ON THE EXPLOITATION OF ETAD DATA FOR THE ATMOSPHERIC PHASE SCREEN FILTERING OF MEDIUM/HIGH RESOLUTION DInSAR PRODUCTS

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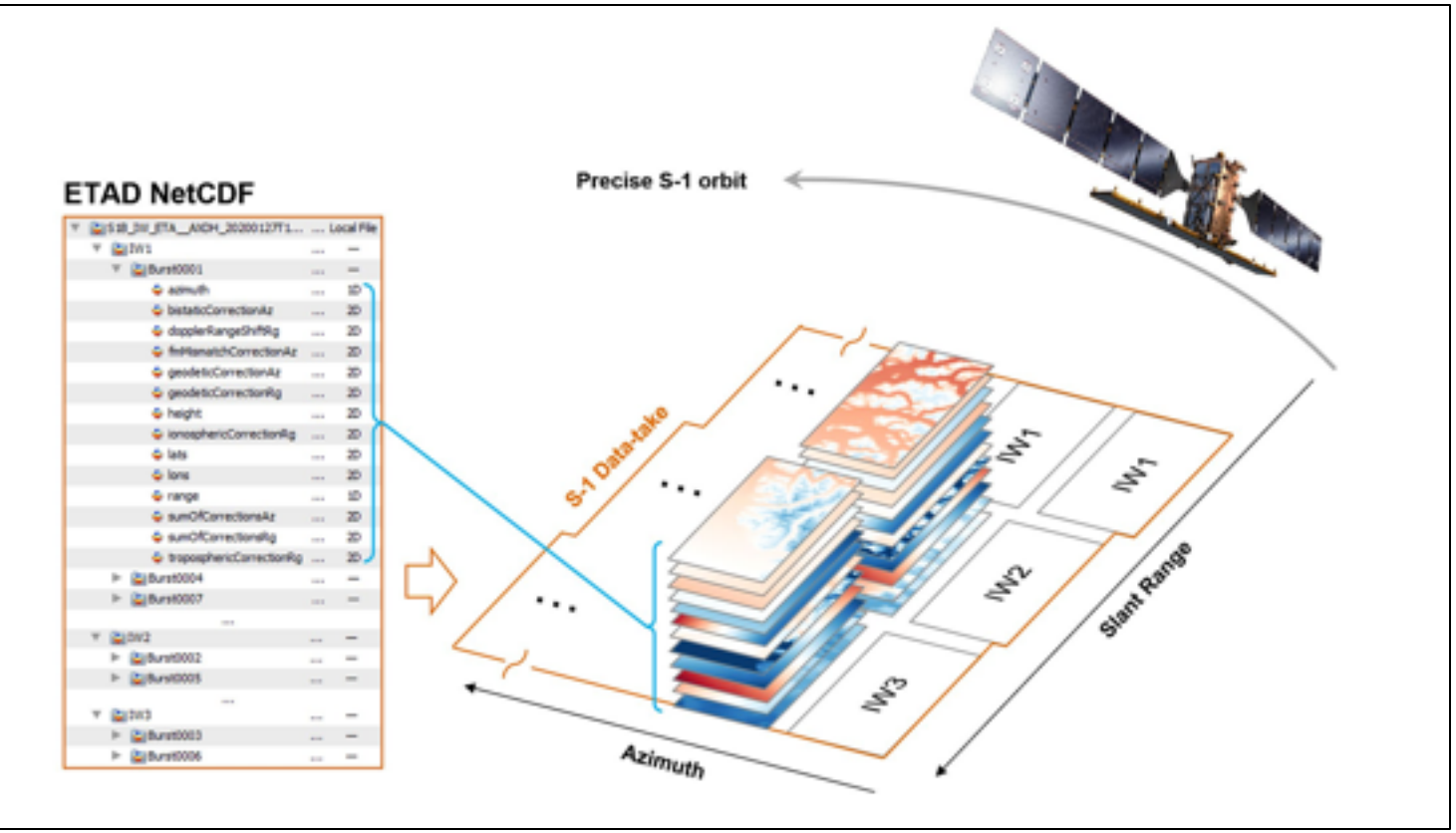
Outline

- Brief introduction to the ETAD data
- Artifacts investigation within the **A**tmospheric **P**hase **S**creen (**APS**) filtered medium/full resolution Sentinel-1 DInSAR interferograms obtained by using the actual ETAD products
- Proposed solution to avoid the revealed (phase) artifacts for multi-temporal interferogram sequences and its simplification for single interferograms
- Concluding remarks

Brief introduction to the ETAD data

The **ETAD** (**E**xtended **T**iming **A**nnotation **D**ataset) data consist of a set of correction layers allowing us to improve the range and azimuth timing of the Sentinel-1 SAR images (centimetric accuracy of the image pixels)

ETAD data details



C. Gisinger *et al.*, "The Extended Timing Annotation Dataset for Sentinel-1—Product Description and First Evaluation Results," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 60, pp. 1-22, 2022, Art no. 5232622, doi: 10.1109/TGRS.2022.3194216.

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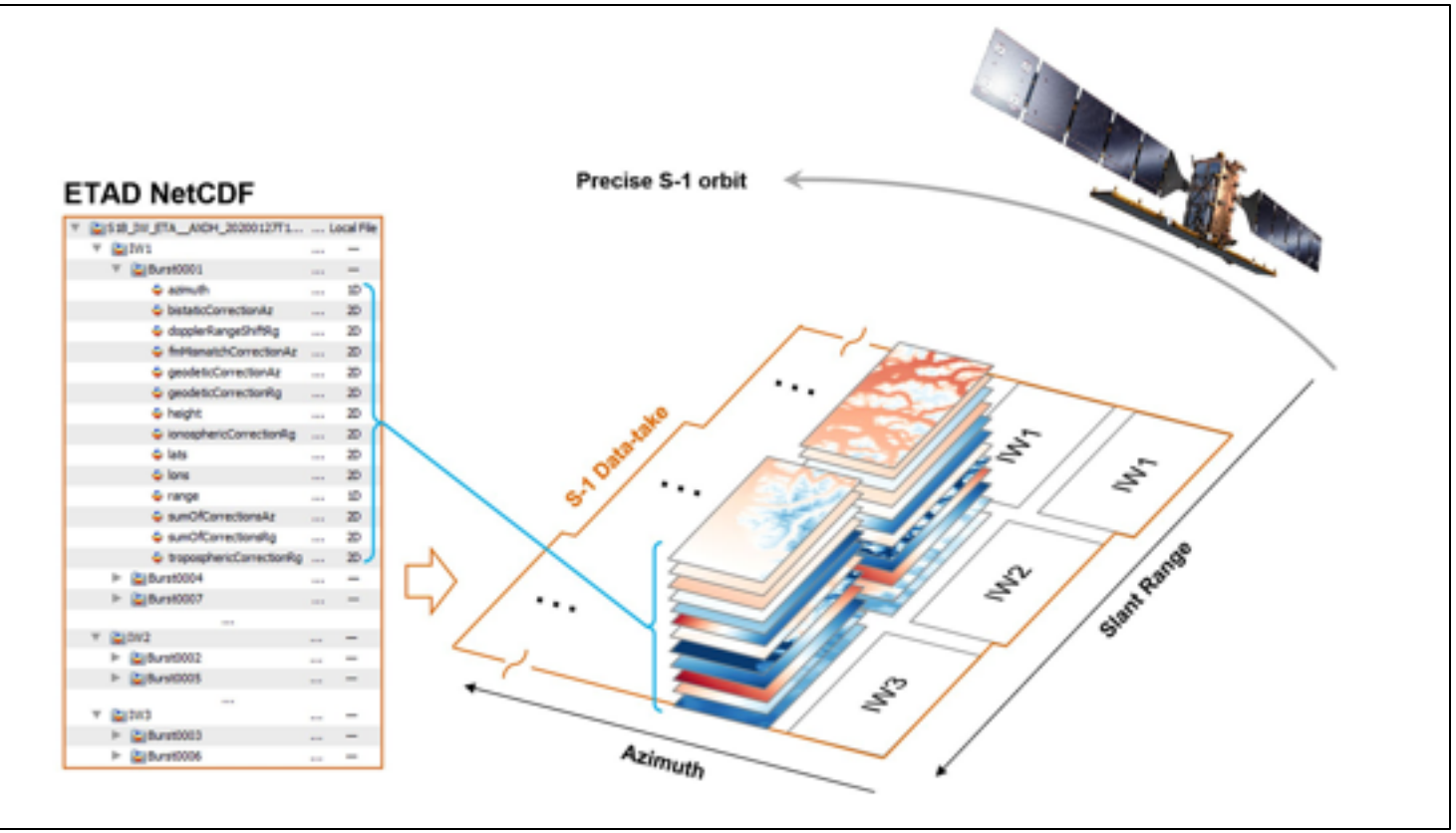

ETAD LAYERS CHARACTERISTICS

- Grid spacing of 200 m for the entire data take (*sub-sampled* of a factor of 52 in range and 14 in azimuth with respect to the corresponding S-1 SLC full resolution burst images)
- Available at burst level

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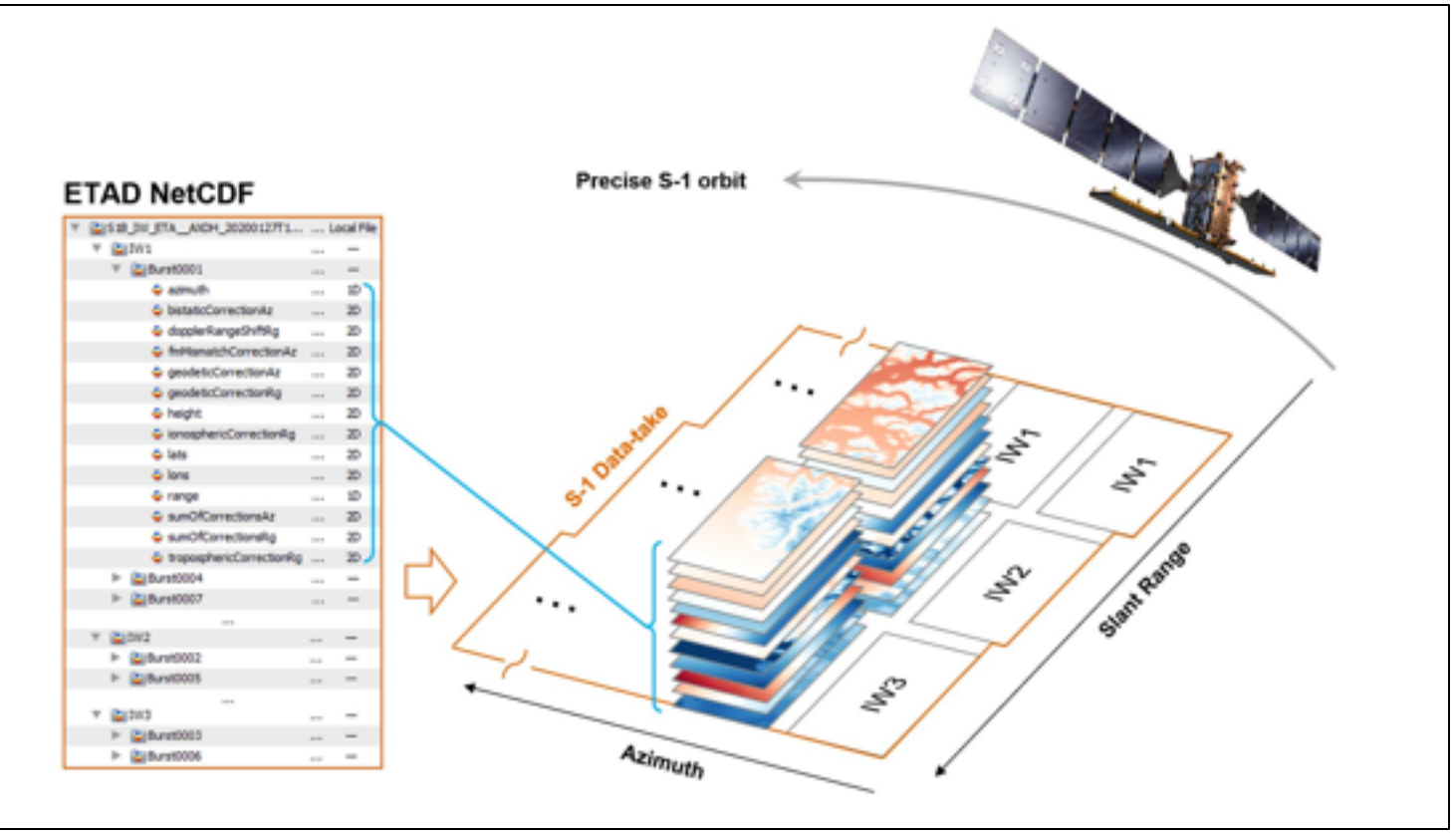

ETAD LAYERS LIST

- Tropospheric delay in range
- Ionospheric delay in range
- Solid Earth tidal displacements
- Bistatic azimuth shifts
- Doppler-induced range shifts
- FM-rate mismatch azimuth shifts

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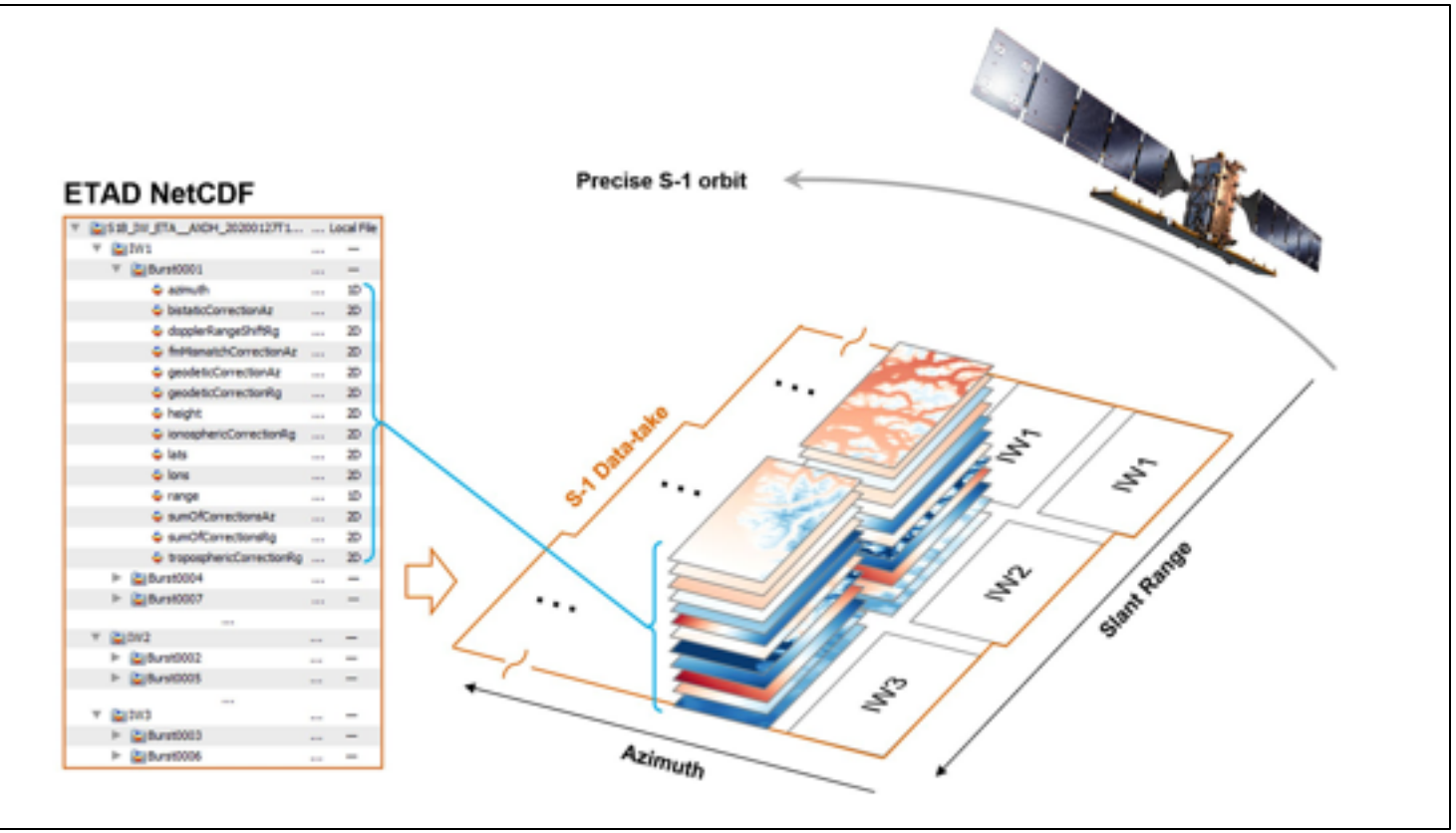

ETAD LAYERS LIST

- Tropospheric delay in range
- Ionospheric delay in range
- Solid Earth tidal displacements

THESE LAYERS CAN BE USED TO MITIGATE THE APS SIGNAL COMPONENT AFFECTING THE DInSAR INTERFEROGRAMS

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Brief introduction to the ETAD data

For each S-1 image and for each burst we:

- extract the required ETAD correction layers and all the associated information
- resample the selected ETAD layers to SLC image resolution by applying a bilinear interpolation for t and τ
- apply the SAR SLC master to secondary co-registration parameters from the interferometric processing to the selected ETAD correction layers
- compute the differential range delay correction:

$$(\text{troposphericCorrectionRg} + \text{geodeticCorrectionRg} - \text{ionosphericCorrectionRg} + \text{burst:instrumentTimingCalibrationRange})_{master} - (\text{troposphericCorrectionRg} + \text{geodeticCorrectionRg} - \text{ionosphericCorrectionRg} + \text{burst:instrumentTimingCalibrationRange})_{secondary}$$

- convert the differential range delay correction to interferometric phase

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Exploited Sentinel-1 images and ETAD data

Area of interest	Central/Southern Italy
Sensors	Sentinel-1 A/B
Orbits	Ascending
Time span (dd/mm/yyyy)	10/01/2020-23/12/2020
Number of images	34

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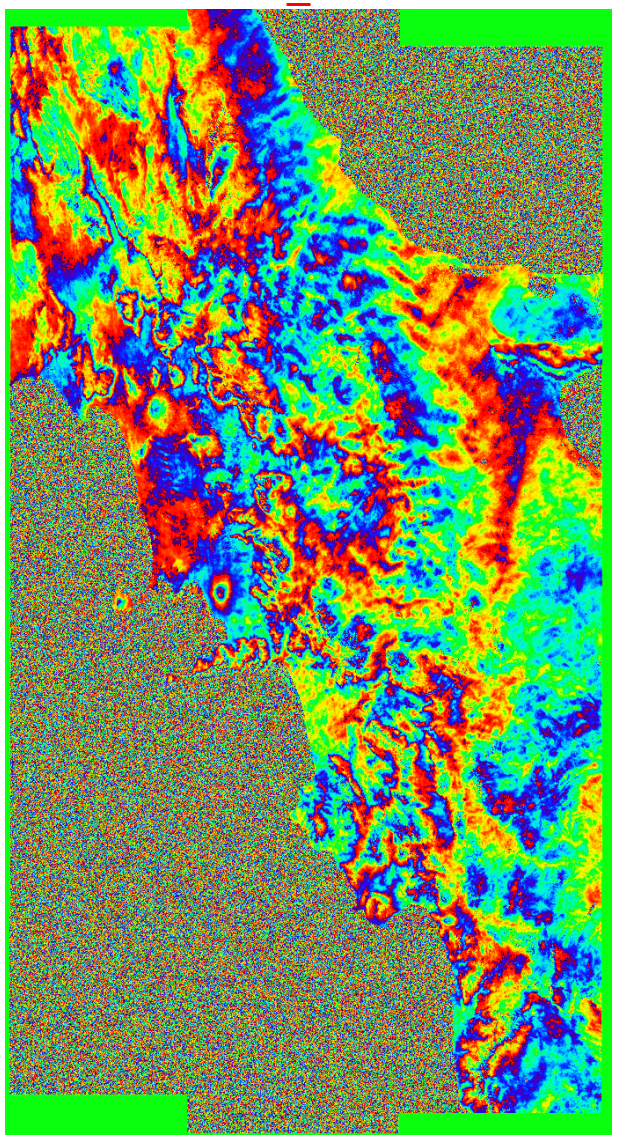
APS-filtered medium/high resolution DInSAR interferograms analysis

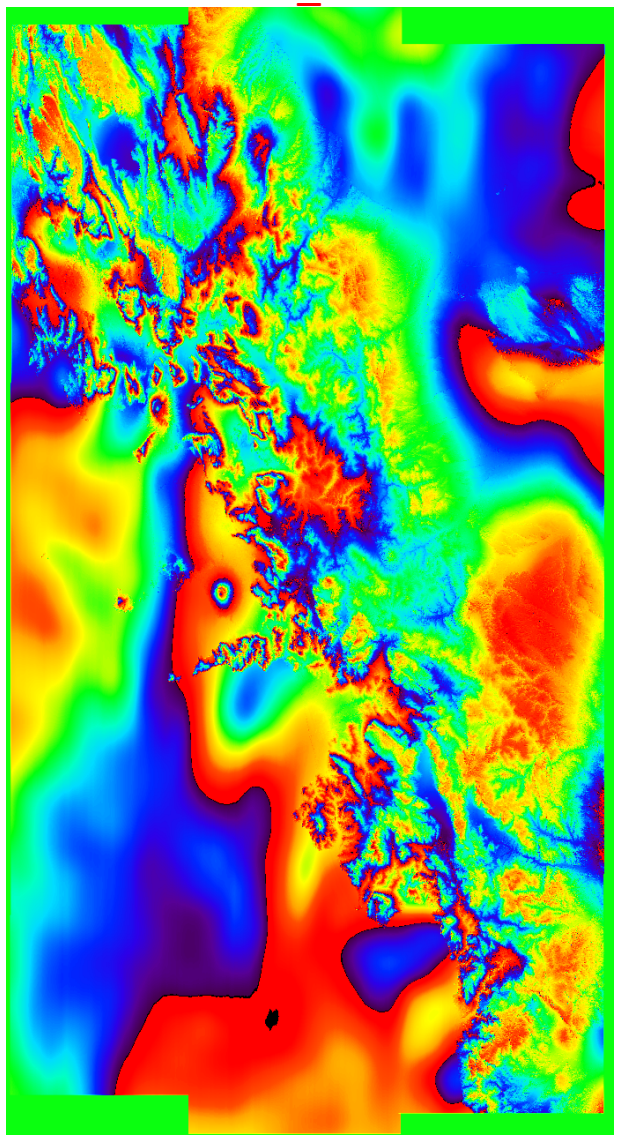
Original interferogram

03022020S1A_15022020S1A



ETAD-based APS correction

03022020S1A_15022020S1A



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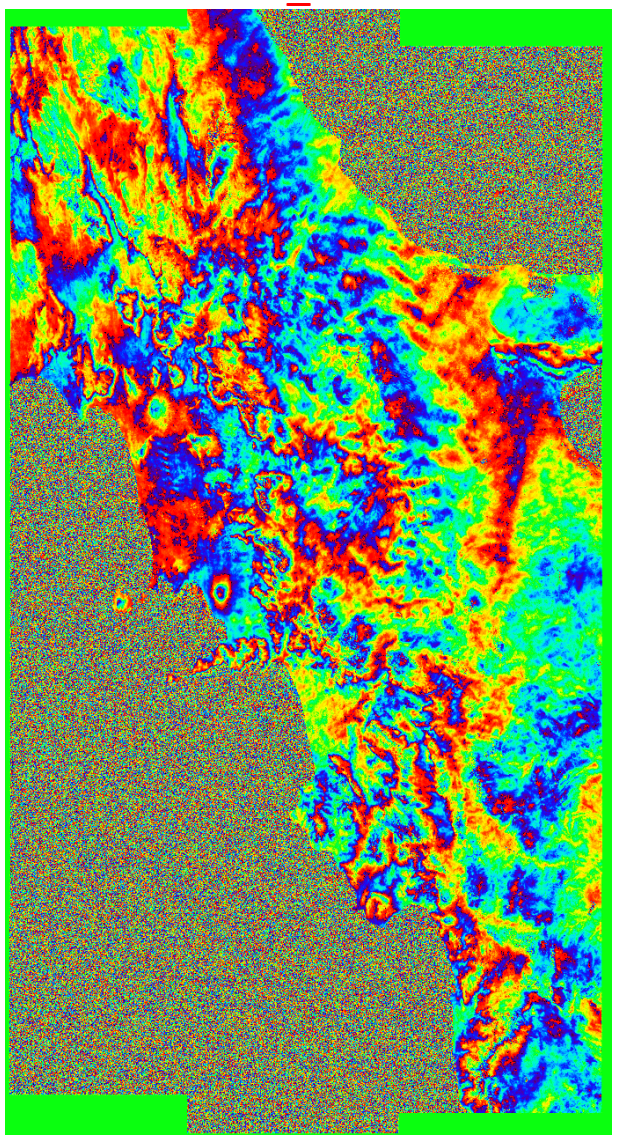
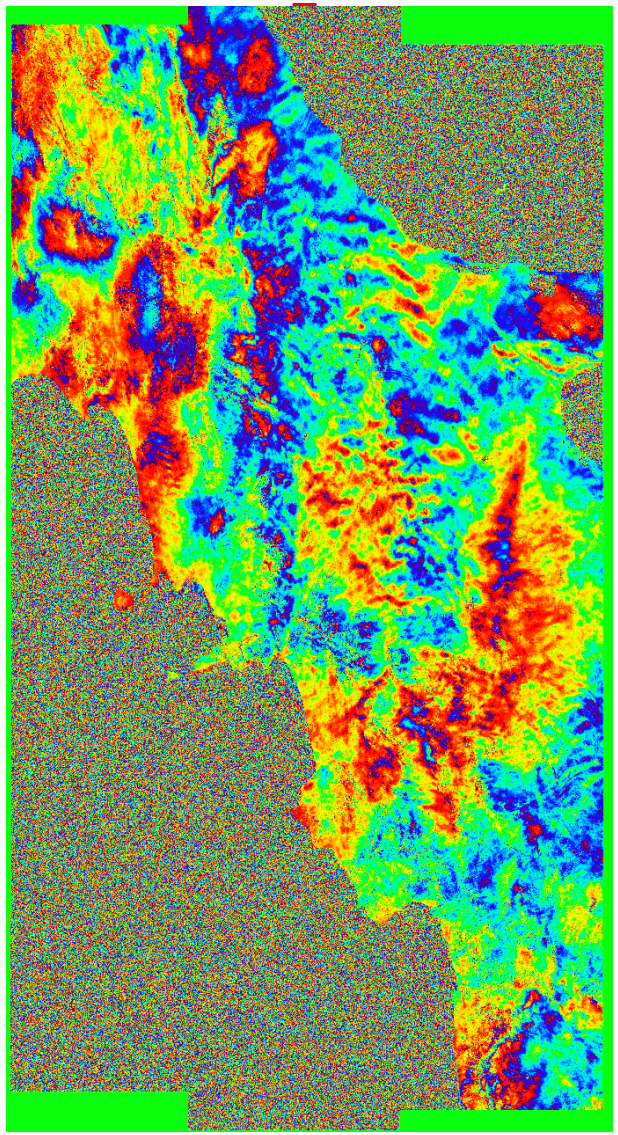
Original interferogram

03022020S1A_15022020S1A



Interferogram after APS correction

03022020S1A_15022020S1A



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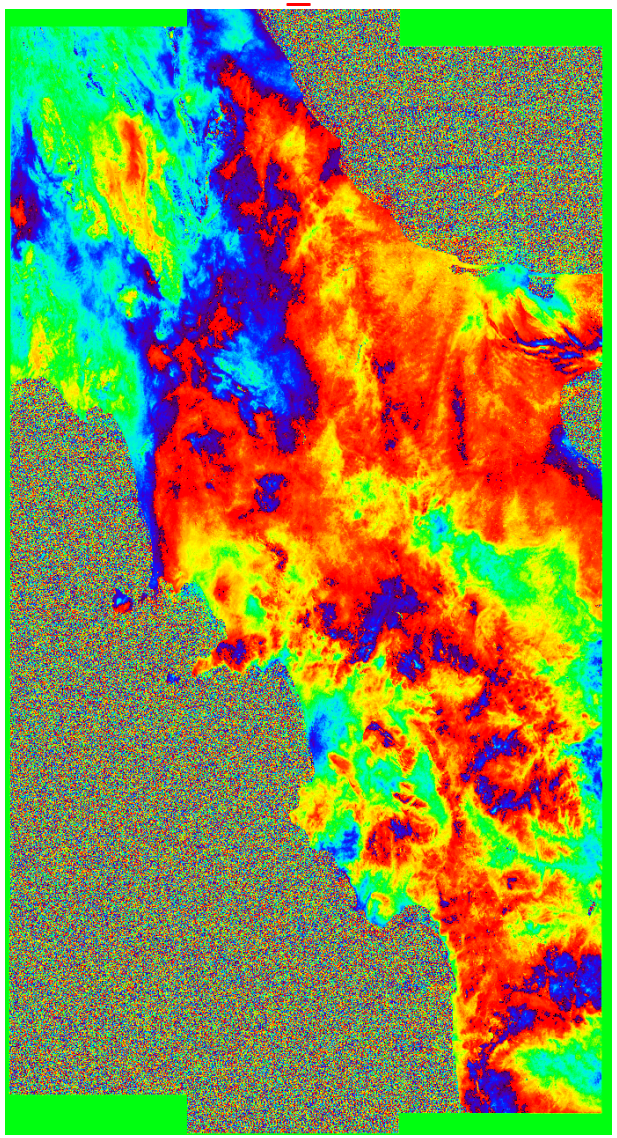
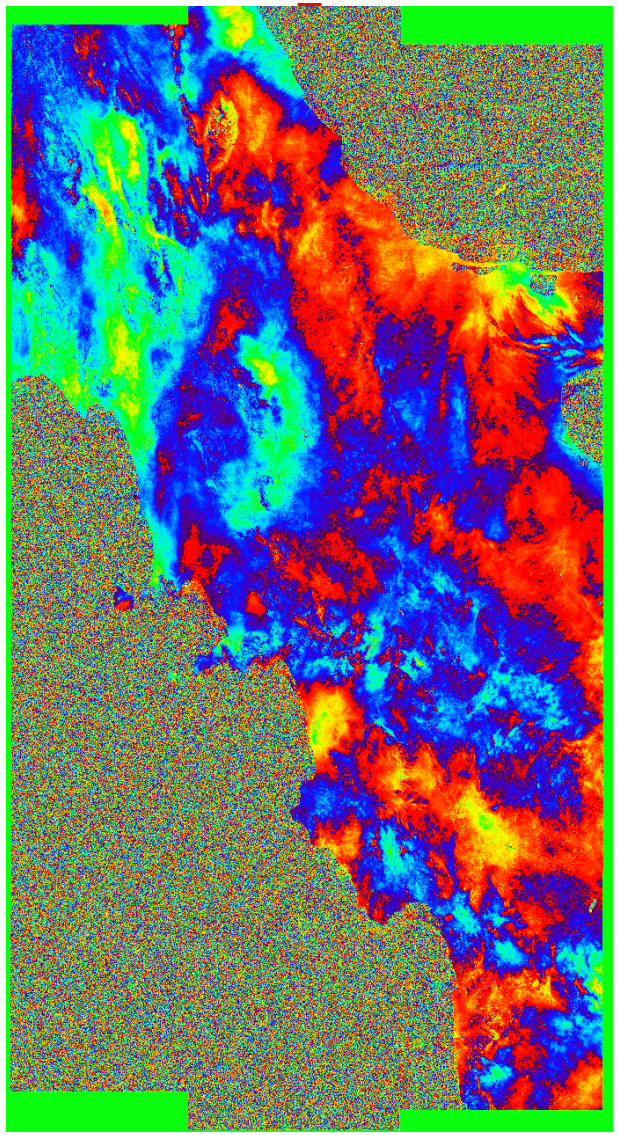
APS-filtered medium/high resolution DInSAR interferograms analysis

Original interferogram
10012020S1A_22012020S1A



Interferogram after APS correction
10012020S1A_22021020S1A



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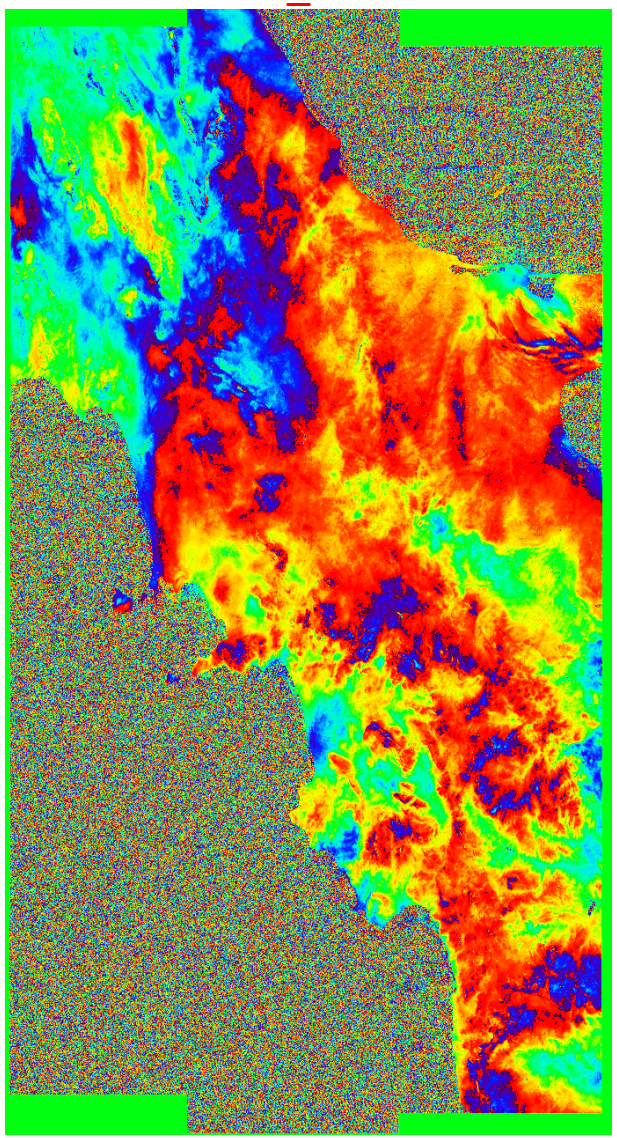
APS-filtered medium/high resolution DInSAR interferograms analysis

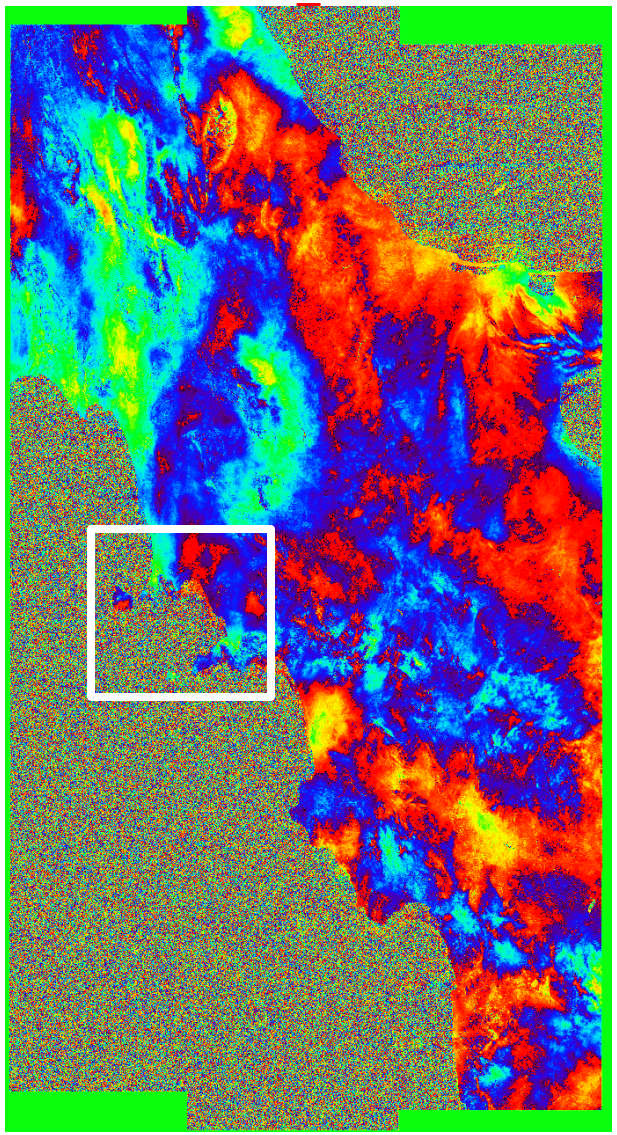
Original interferogram

10012020S1A_22012020S1A



Interferogram after APS correction

10012020S1A_22021020S1A



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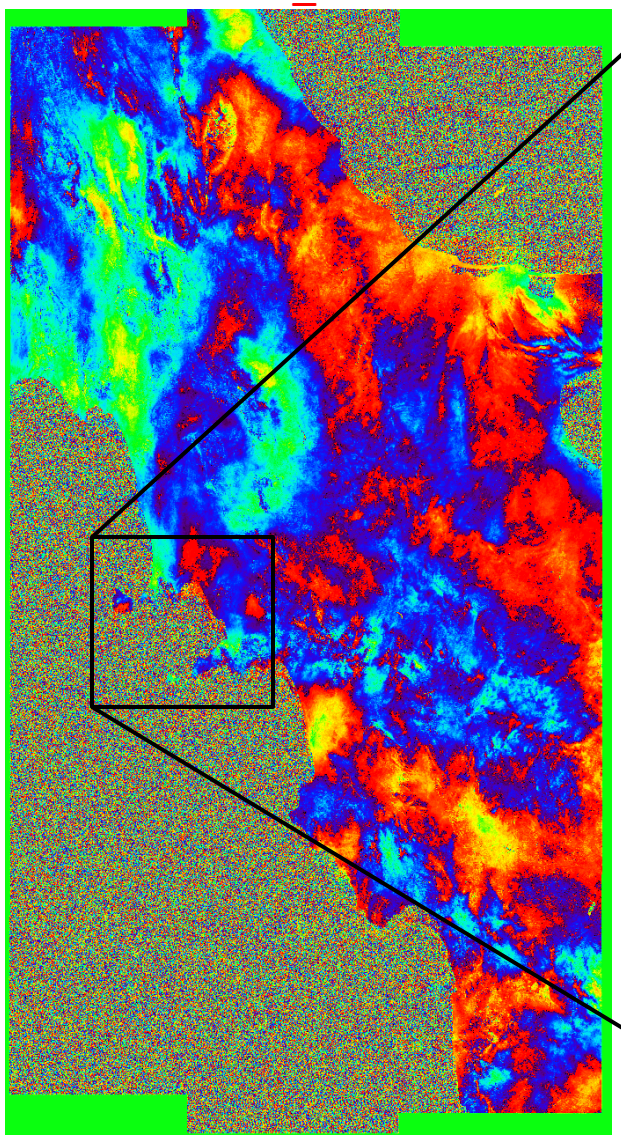
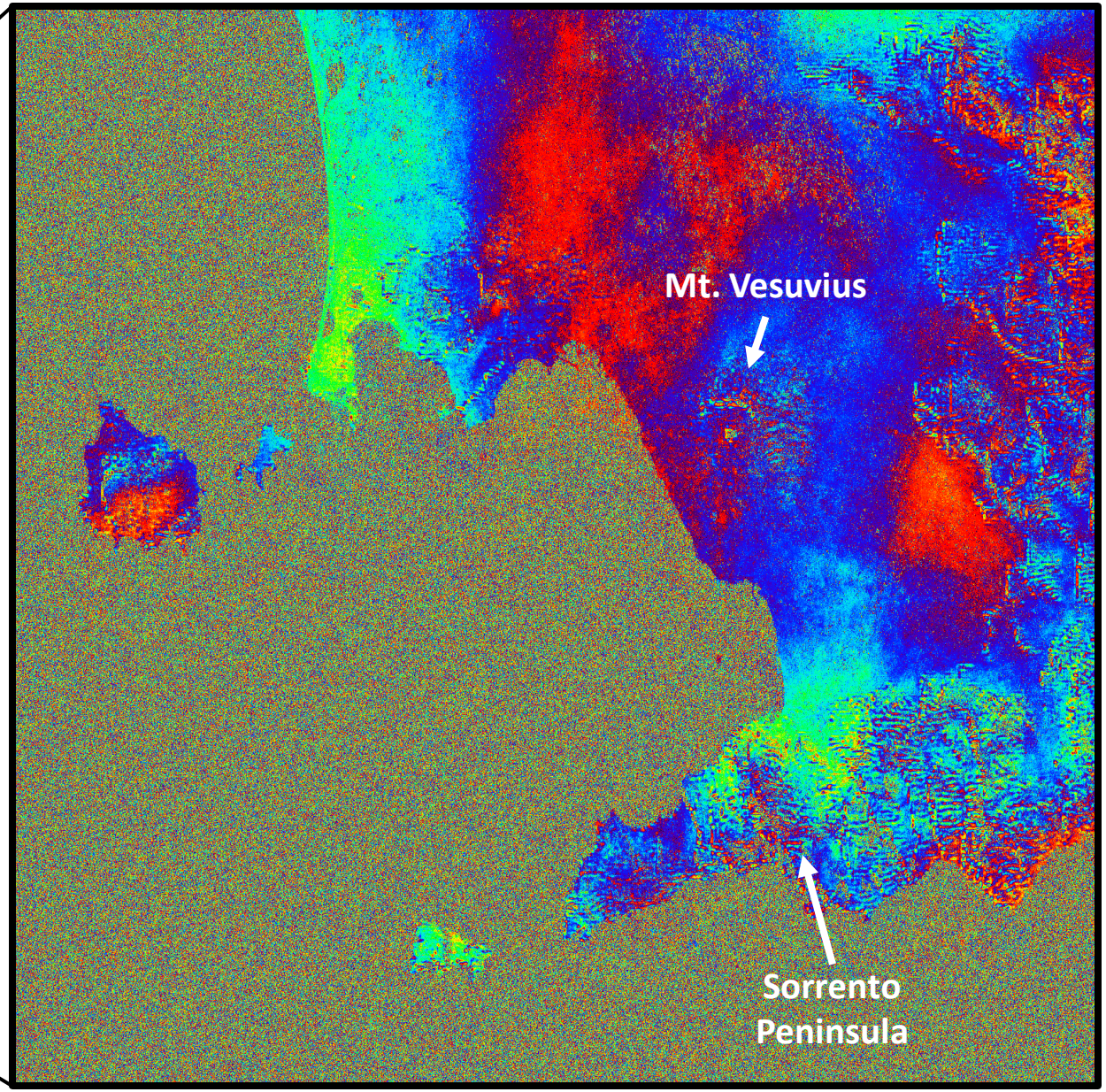
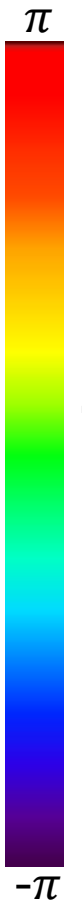
APS-filtered medium/high resolution DInSAR interferograms analysis

Interferogram after APS correction

10012020S1A_22021020S1A







Note that 80 m x 80 m multilooked interferograms are considered

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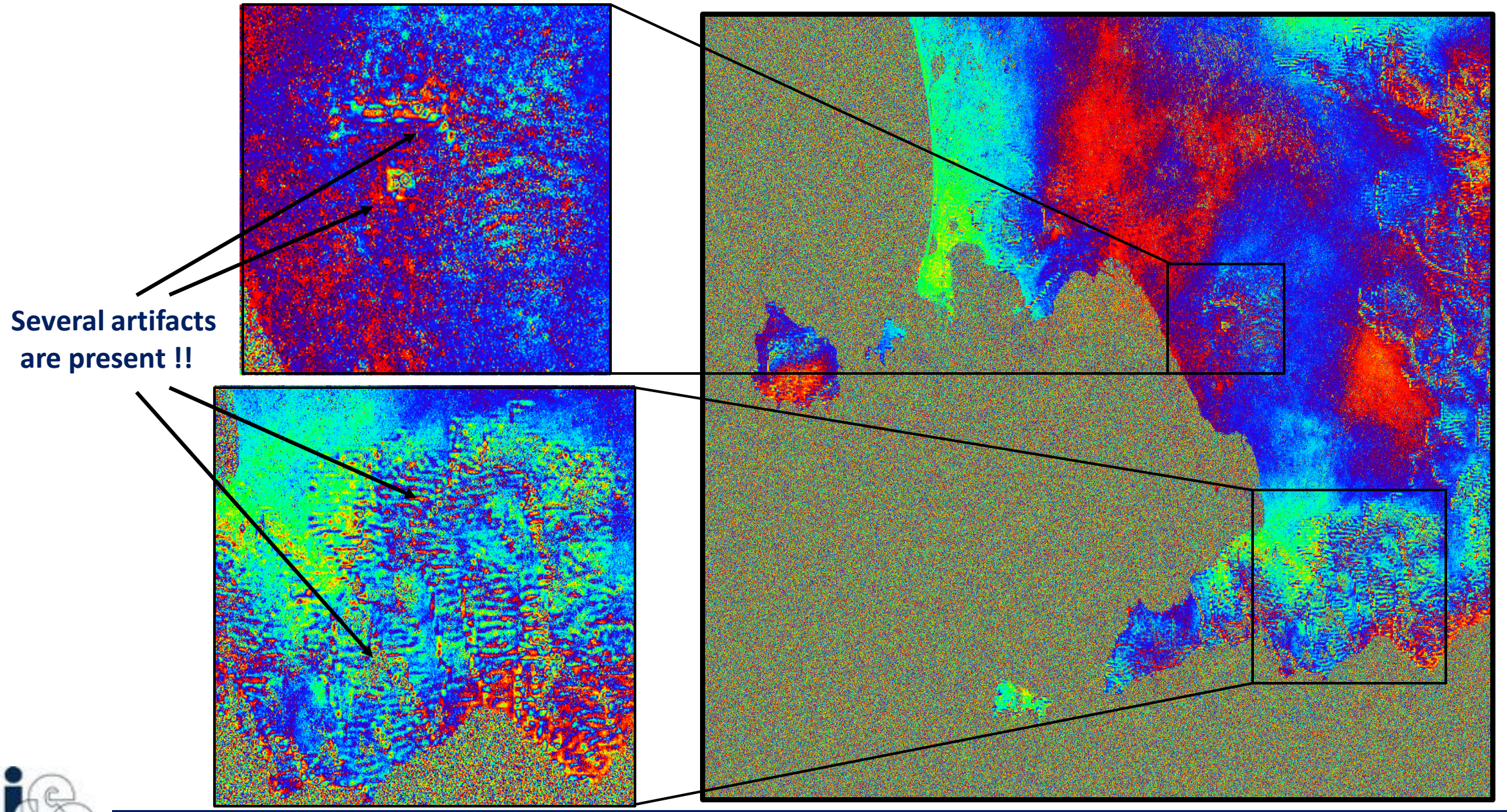
Problem



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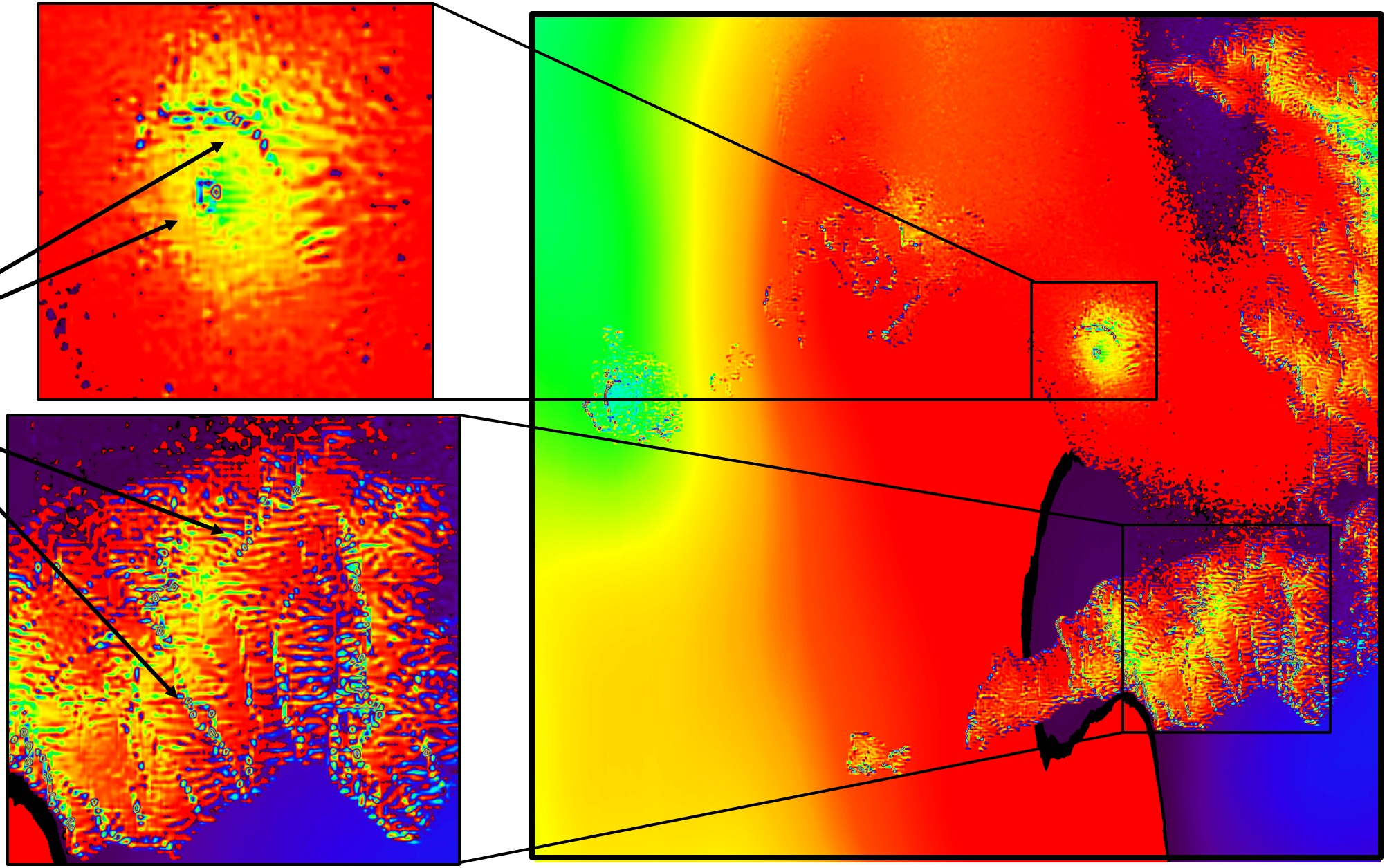
Problem

The artifacts are due to the Tropospheric component



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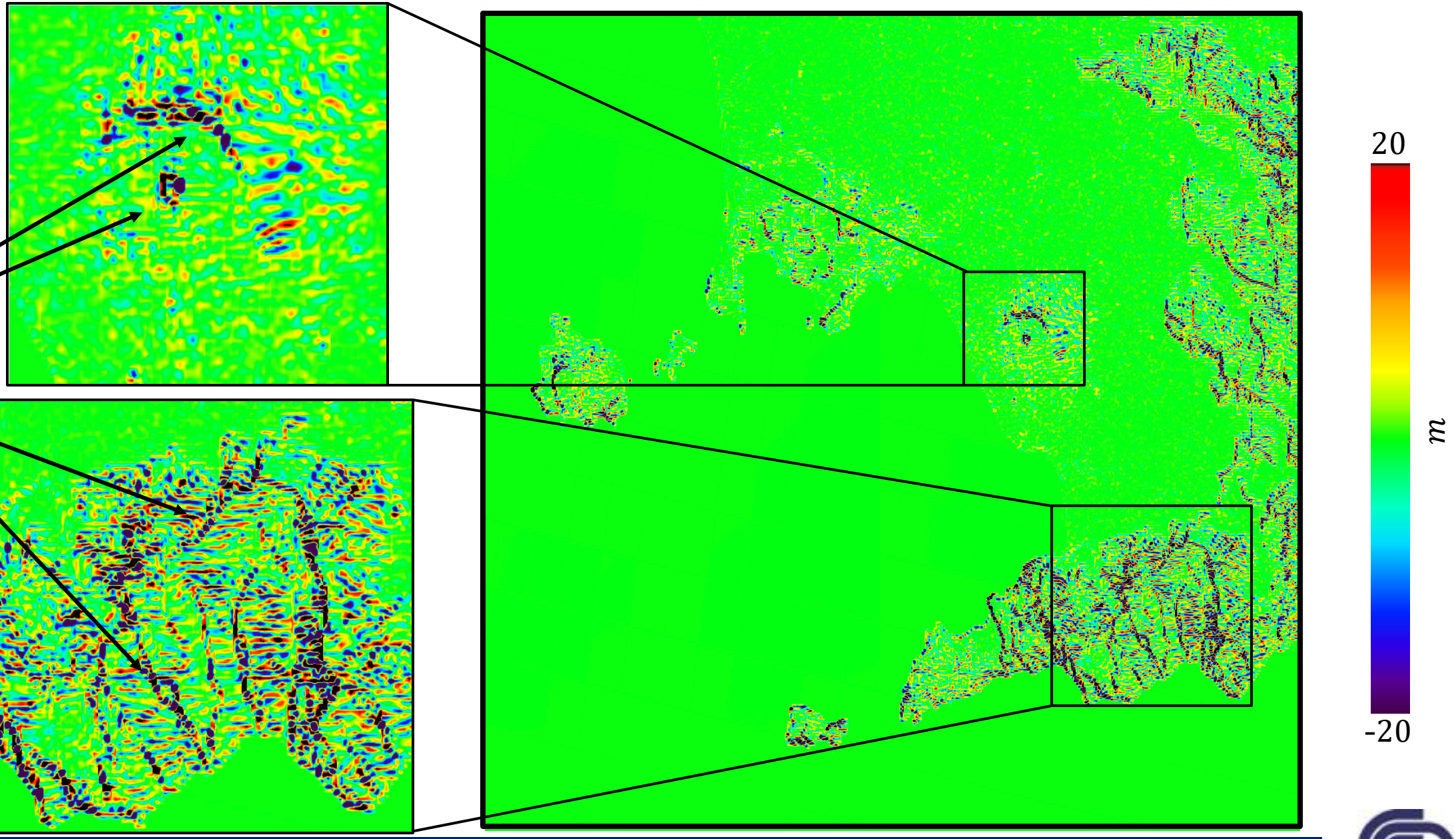
Problem

The artefacts are caused by the DEM height variations due to the different projections within the range-azimuth grid of each Sentinel-1 image.



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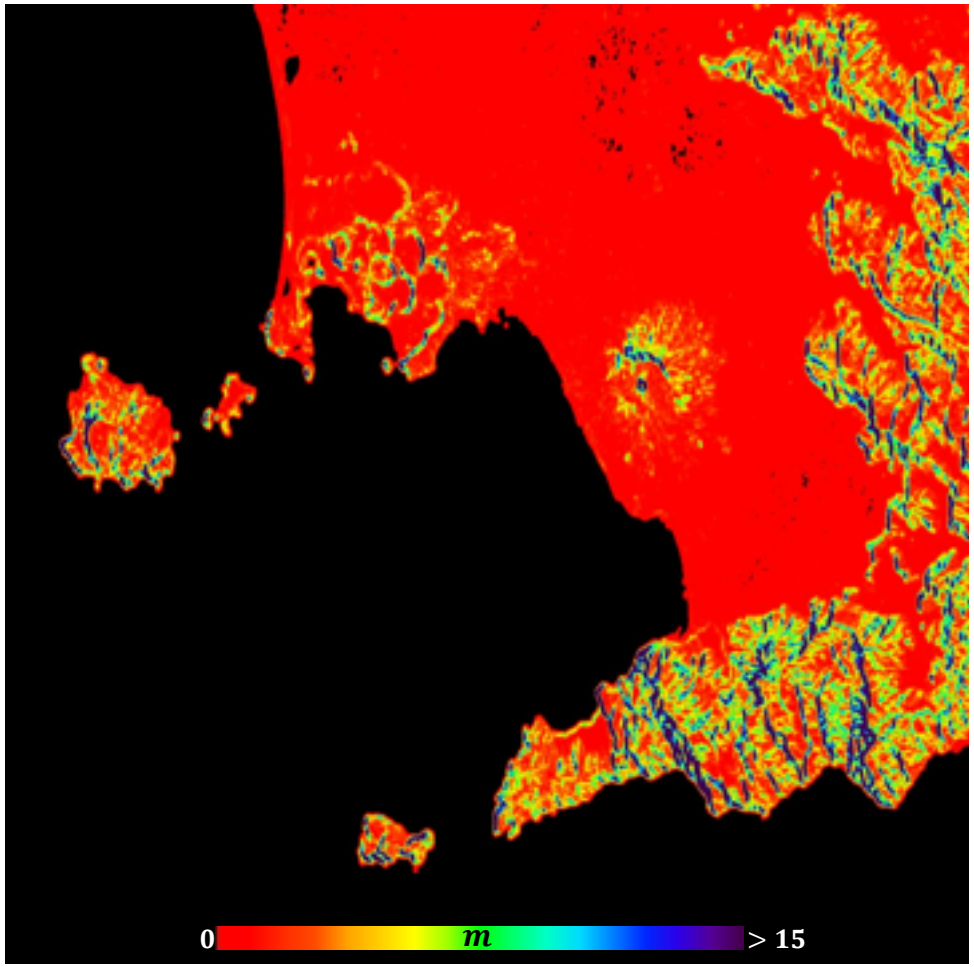
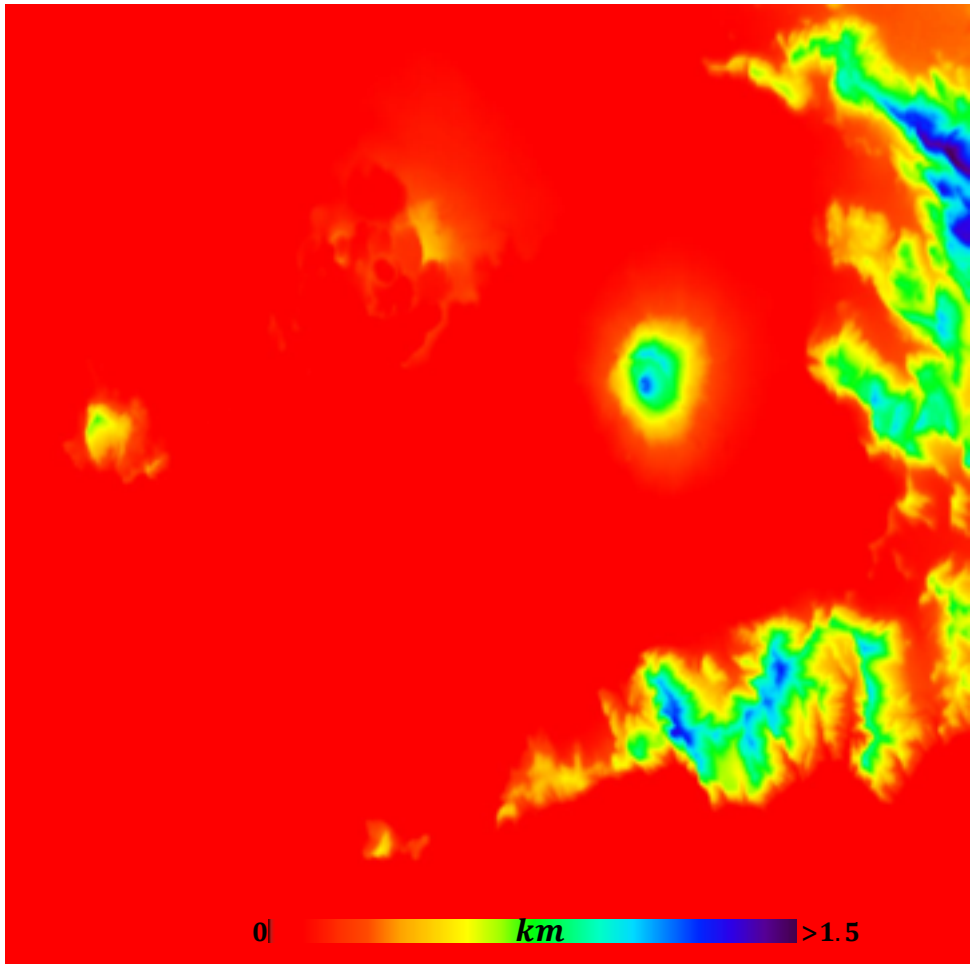
Problem

DEM standard deviation (multi-temporal acquisitions)



The artifacts can be easily identified through the evaluation of the DEMs standard deviation

Mean DEM (multi-temporal acquisitions)



We can exploit the DEM available in each ETAD product to compute a mean DEM

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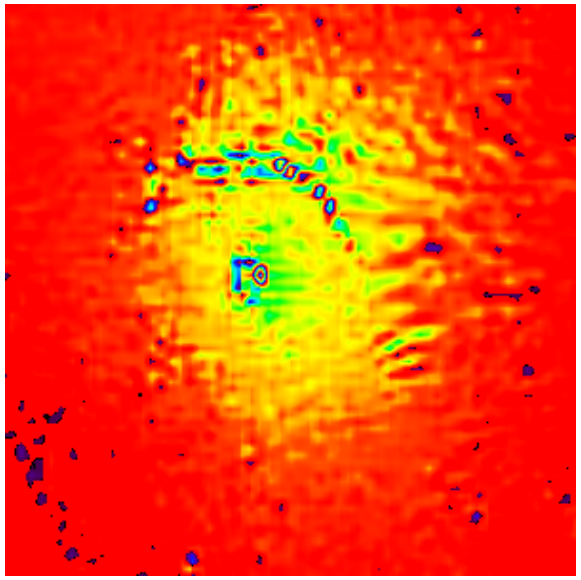
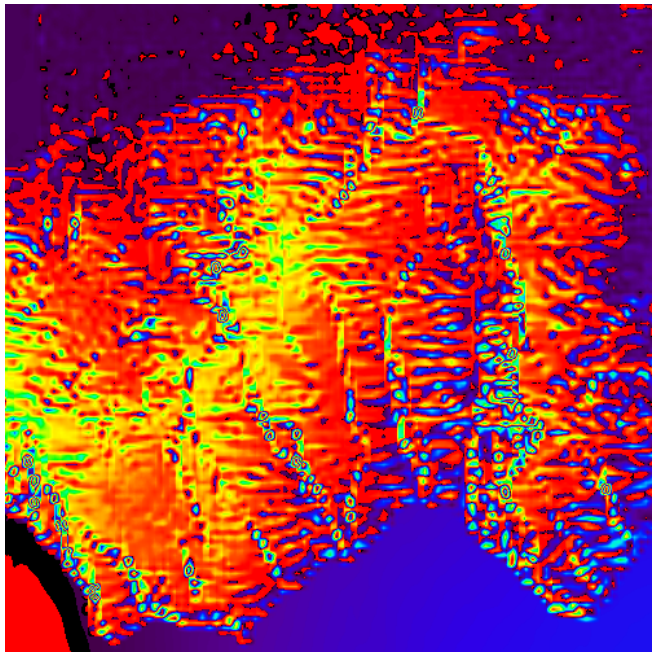
Proposed solution





Artifacts-affected Tropospheric component

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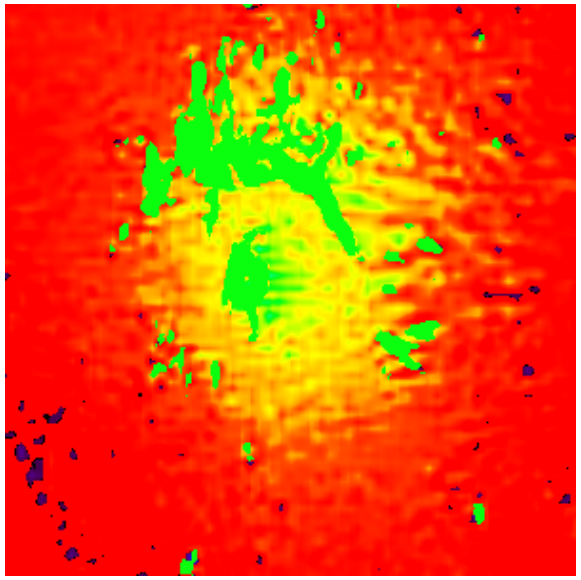
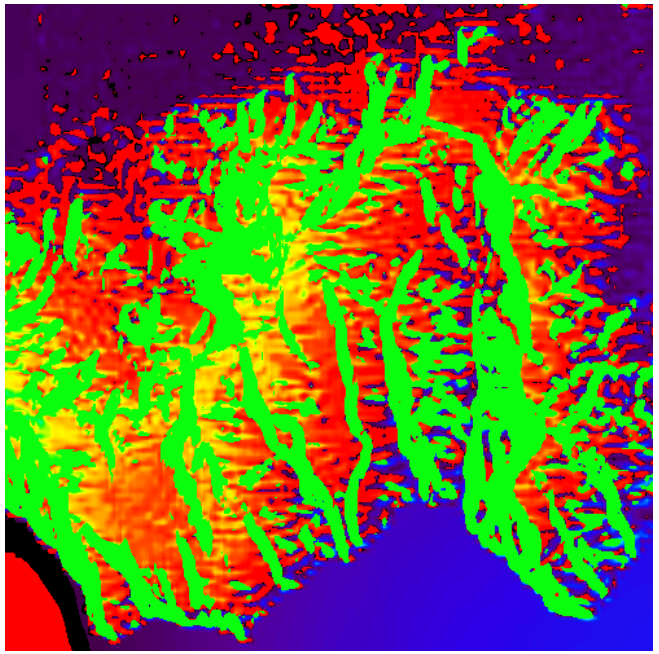
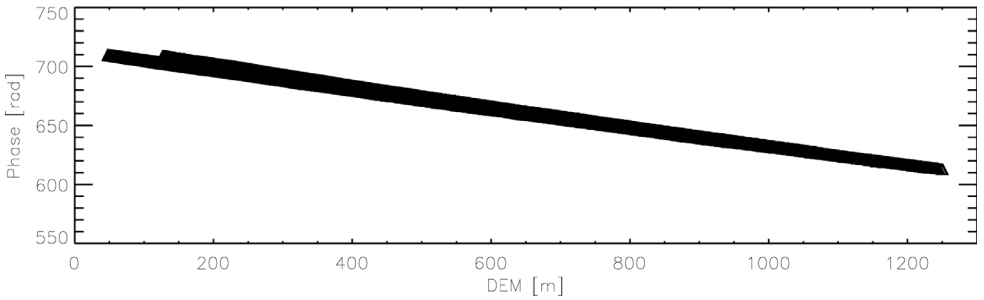
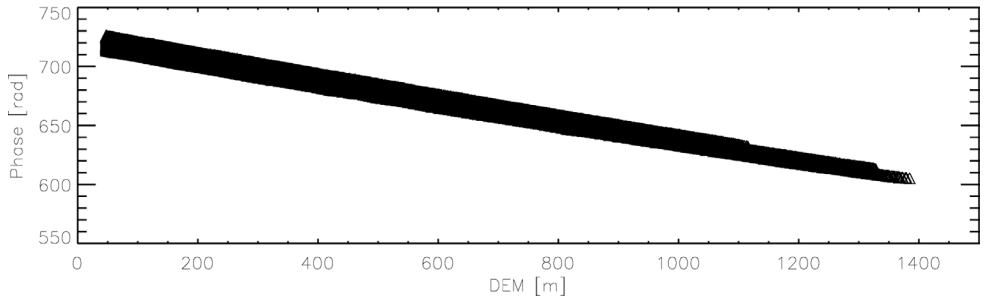
Proposed solution



We can mask out the pixels with high values of the DEM standard deviation







We can very easily exploit the computed mean DEM and the quasi linear height dependence (particularly for moderate height differences) of the tropospheric signal to remove the identified artifacts

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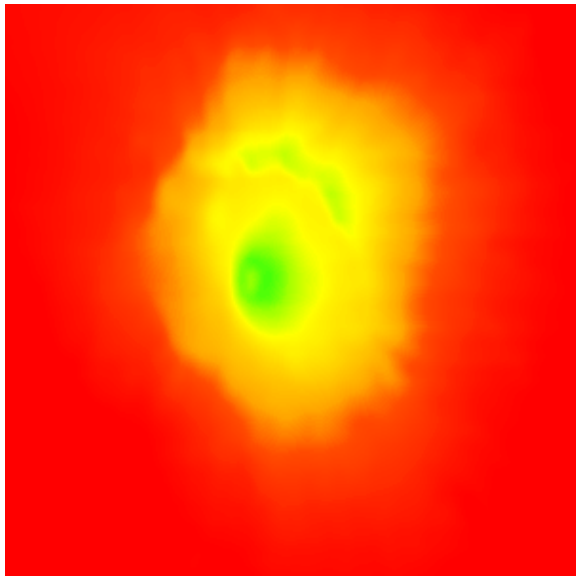
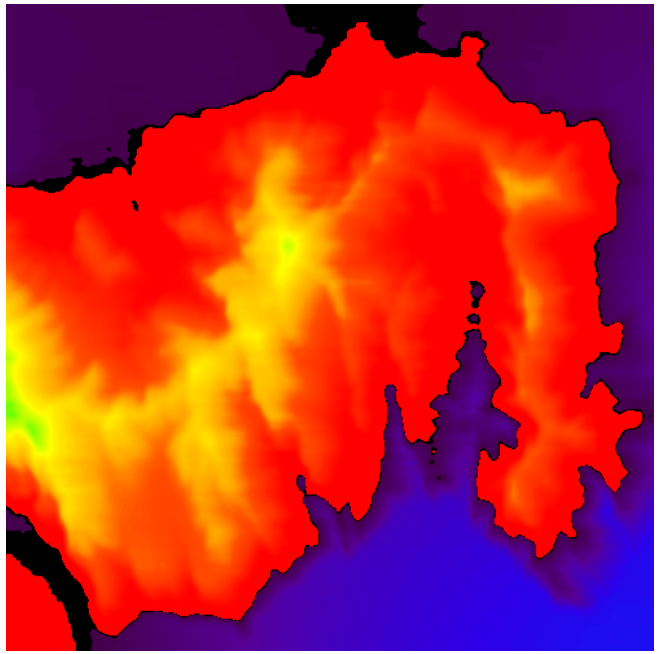
Proposed solution





Artifacts-free Tropospheric component

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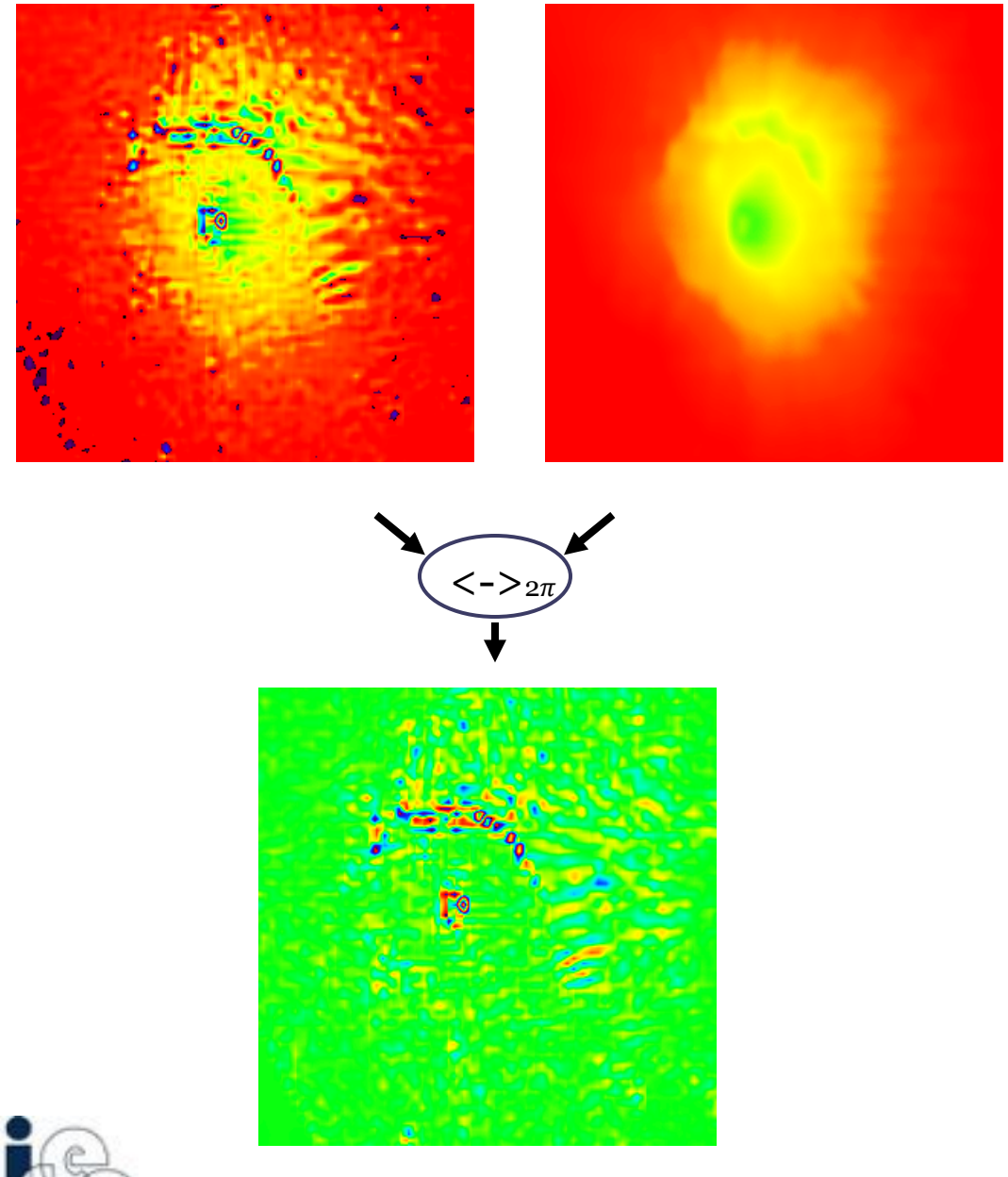
Proposed solution



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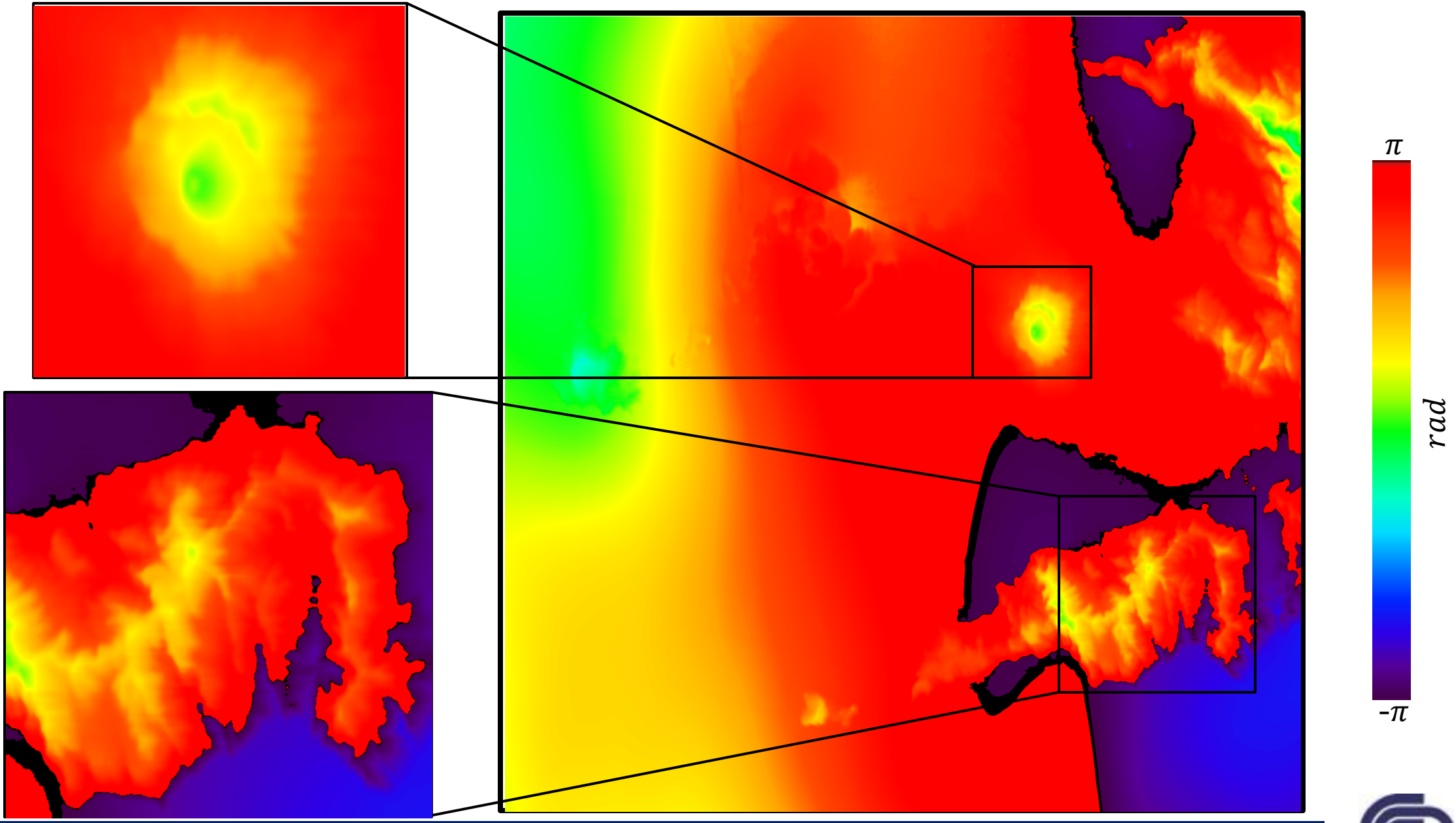
Proposed solution

The artifacts within the Tropospheric component are corrected



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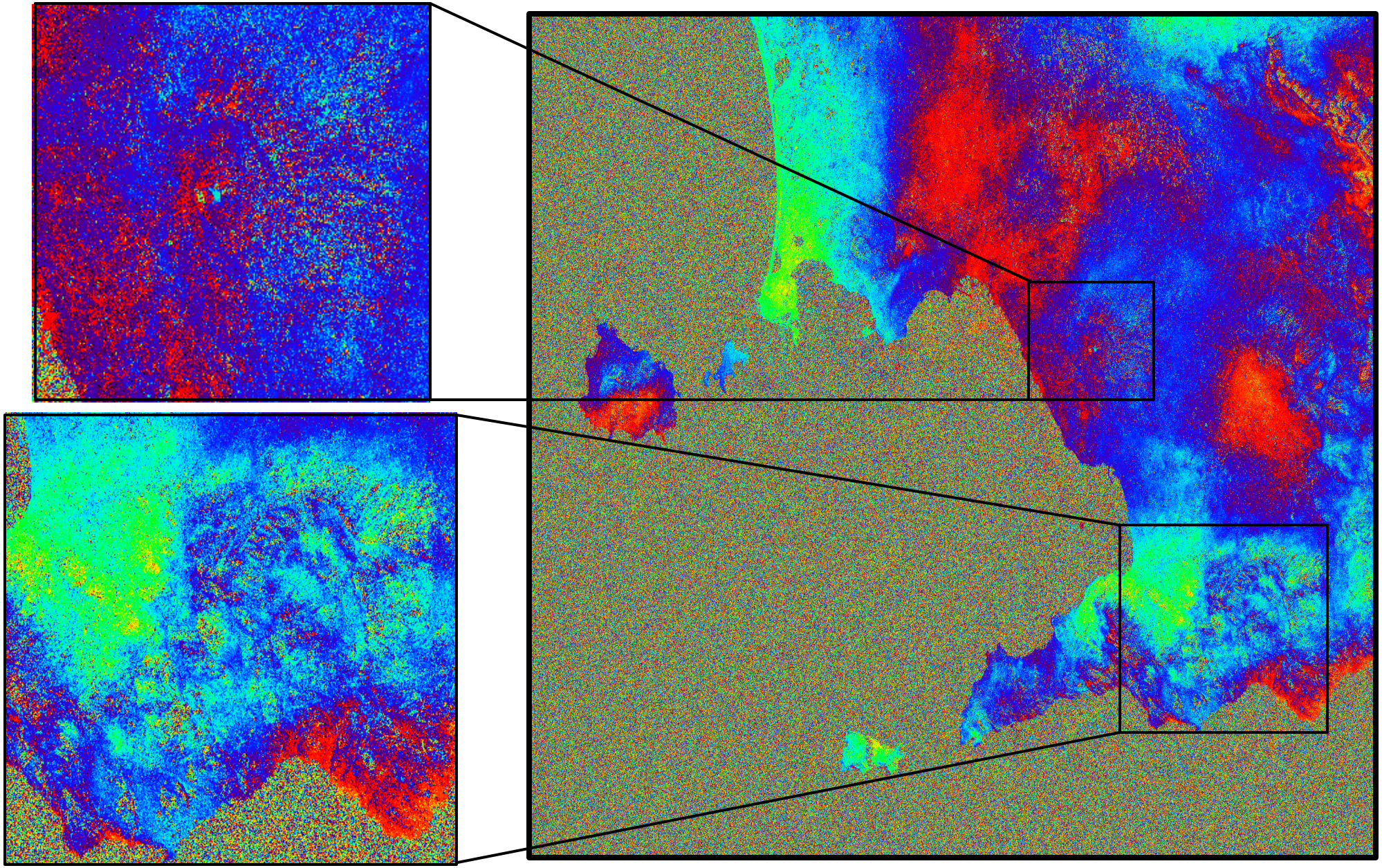
Proposed solution

There are no more artifacts within the ETAD-corrected interfergrams



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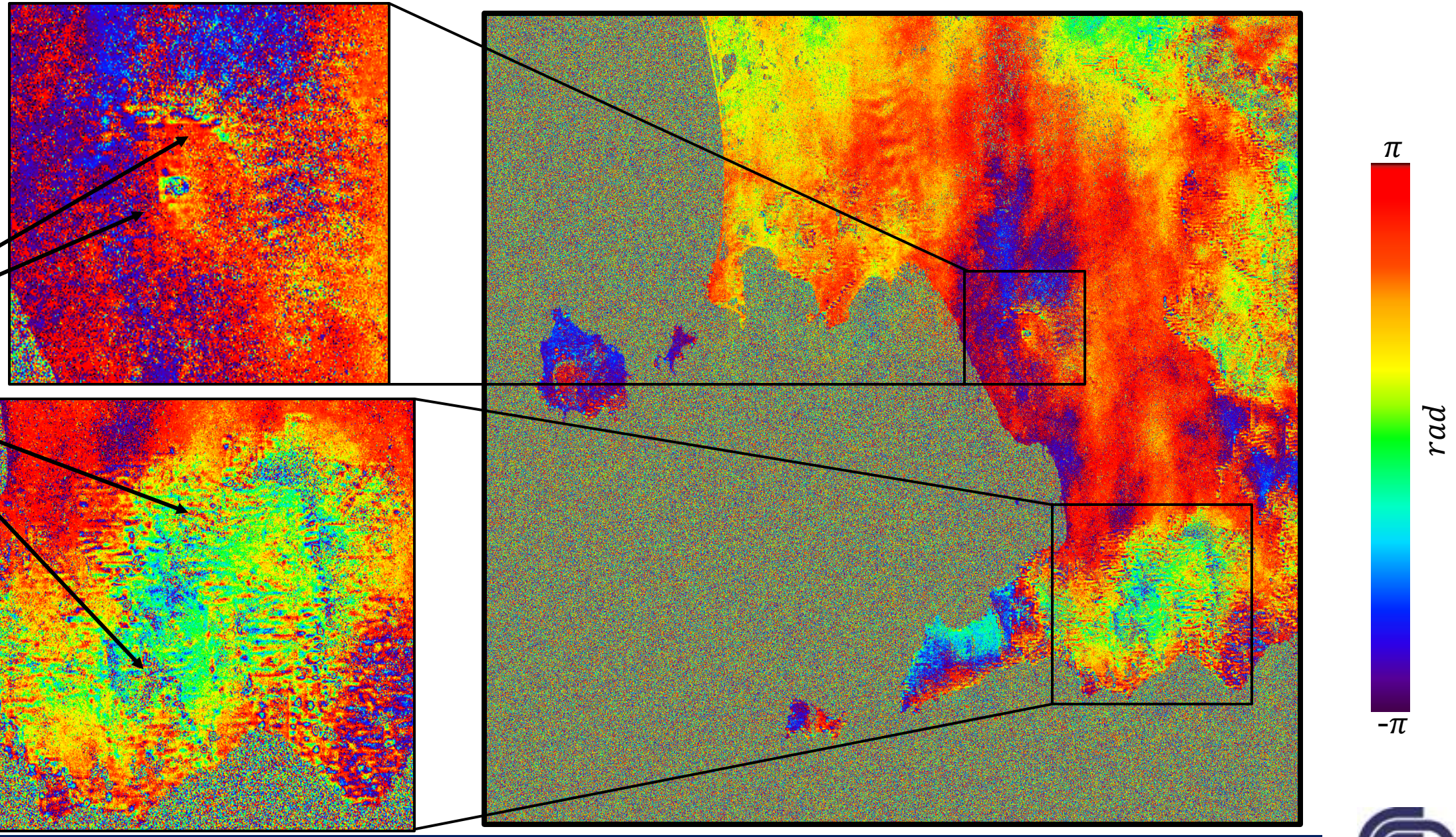
Just another example: 22012020S1A-03023030S1A interferogram



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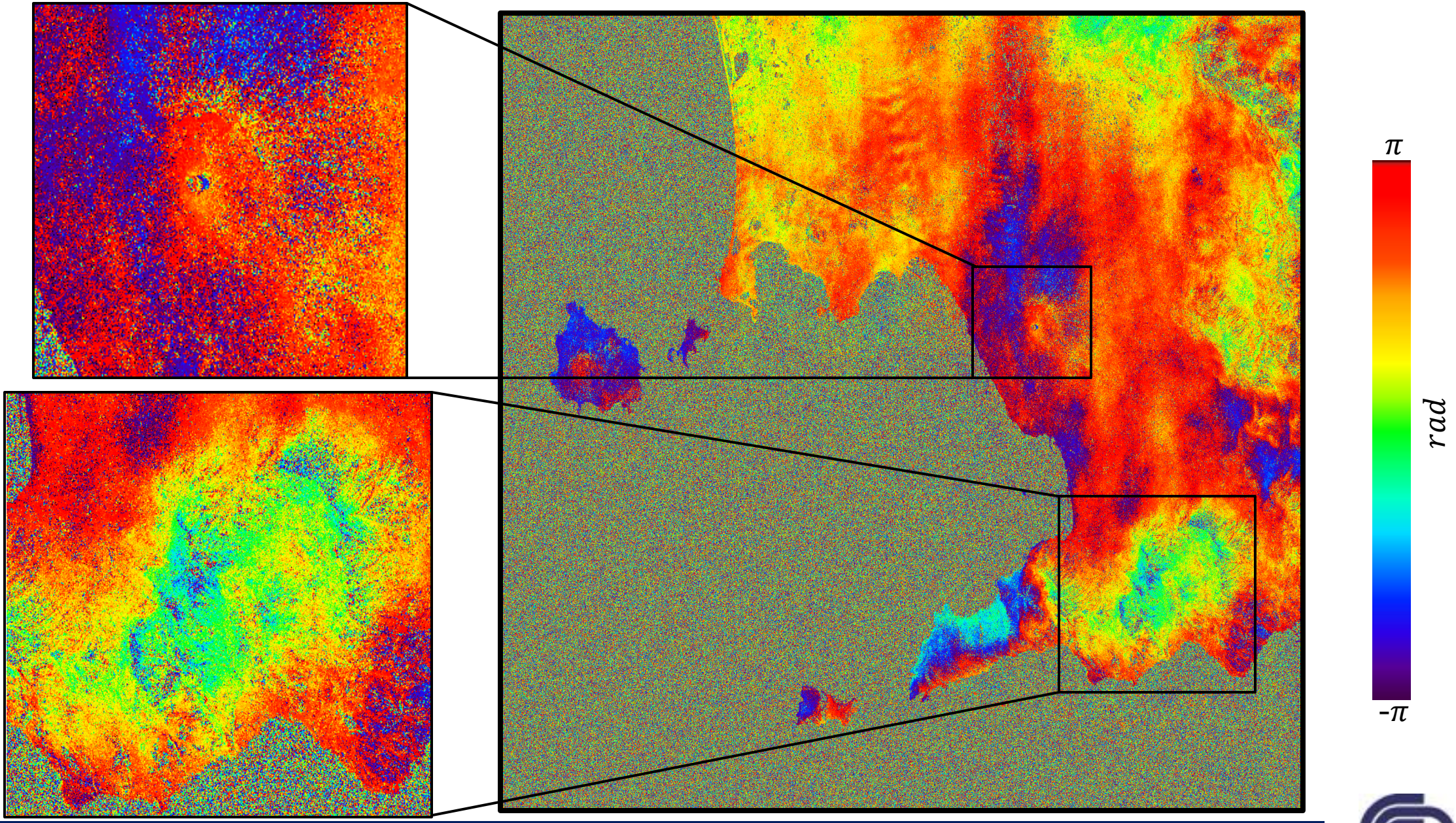
Just another example: 22012020S1A-03023030S1A interferogram

Artifatcs-free ETAD-corrected interferogram obtained through the proposed solution



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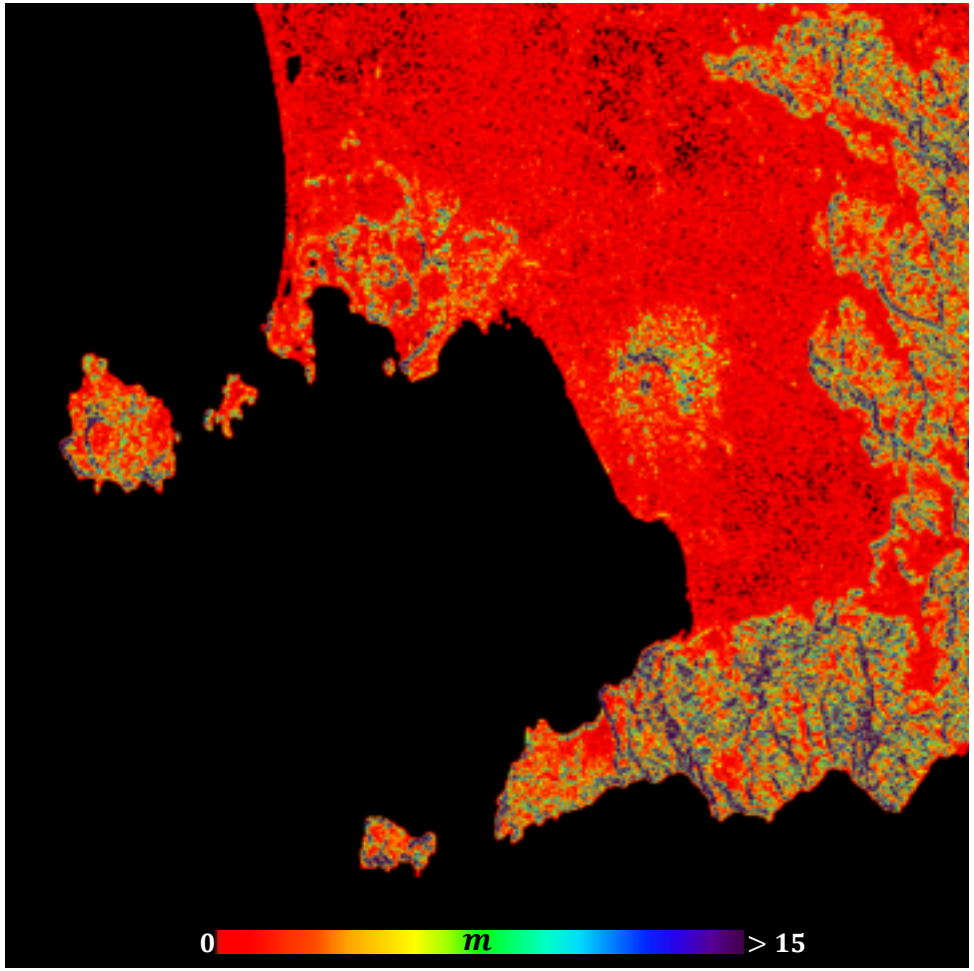
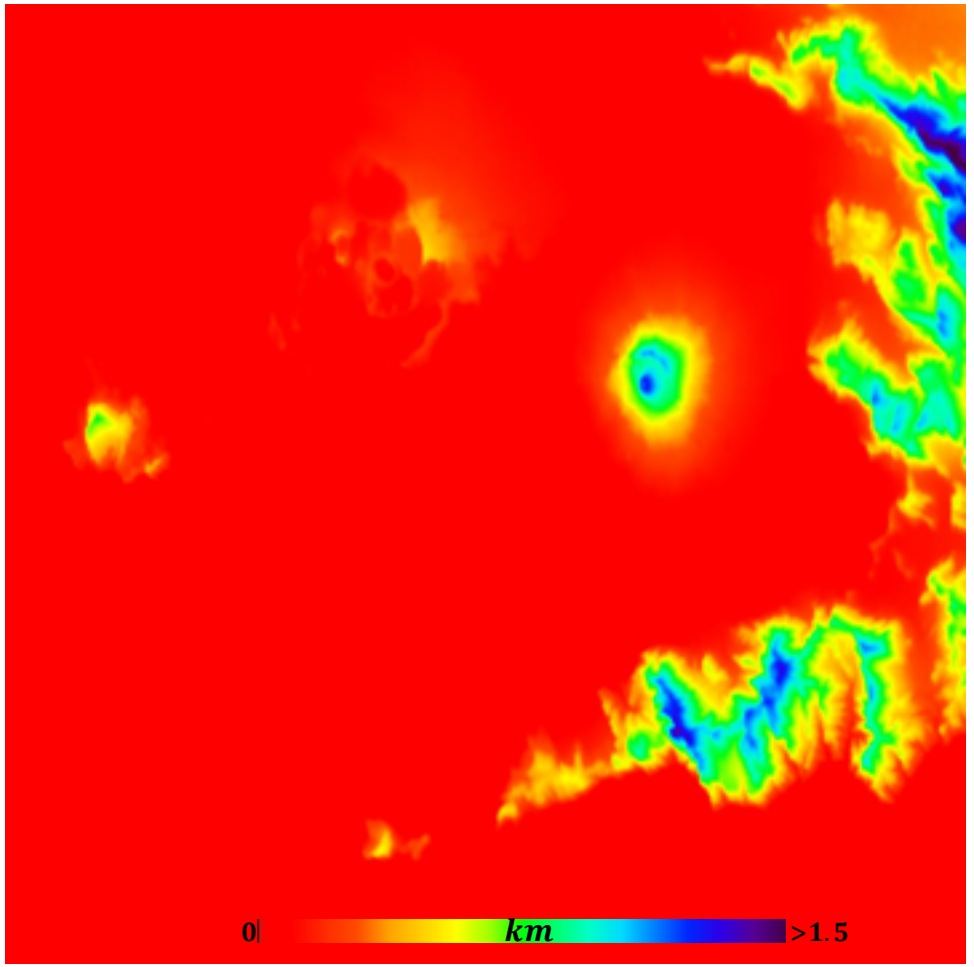
Proposed solution for an interferometric pair

DEM difference (acquisition pair)



The artifacts can be easily identified through the difference between the two DEMs

Averaged DEM (acquisition pair)



We can exploit the DEM available in each ETAD product to compute the averaged DEM

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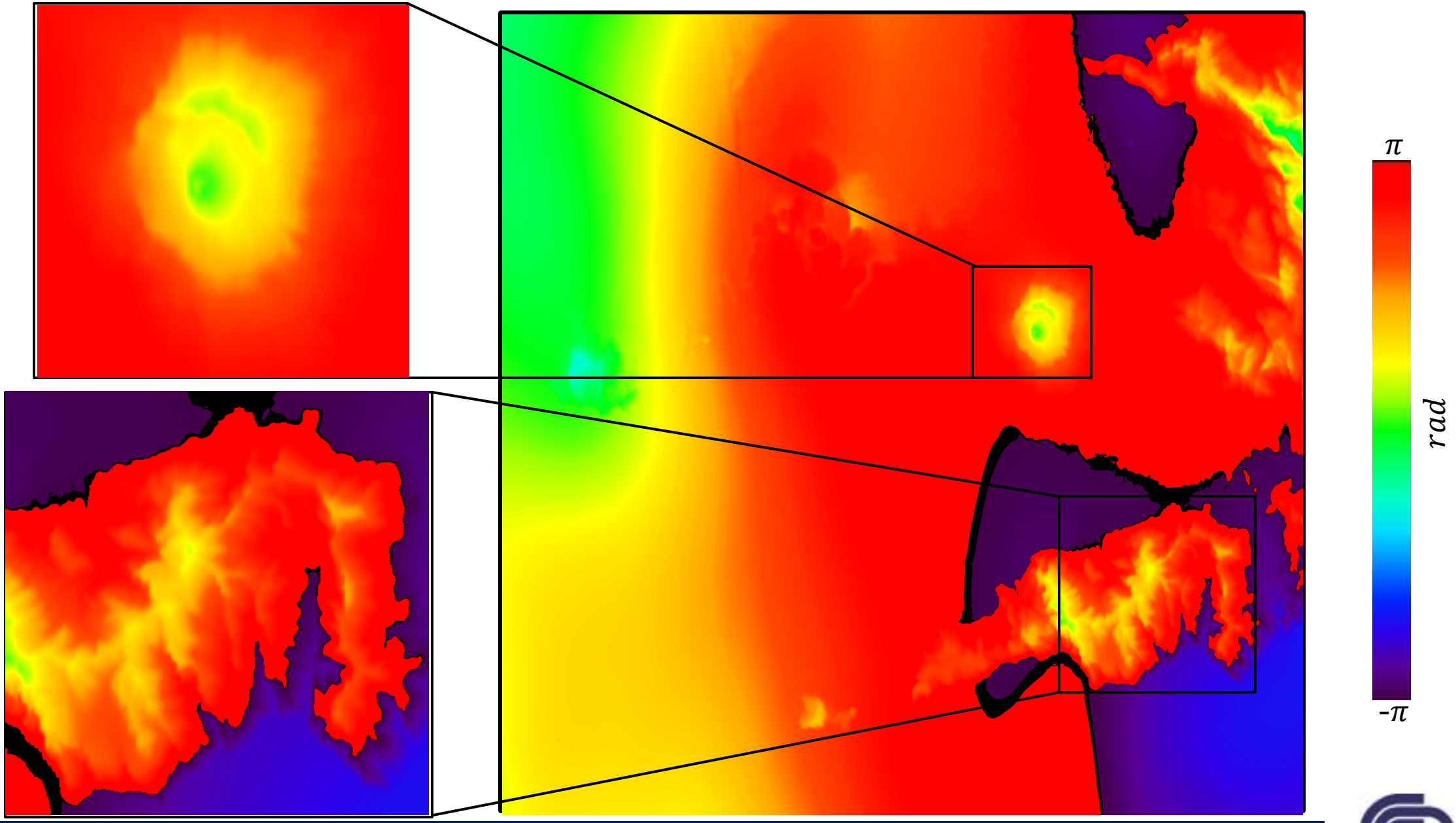
Proposed solution for an interferometric pair

The artifacts within the Tropospheric component are corrected



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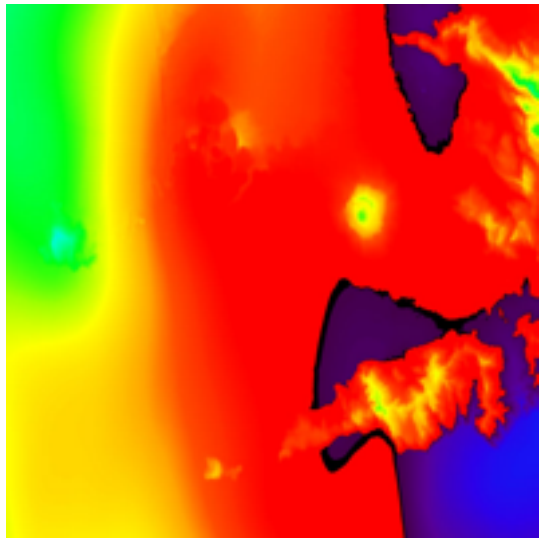
Proposed solution for an interferometric pair

ETAD-based APS correction with the **acquisition pair**
10012020S1A_22012020S1A



ETAD-based APS correction with the **n-acquisitions**
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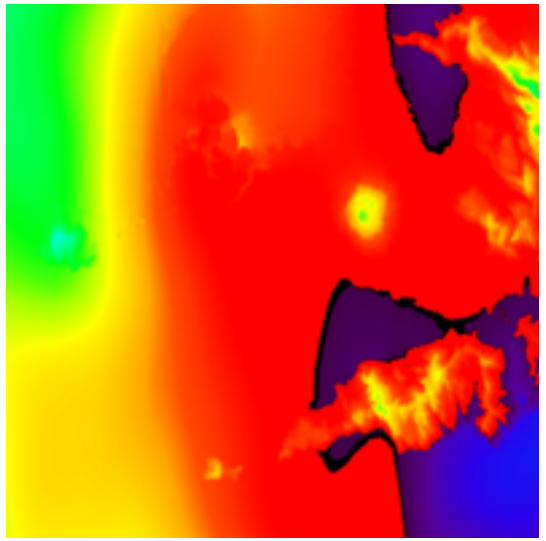

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Proposed solution for an interferometric pair

ETAD-based APS correction with the **acquisition pair**
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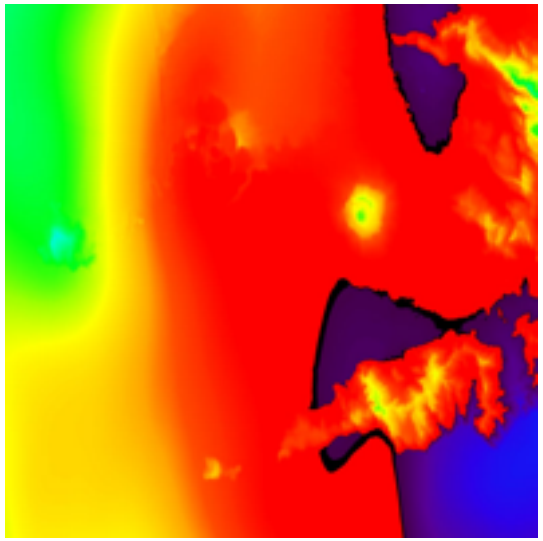
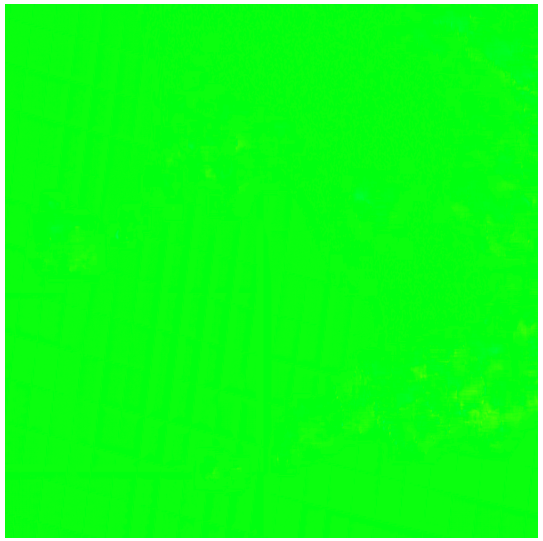


<-> 

ETAD-based APS correction with the **n-acquisitions**
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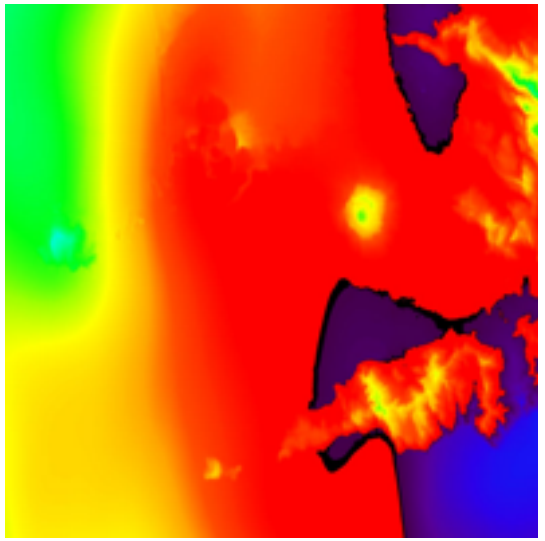

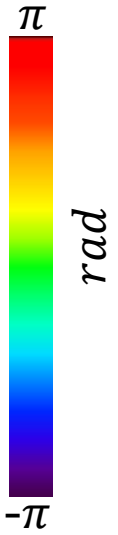

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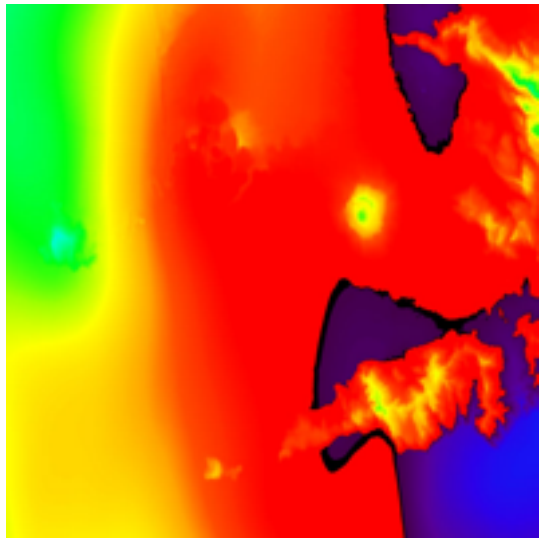
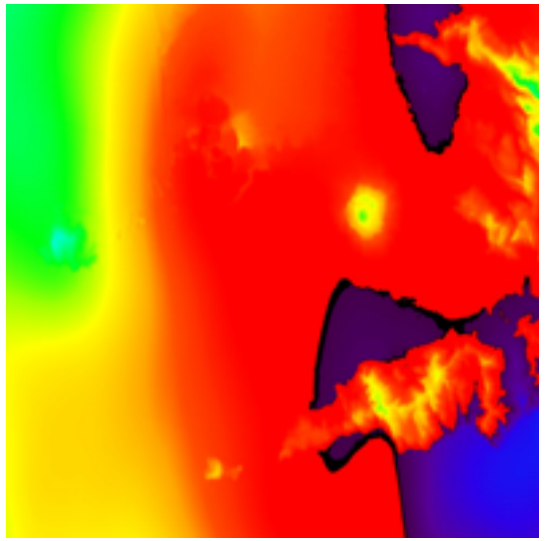
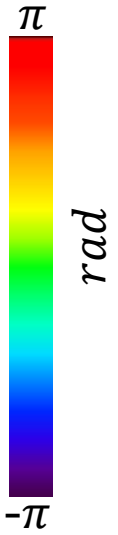
Proposed solution for an interferometric pair

ETAD-based APS correction with the **acquisition pair**
10012020S1A_22012020S1A

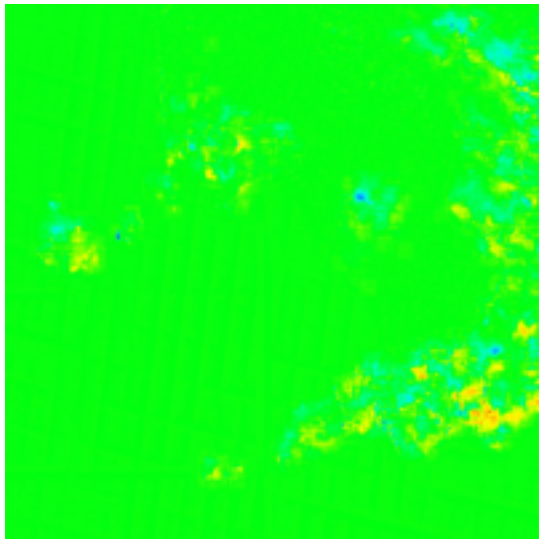


ETAD-based APS correction with the **n-acquisitions**
10012020S1A_22012020S1A





<->$_{2\pi}$



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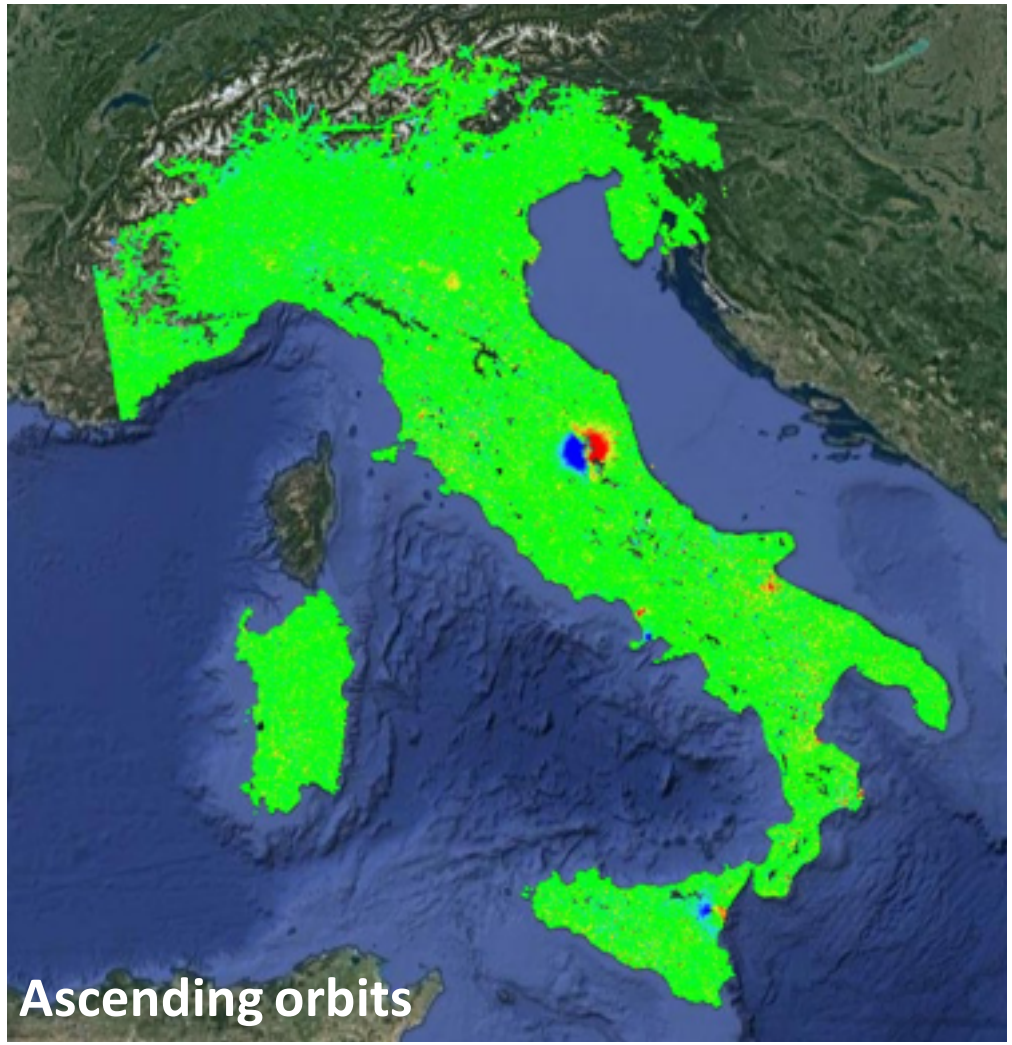
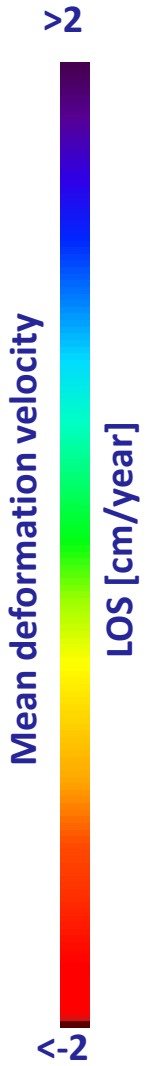
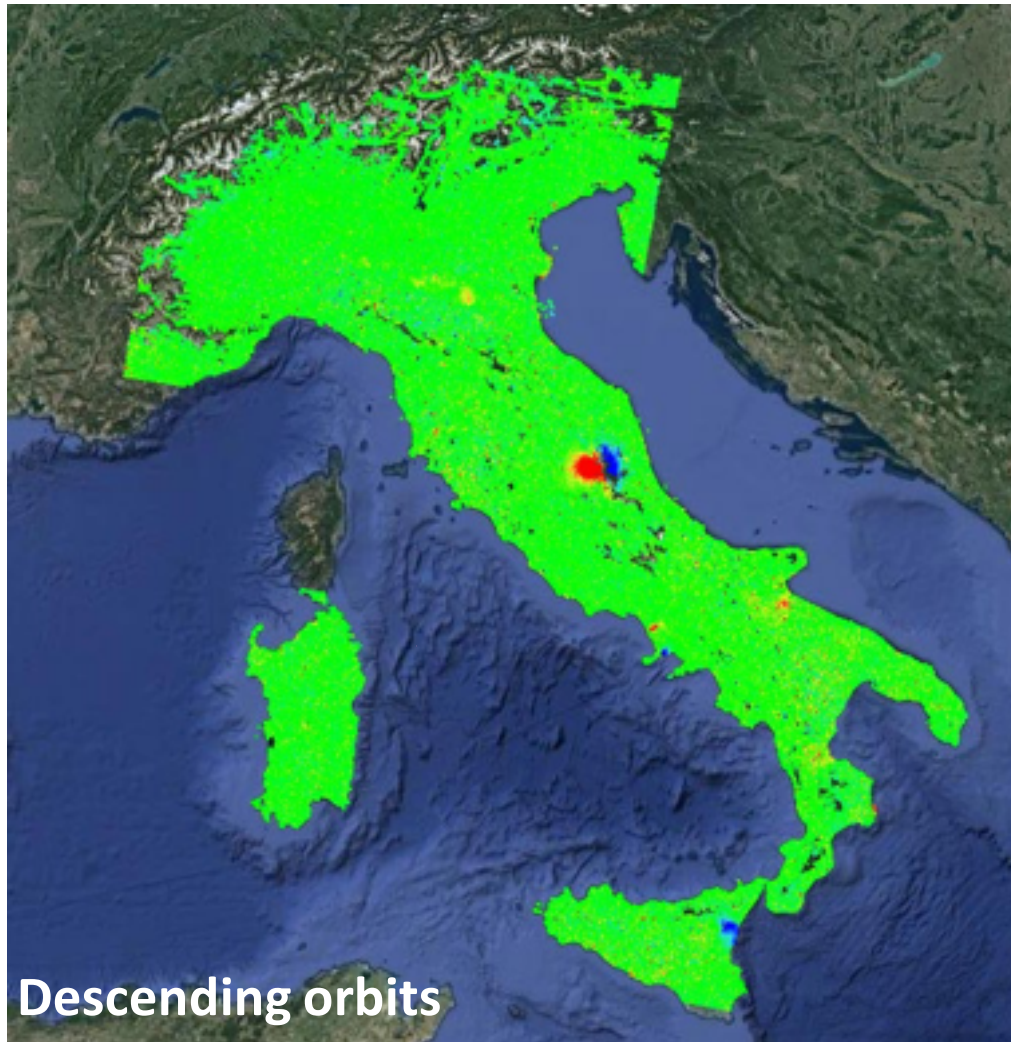
Work in progress: ETAD corrections performance analysis







The focus will be on the Italian National scale

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Work in progress: ETAD corrections performance analysis

Statistical analysis will be based on the following metrics:

- **Interferometric Phase Standard Deviation**
- **Correlation between unwrapped interferometric phase and elevation**
- **Variograms evaluation**

The statistics will be computed with respect to the original and the ETAD corrected interferograms and, based on their comparison, the percentages of successful corrections on the interferograms will be analyzed.

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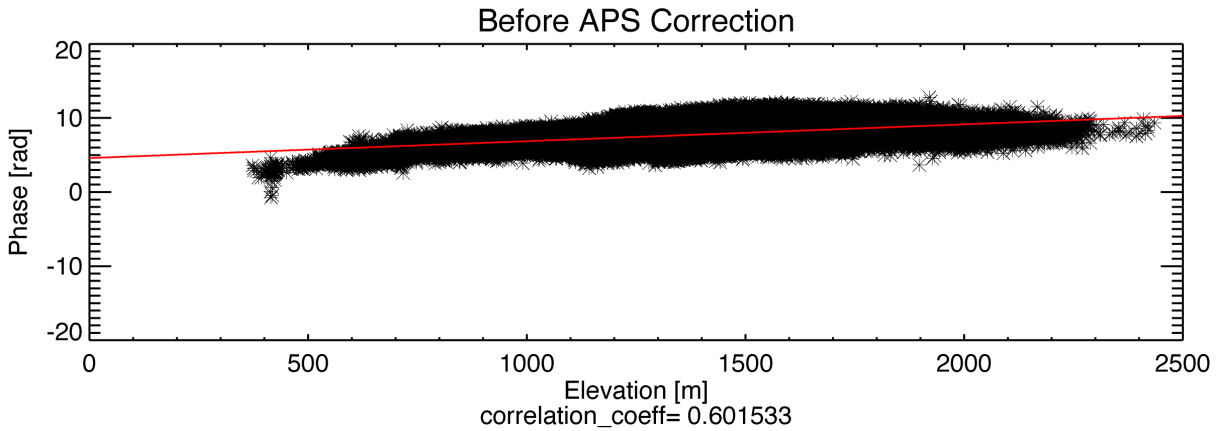
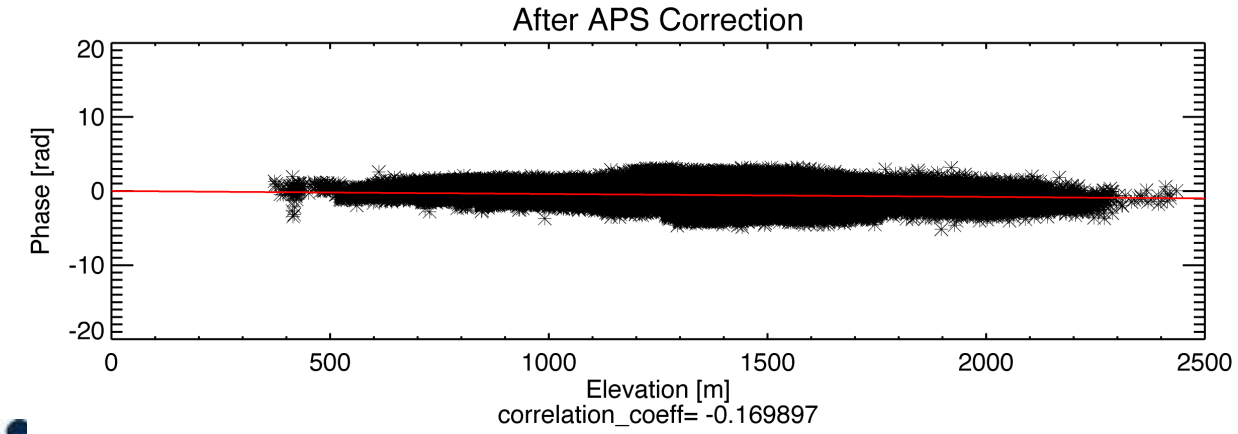
Work in progress: ETAD corrections performance analysis

Phase-Elevation correlation (Two examples of effective corrections)

03022020S1A_15022020S1A





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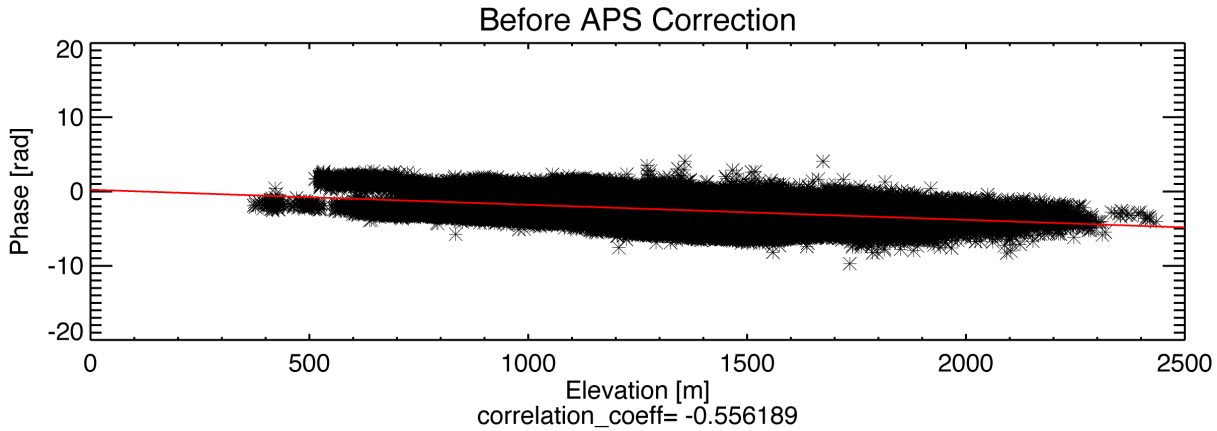

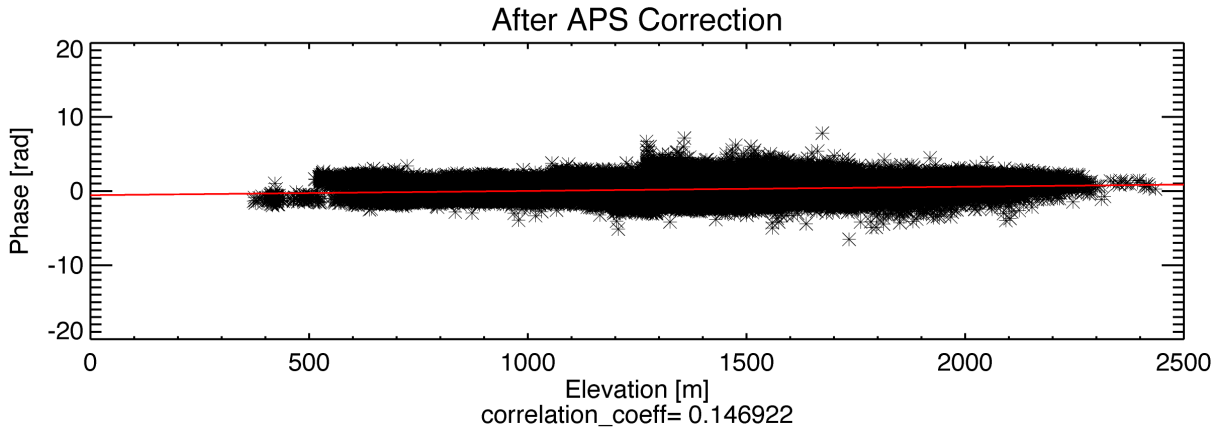

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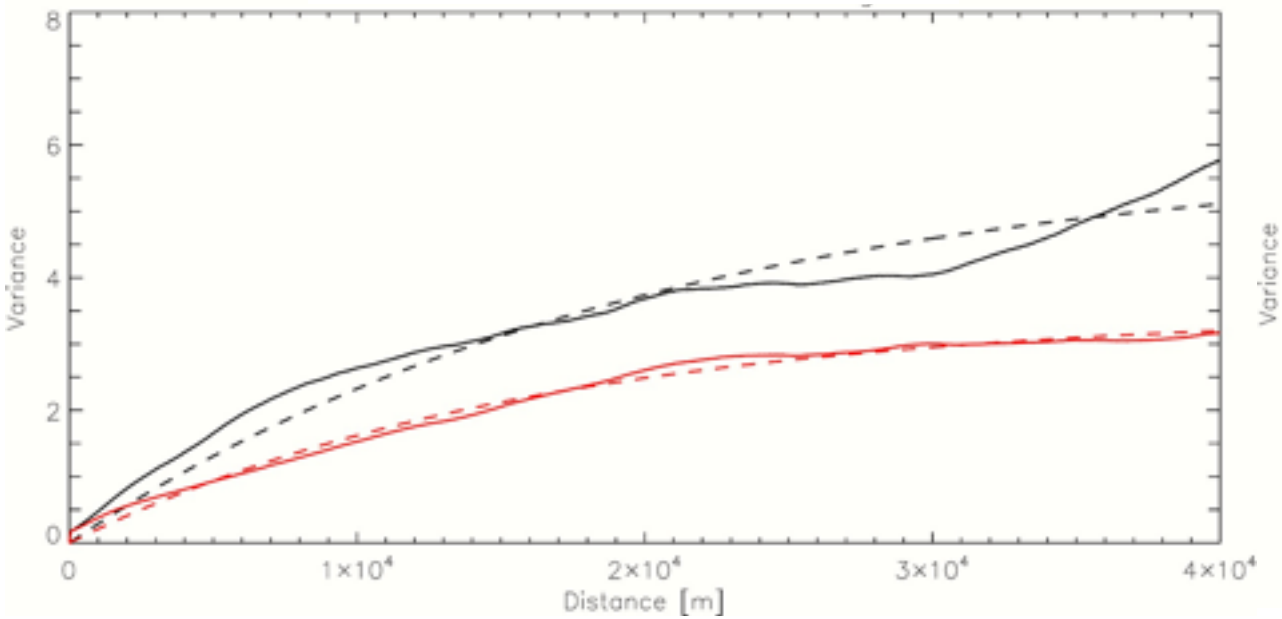
Work in progress: ETAD corrections performance analysis

Variograms (Two examples of effective corrections)

03022020S1A 15022020S1A



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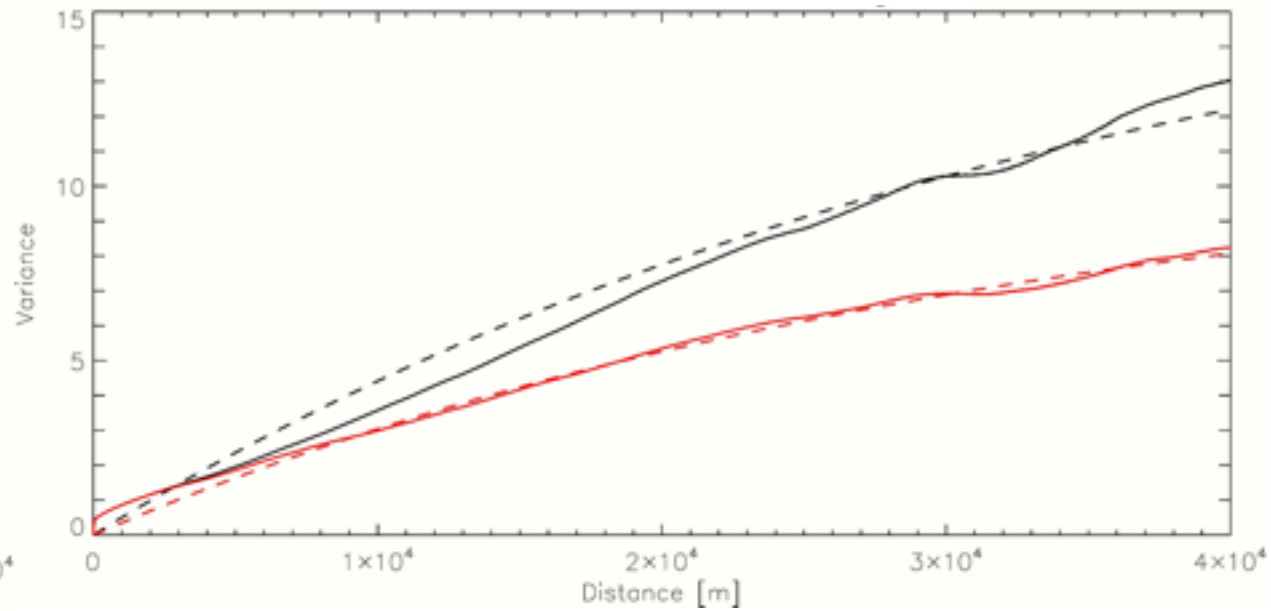

black: before APS correction
solid lines: experimental variogram

red: after APS correction
dashed lines: exponential fitted behavior

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Concluding remarks

- ✓ When working at full or at medium resolution, the Sentinel-1 DInSAR interferograms corrected by using ETAD-based APS compensations present evident artifacts.
- ✓ These artifacts are related to the fact that ETAD tropospheric components are evaluated by using a DEM that present height variations due to the different projections within the range-azimuth grid of each Sentinel-1 image, which cannot be compensated with co-registration.
- ✓ The presented solution permits to easily and properly re-generate the ETAD-based APS corrections for multi-temporal sequences of Sentinel-1 interferograms without artifacts and with no need to change the actual ETAD data characteristics.
- ✓ The proposed solution appears to be rather effective also for single interferograms.
- ✓ The analysis of the ETAD-based APS correction performance is in progress, focused on the Italian territory.

Thank you !

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