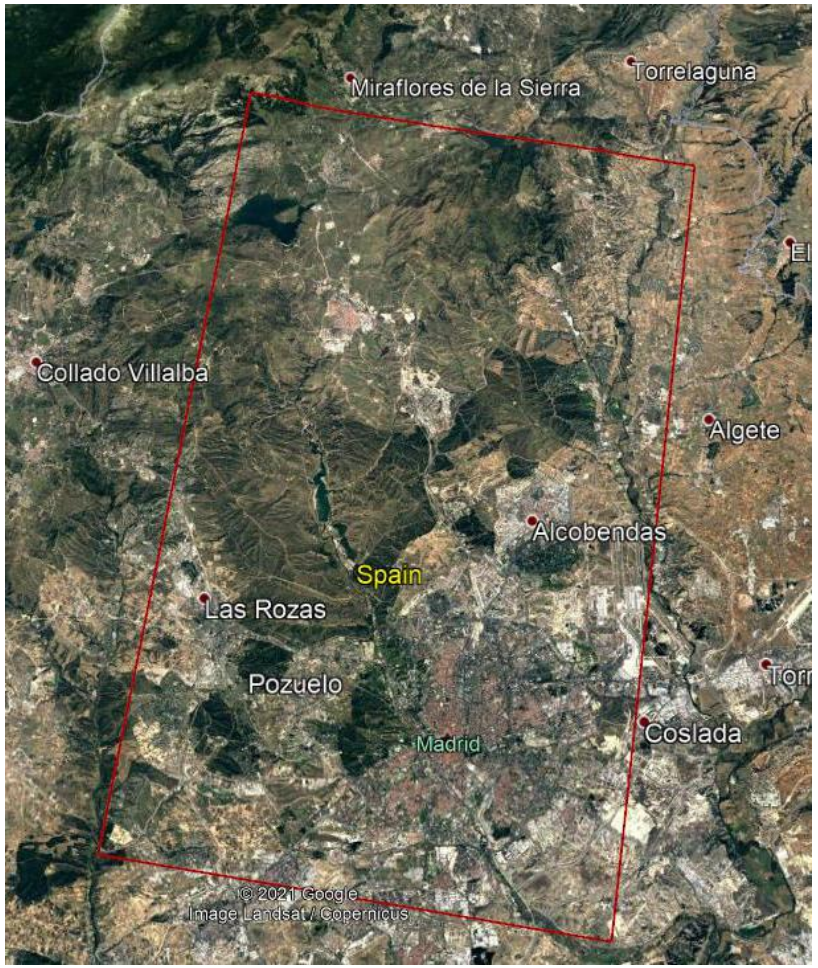
- Madrid strip 13 dataset covers two of the main classes: urban area (Madrid city) and forested area on top



Coherence PAZ 2020.01.28 – TSX 2020.01.24



Land cover map (CORINE)

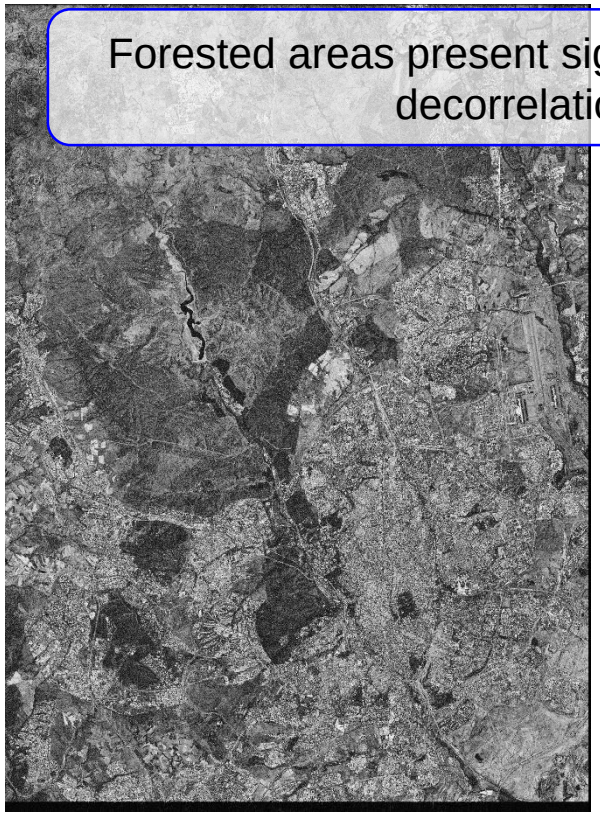


Optical image

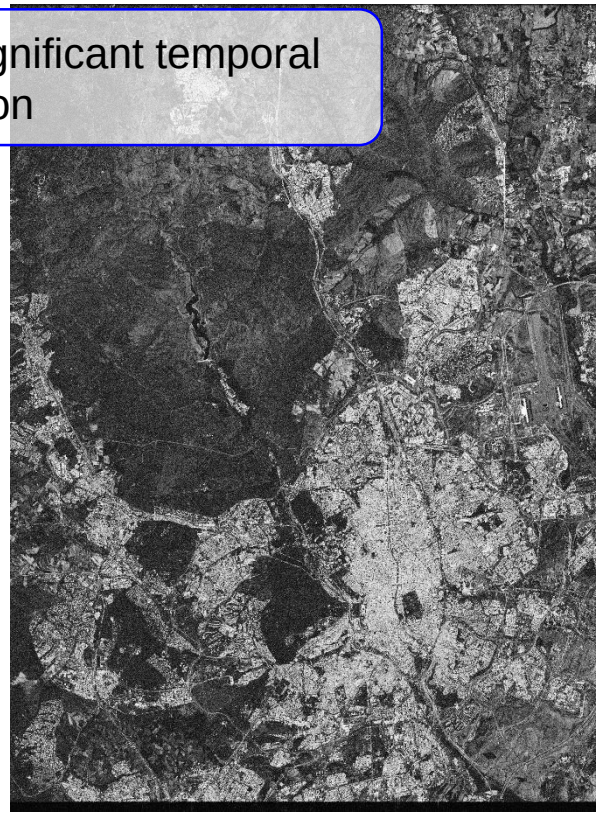
Time series: Madrid strip 13 – HH

- The time series reveals the different behavior of coherence for the different land cover types

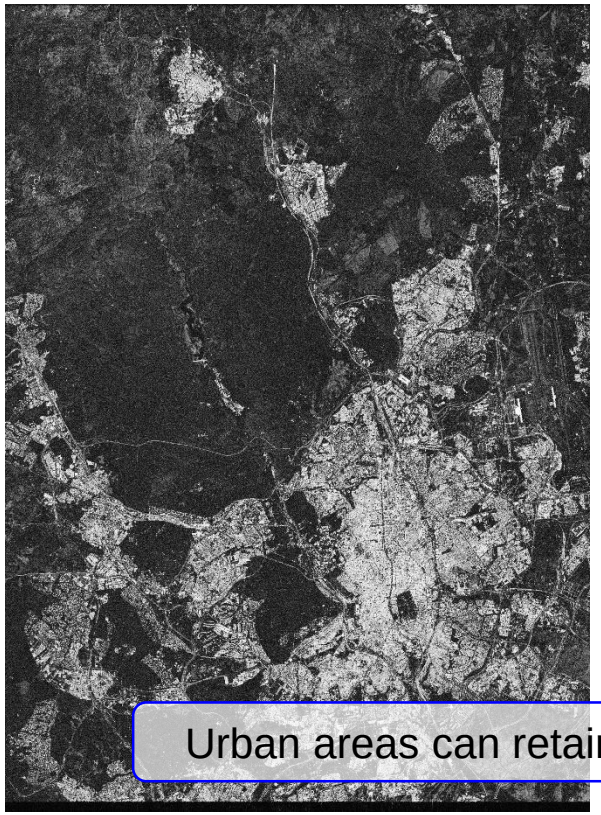
Forested areas present significant temporal decorrelation



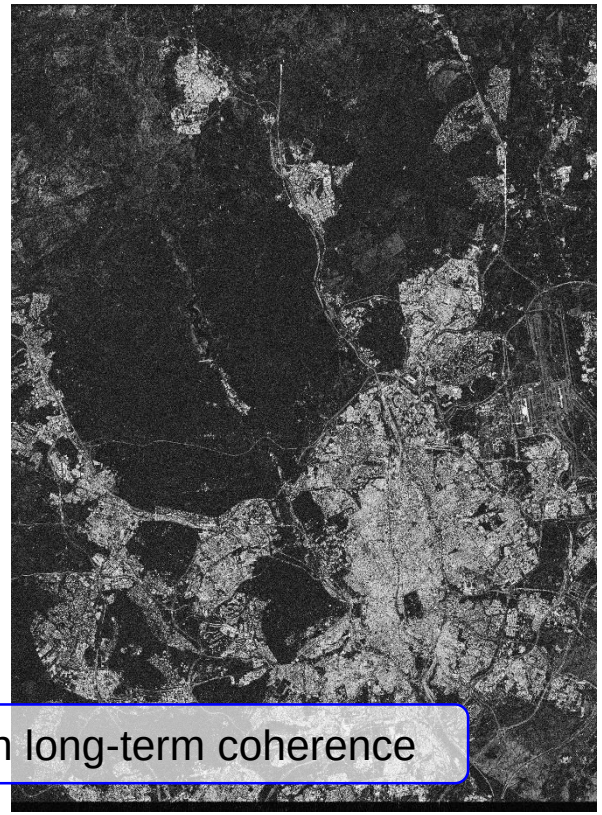
Coherence (4 days; -85m)



Coherence (18 days; -2m)



Coherence (51 days; 8m)



Coherence (62 days; 176m)

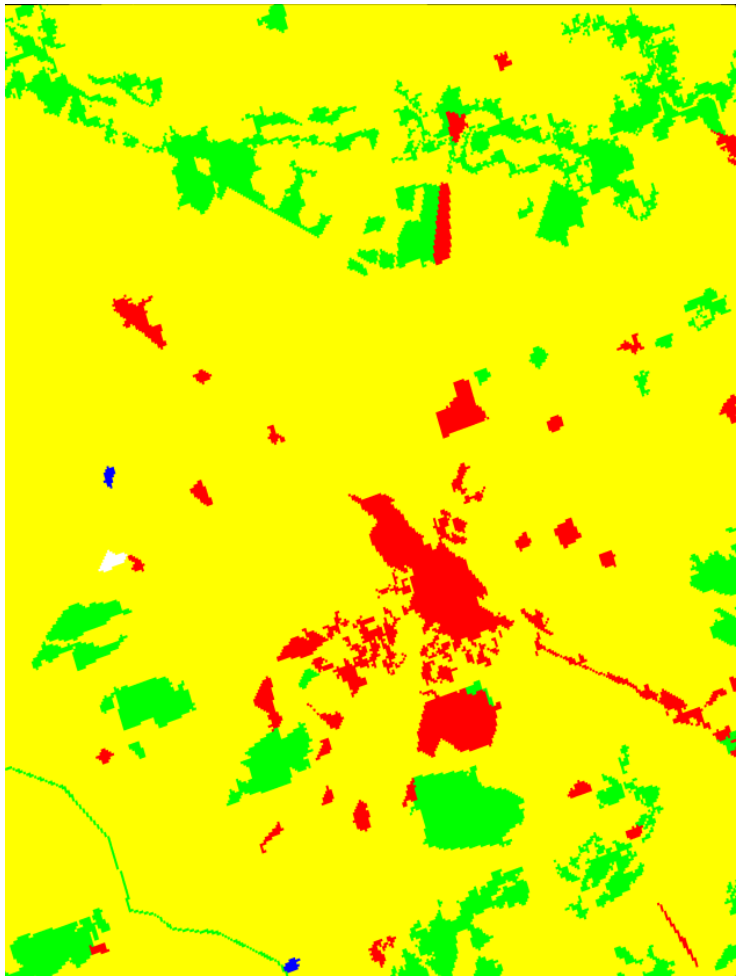
Urban areas can retain long-term coherence

Coherence TSX – PAZ

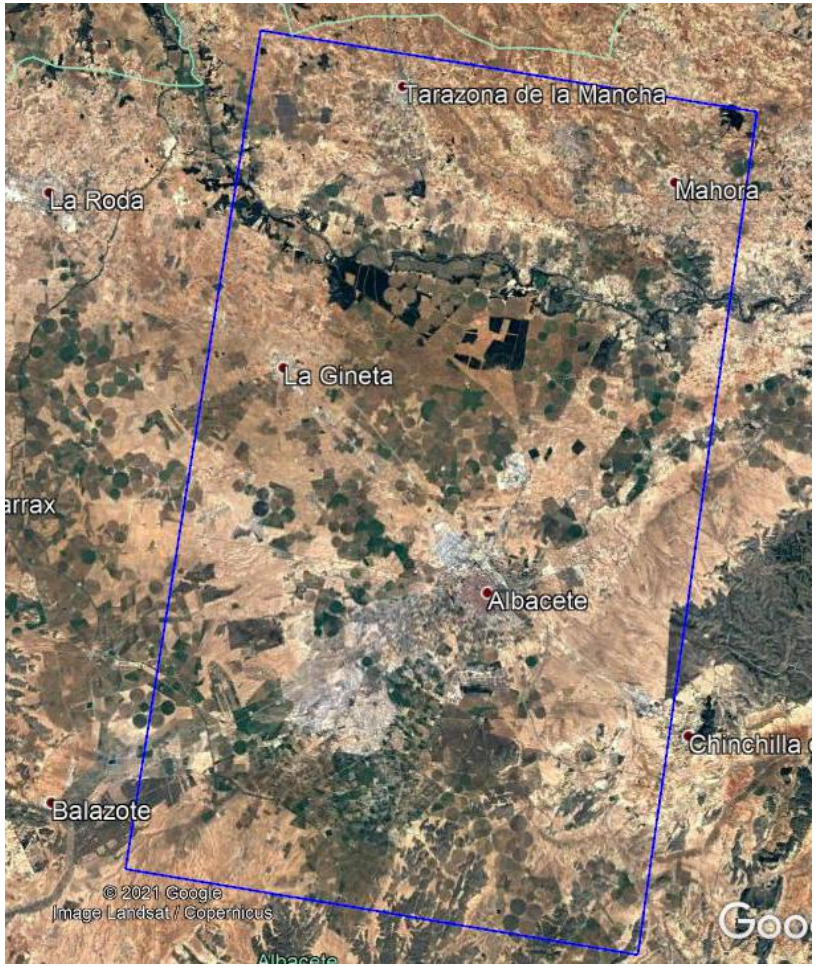
Time series: Albacete strip 11 – HH

- Albacete test site shows the temporal evolution of the coherence over agricultural fields

Coherence TDX – PAZ (4 days ; 380m)



Land Cover map (CORINE)



Optical image

Time series: Albacete strip 11 – HH

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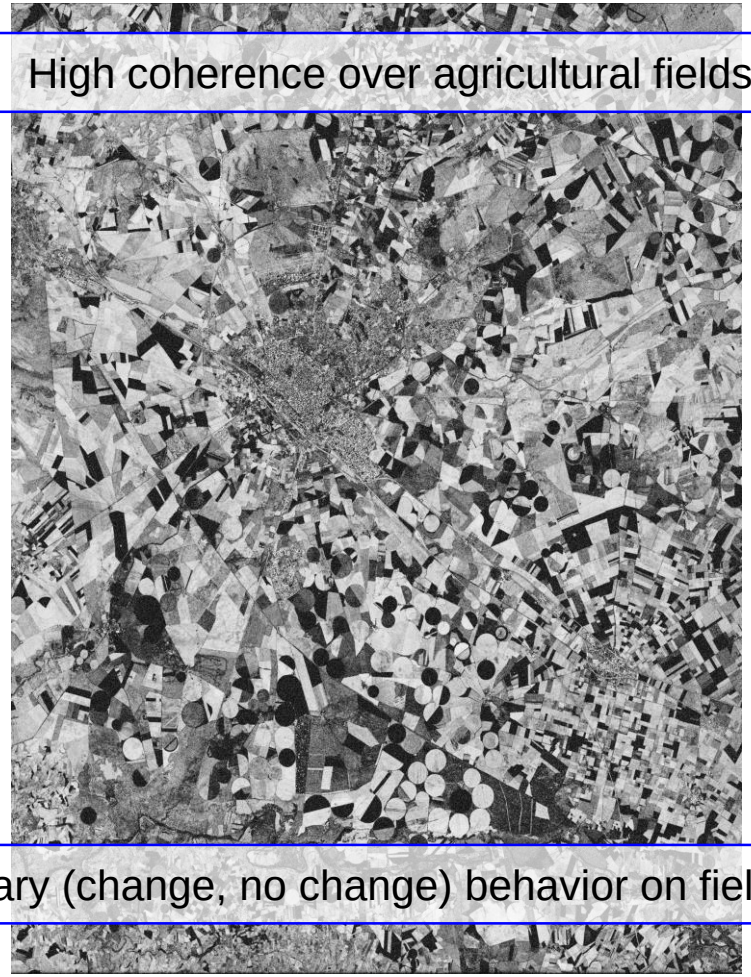


Coherence TDX – PAZ (15 days ; 330m)

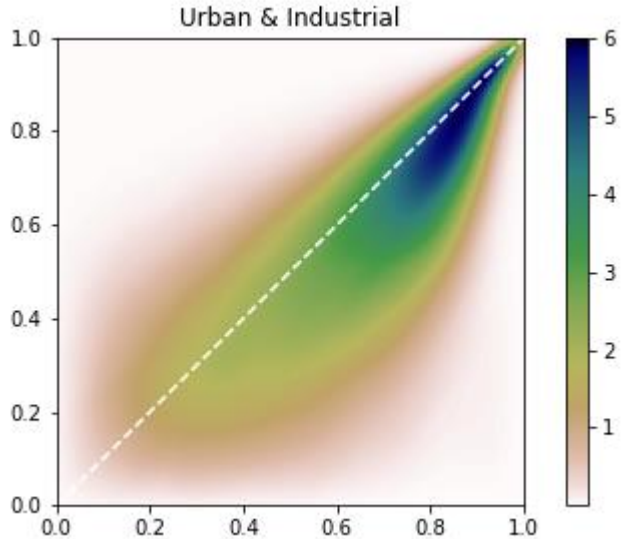
Coherence TDX – PAZ (48 days ; 410m)

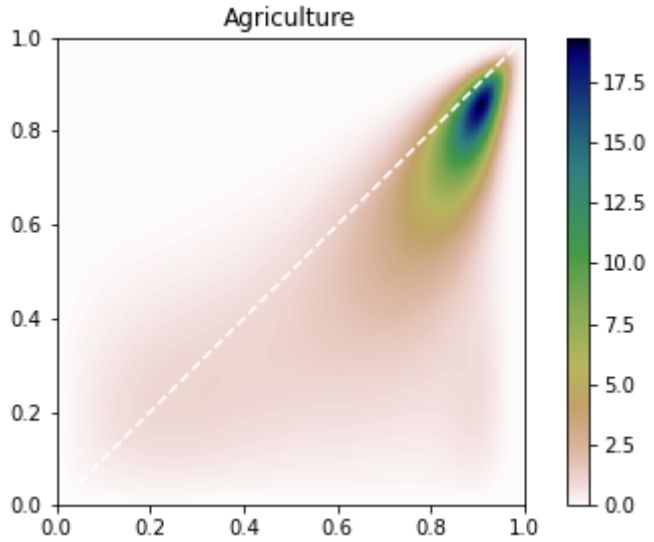
High coherence over agricultural fields

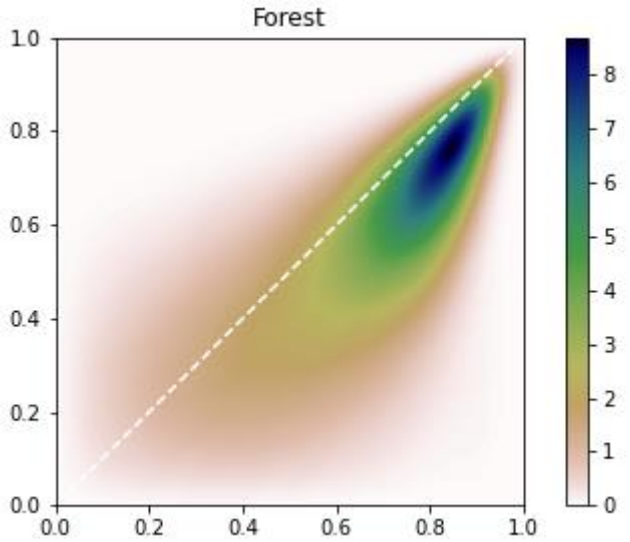
Binary (change, no change) behavior on fields

Time series: Coherence signature for different land cover

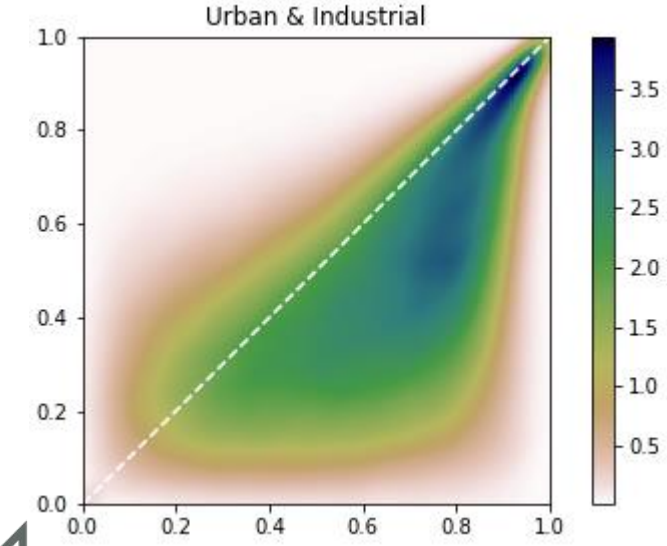
4 days vs. 15 days

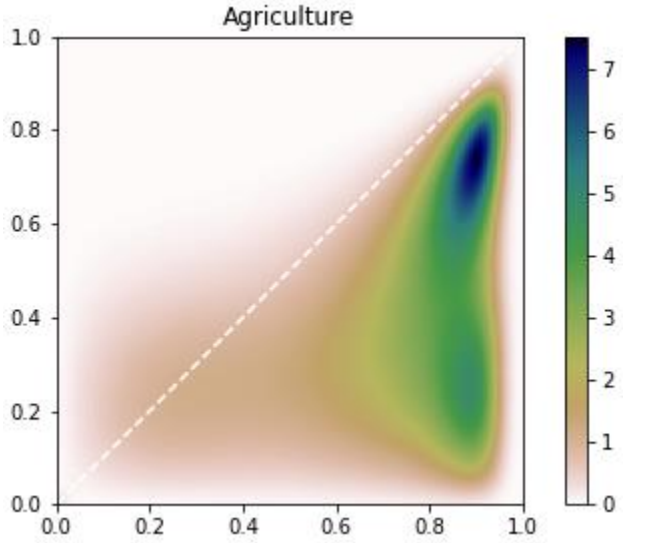


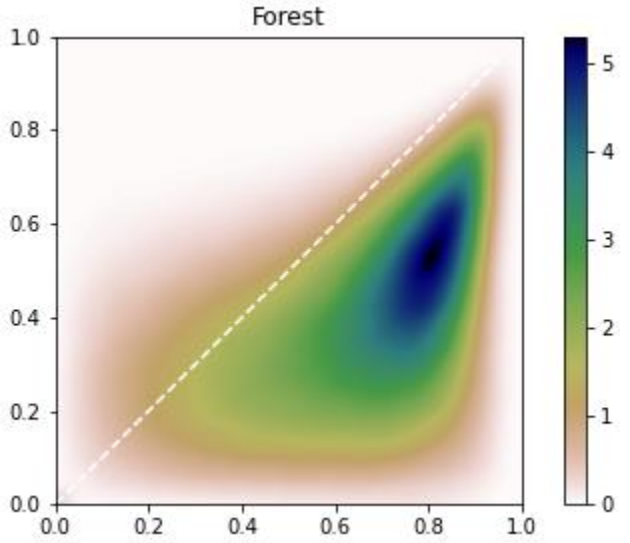




4 days vs. 48 days







Conclusions

- Very good interoperability between TeraSAR-X/TanDEM-X and PAZ
  - Very similar coherence and results than TSX/TDX interferograms – no performance loss by exchanging both sensors
  - Both sensors are interchangeable to build denser time series with 4/7 days temporal difference
- Temporal decorrelation at X-band over dense forest is the largest decorrelation source
  - Even zero baseline acquisition with 4 days temporal difference present large decorrelation over forested areas in Neustrelitz
- Over areas with not so significant forested coverage, the coherence remains high enough
  - Coherence and phase good enough over these areas to perform repeat pass DEMs at X-band
  - Agricultural areas present high coherence until a phenological change generates decorrelation

Alonso-González, A., Martínez, N. G., Hajnsek, I., Revenga, P. C., Bonilla, M. J. G., Grigorov, C., ... & Rodríguez, M. G. (2021). Joint PAZ & TanDEM-X Mission Interferometric Experiments: Interoperability and Products. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 14, 6069-6082.

Thank you for your attention!