Towards a Universally Applicable Phase Bias Correction for Short-Term Multi-Looked Interferograms: Challenges and Progress

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Introduction

- The velocity estimated by the multilooked short-term interferograms reveal a systematic signal (AKA “fading signal”) (De Zan et al. 2018, Ansari et al. 2020)
- We previously developed an empirical mitigation strategy for the phase bias correction (Maghsoudi et al. 2022)

$$\Delta\varphi_{i,i+2} = \delta_{i,i+2} - \left(\delta_{i,i+1} + \delta_{i+1,i+2}\right) + \varepsilon$$

$$\Delta\varphi_{i,i+3} = \delta_{i,i+3} - \left(\delta_{i,i+1} + \delta_{i+1,i+2} + \delta_{i+2,i+3}\right) + \varepsilon$$

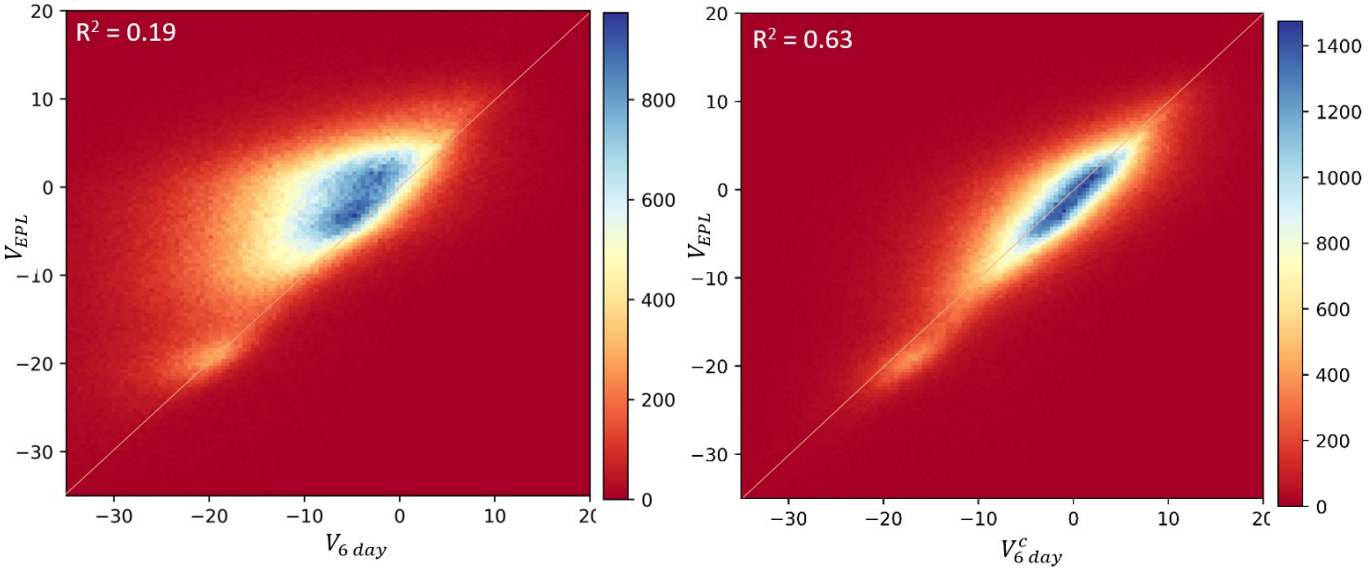
- Assumption: The bias in an interferogram is linearly related to sum of biases in shorter interferograms spanning the same time

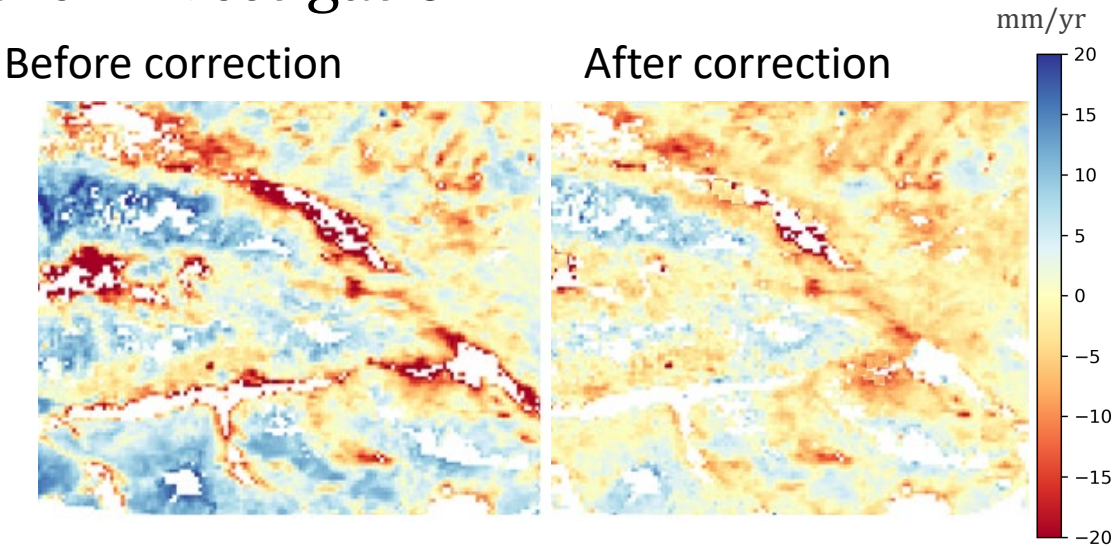
$$\begin{pmatrix}\Delta\varphi_{i,i+2}\\ \Delta\varphi_{i,i+3}\end{pmatrix} = \begin{pmatrix}a_1 - 1 & a_1 - 1 & 0\\ a_2 - 1 & a_2 - 1 & a_2 - 1\end{pmatrix}\begin{pmatrix}\delta_{i,i+1}\\ \delta_{i+1,i+2}\\ \delta_{i+2,i+3}\end{pmatrix}$$

Y. Maghsoudi, A. J. Hooper and T. J. Wright, M. Lazecky and H. Ansari, Characterizing and correcting phase biases in short-term, multilooked interferograms, Remote Sensing of Environment, Volume 275, 2022, 113022, ISSN 0034-4257.

Introduction

- Our mitigation strategy is immune to long-term coherence loss as it only relies on short-term interferograms for estimating the correction terms.
- Unlike phase linking approaches, our proposed strategy only requires the short-term phases to solve for the bias correction through a single-step and computationally inexpensive least square inversion.
- But, the universality of the method needs further investigation

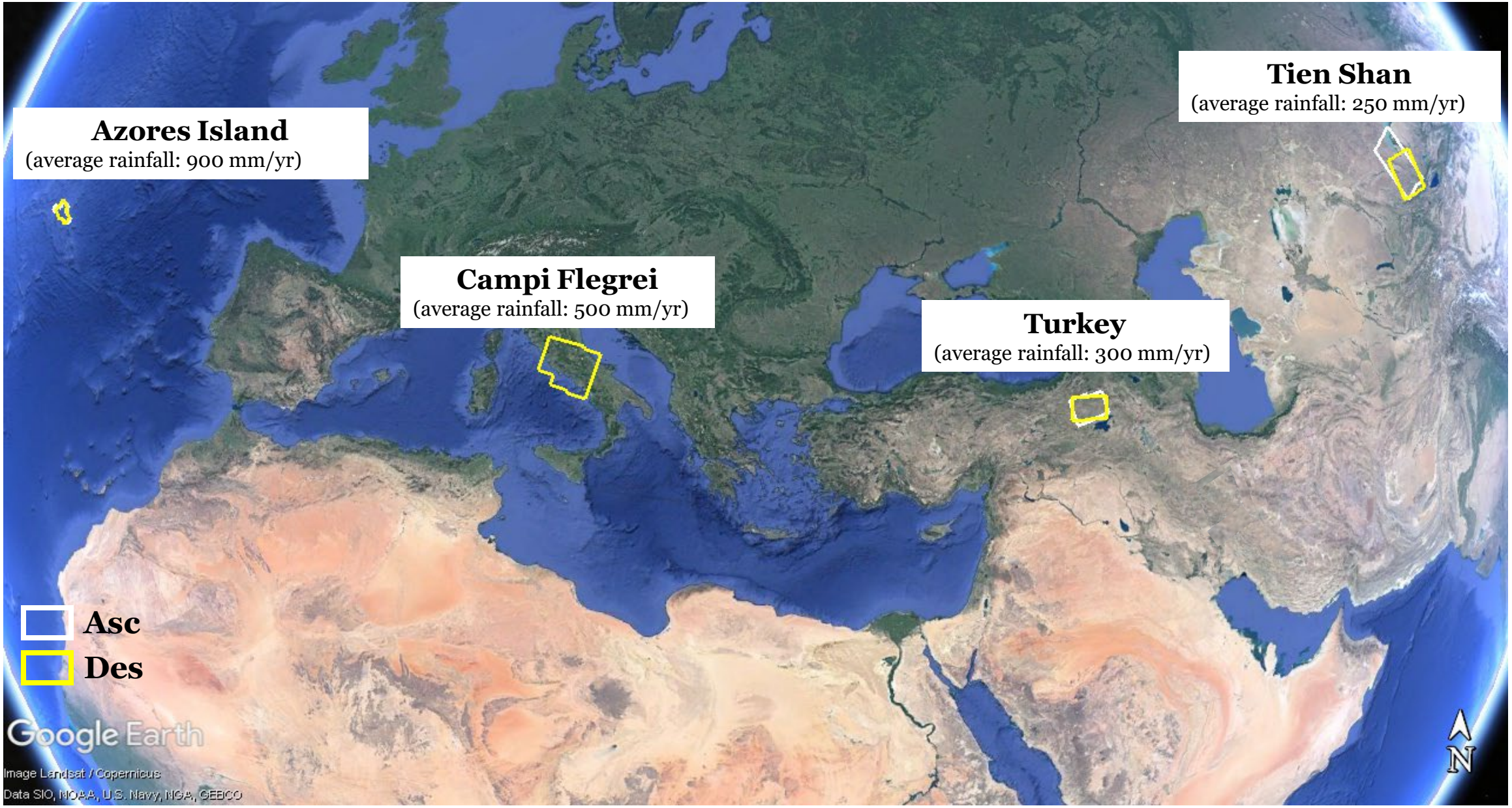




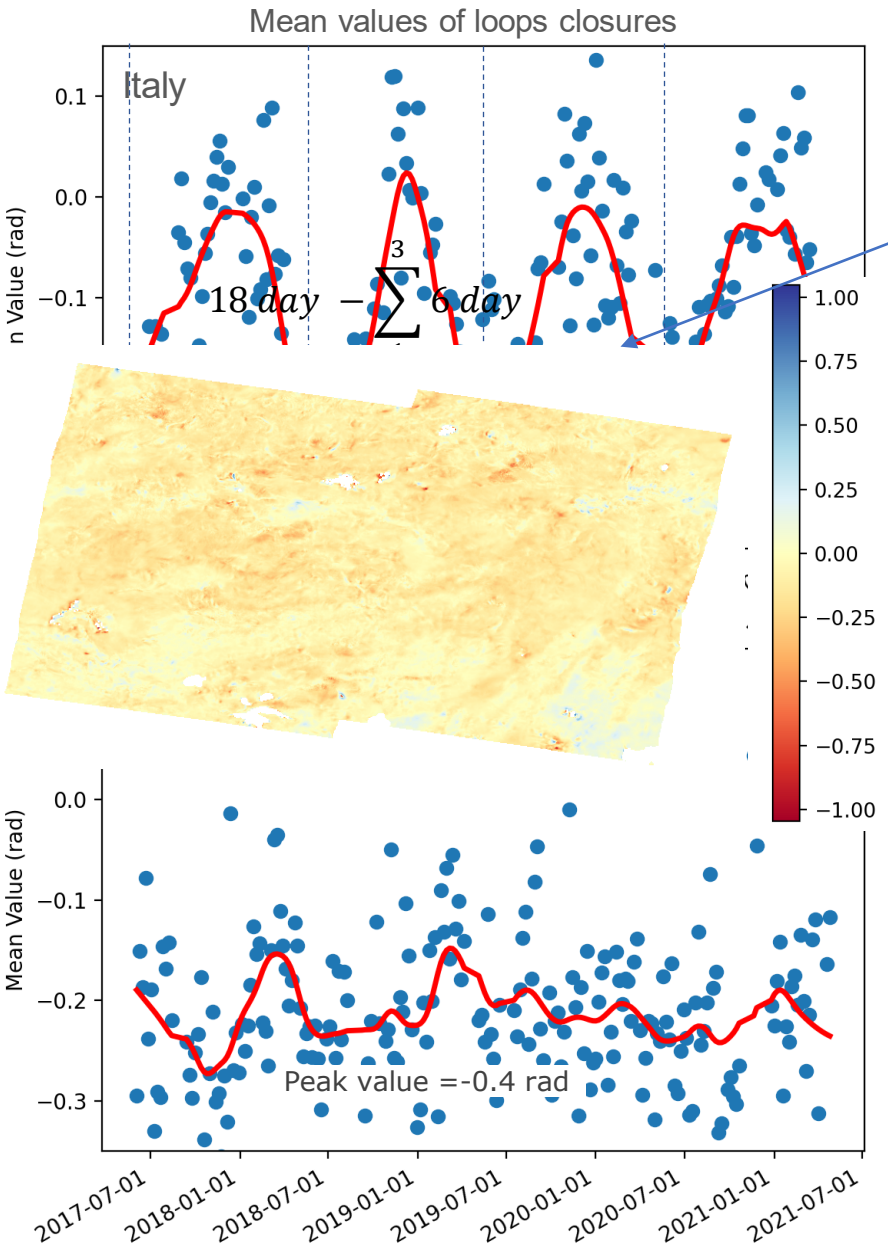
Phase Bias Characterization

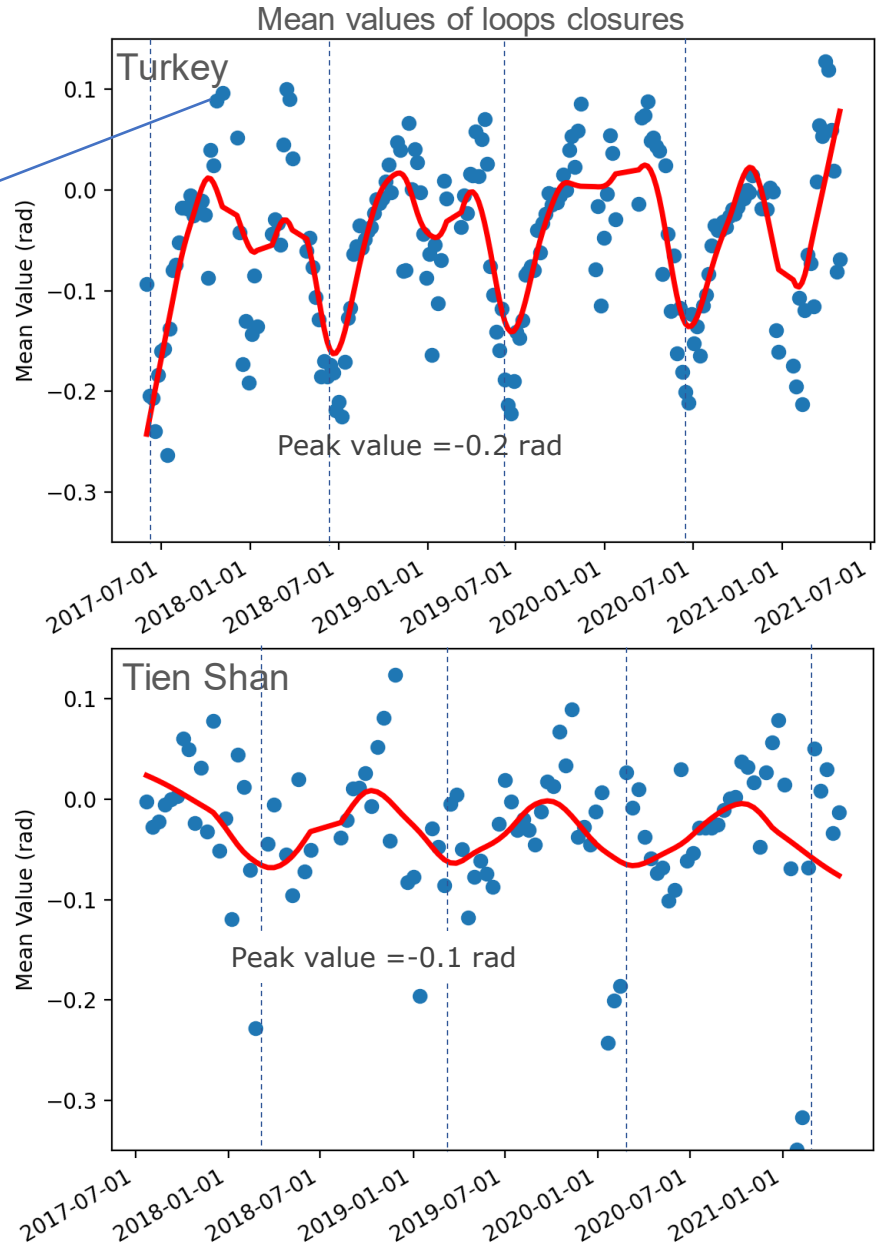
- Loop closure time-series in various regions
- Ascending vs Descending
- Effect of filtering and multilooking
- Landcover investigation
- Polarization dependency
- Correlation with environmental proxies

Selected Frames

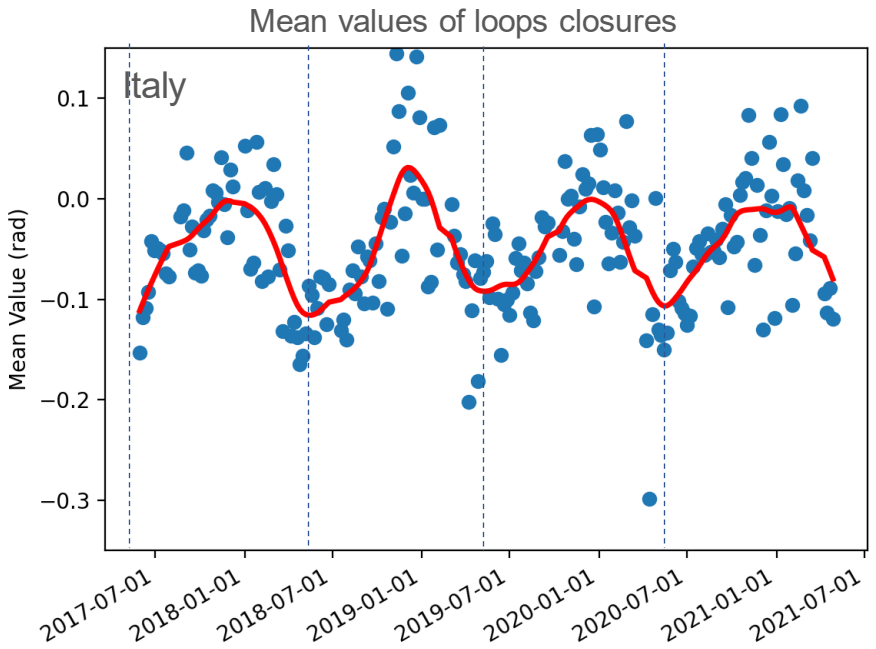


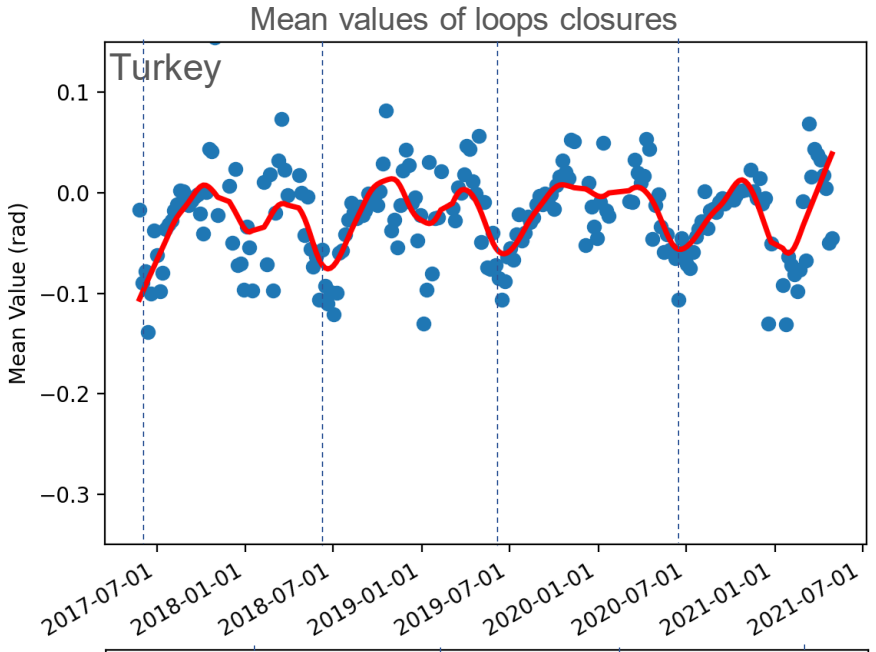
Loop Closure Time-series

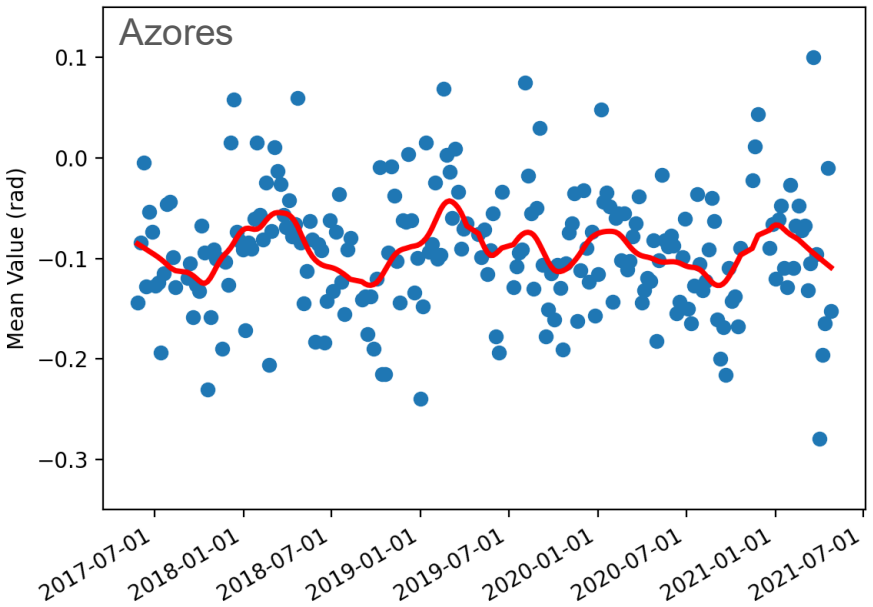


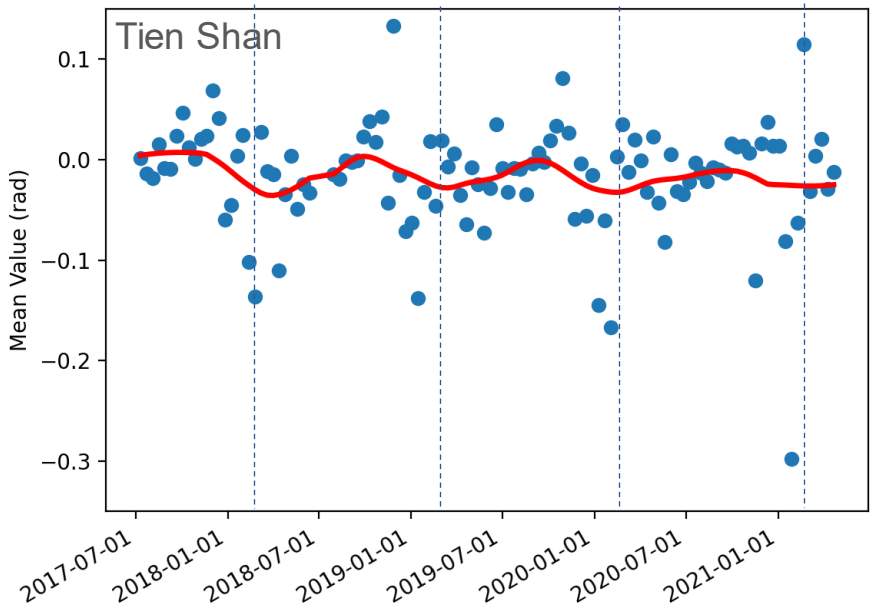


Loop Closure Time-series



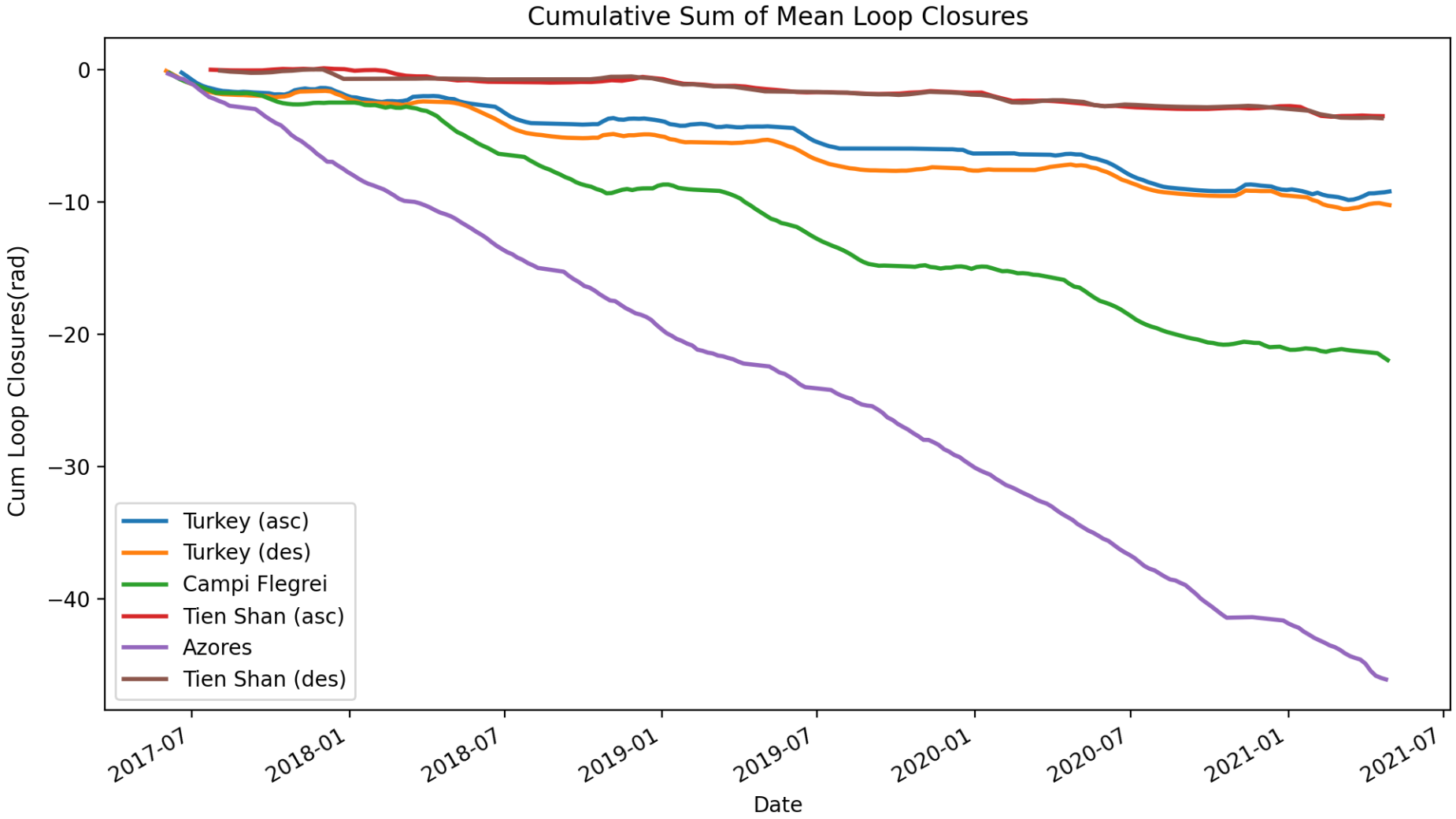




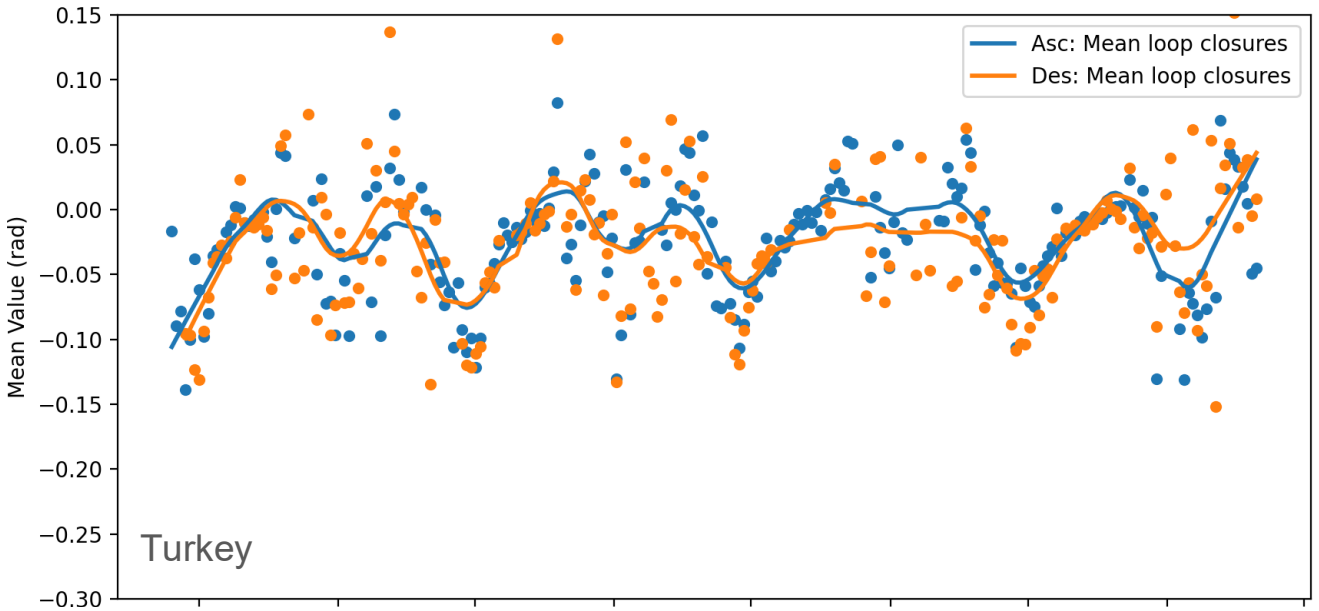


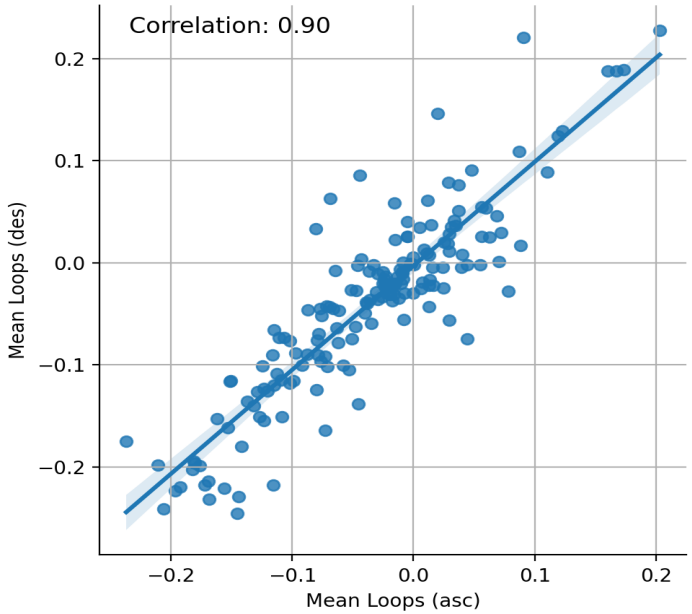
$$12\ day - \sum_{1}^{2} 6\ day$$

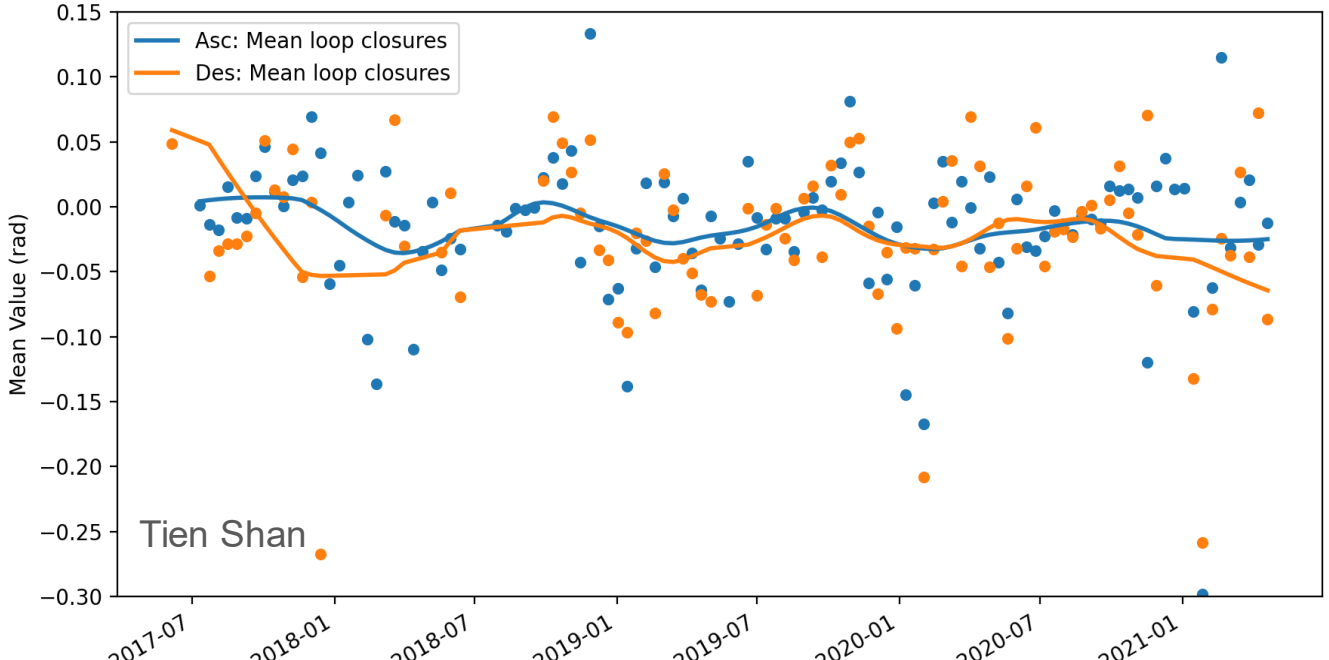
Time-series Cumulative Loop Closures

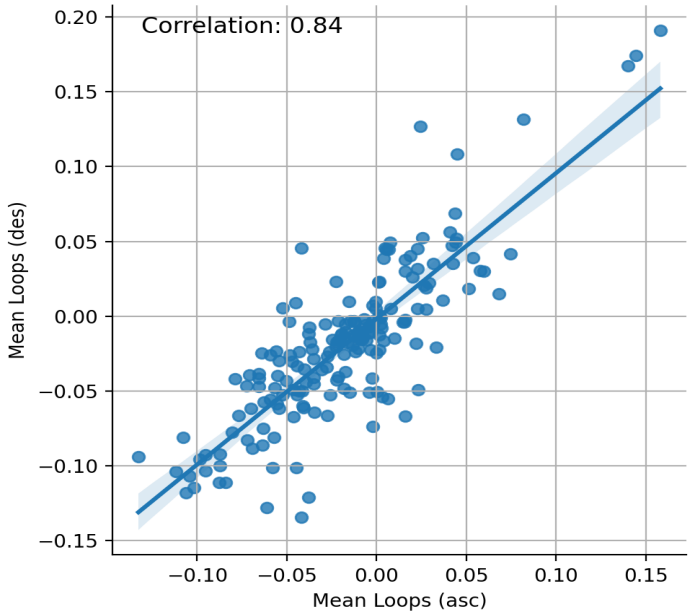


Ascending vs. Descending



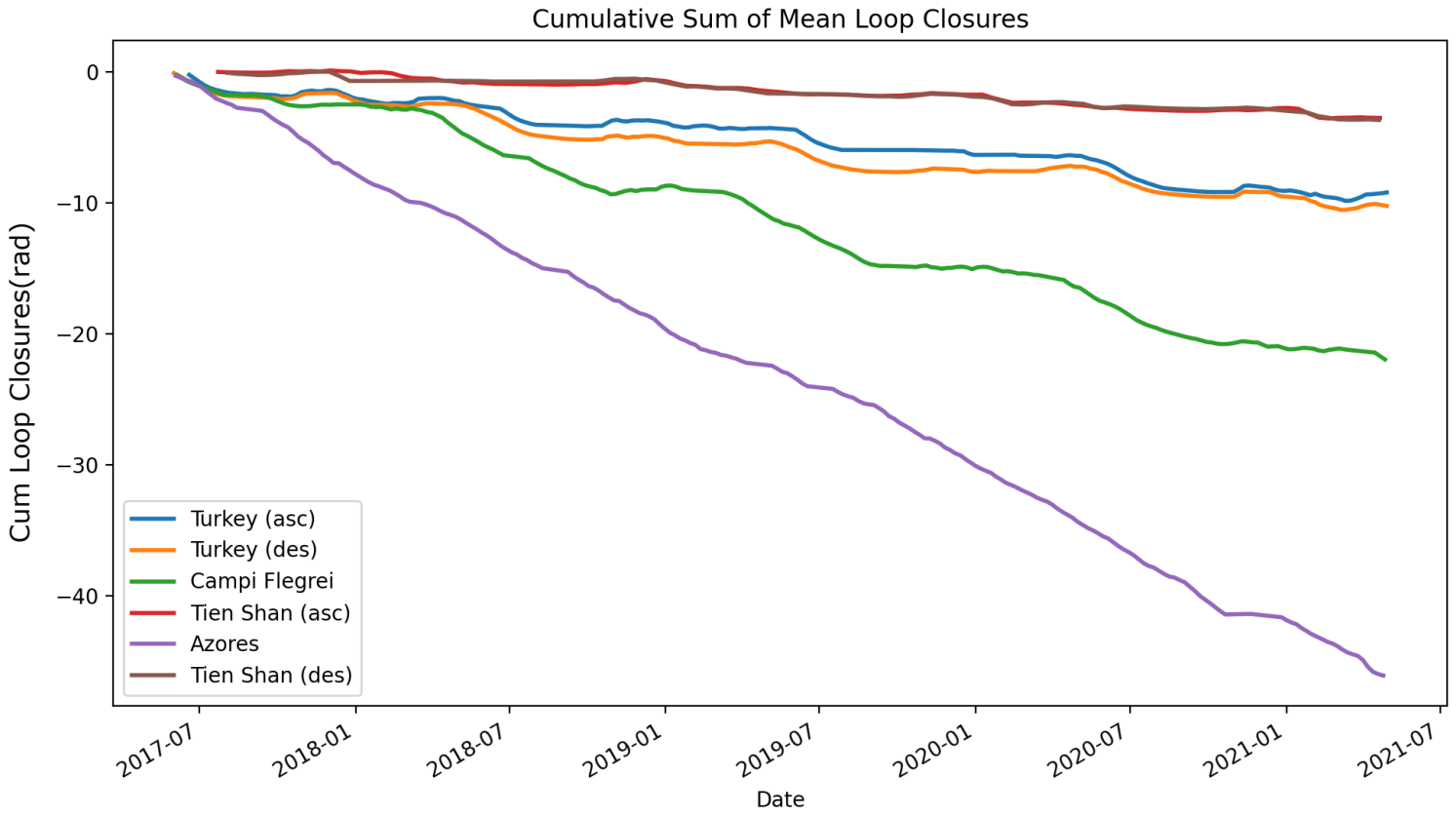






Ascending vs. Descending

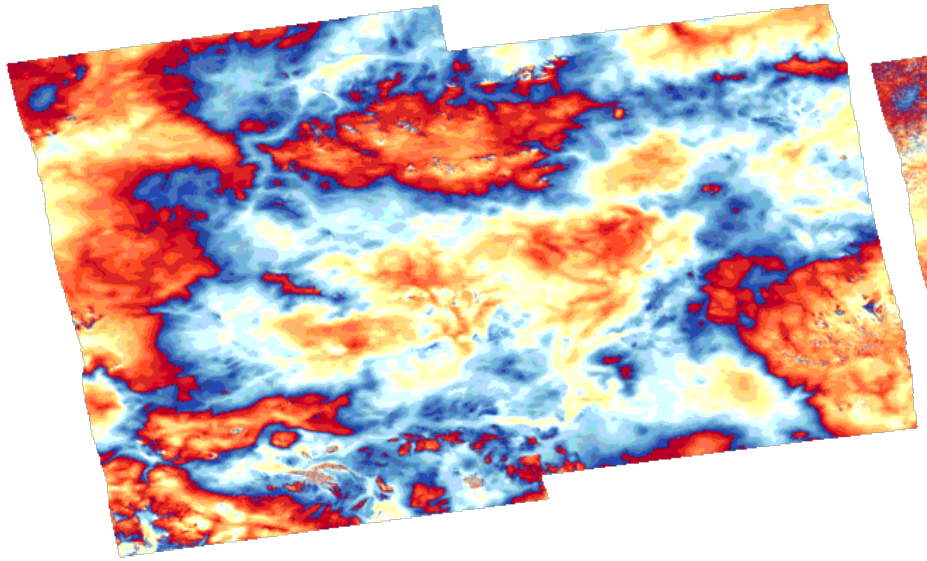
- Phase bias is a lesser concern in the estimation of east-west velocities but takes on greater importance when estimating vertical velocities.



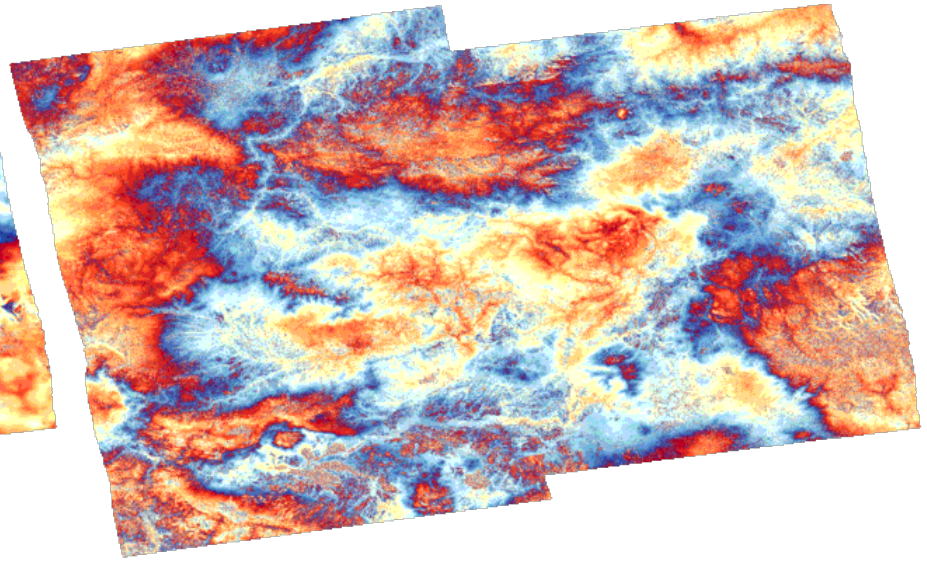
Filtered vs. Unfiltered

- It is a common practice to reduce the phase noise using filtering.
- In COMET-LiCSAR system we generate both filtered and unfiltered interferograms
- It is important to know how much this filtering will increase the closure loops

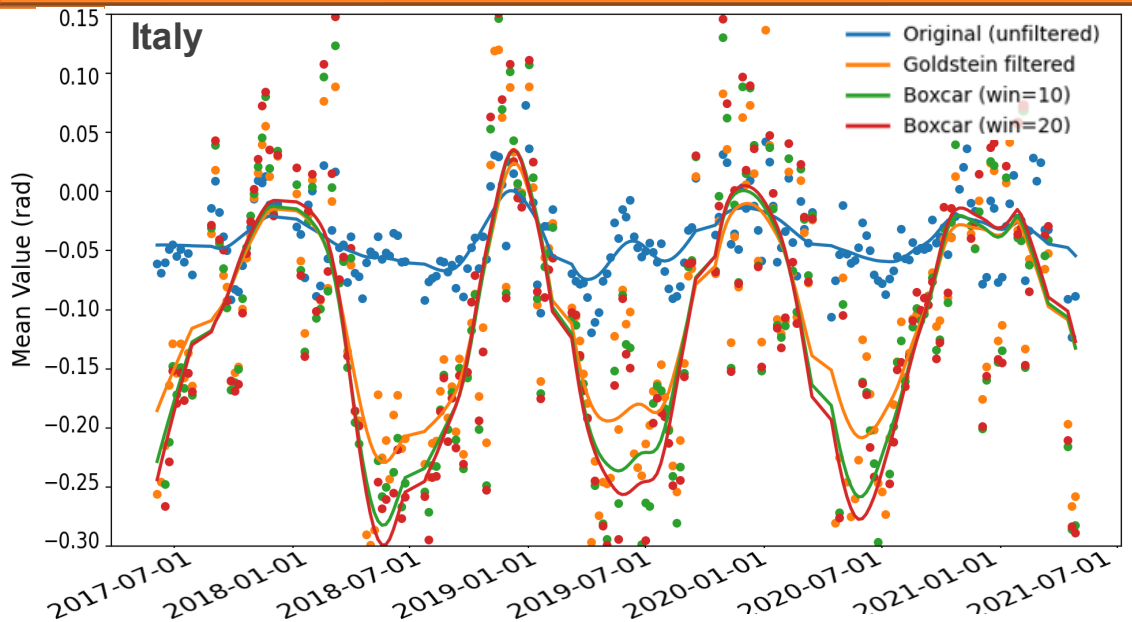
Filtered: Goldstein filtering

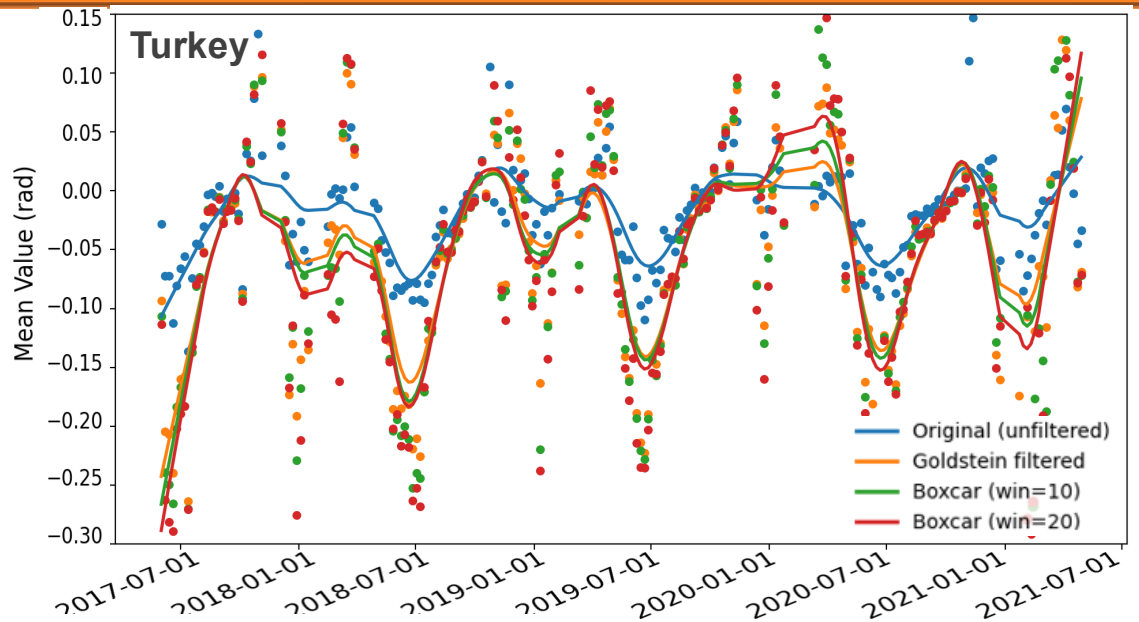


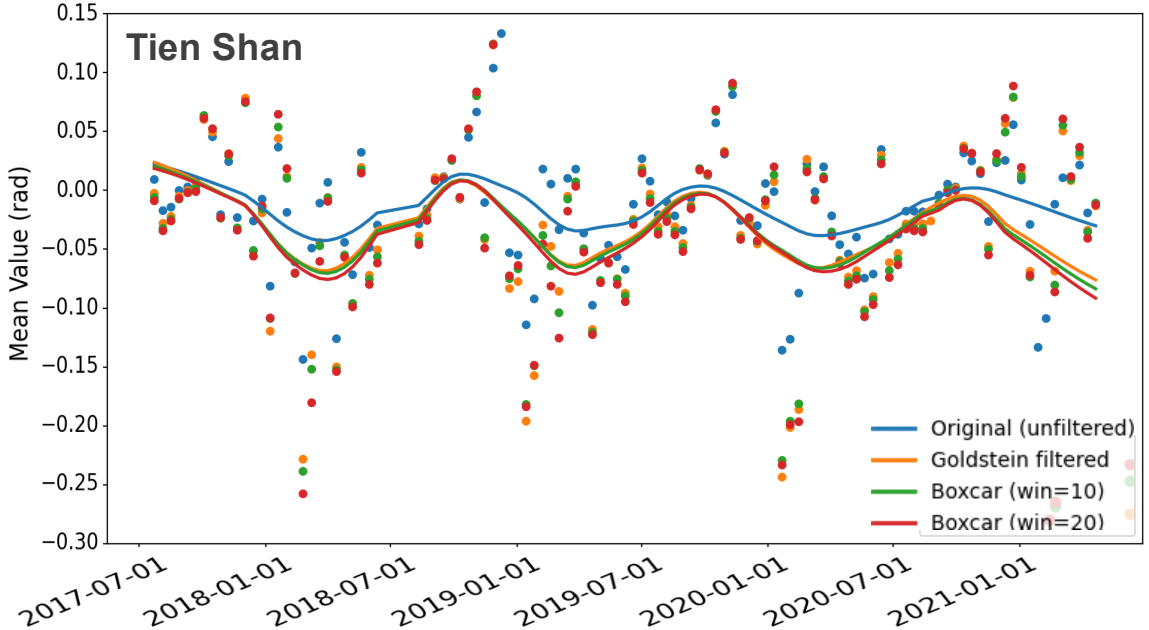
Unfiltered (ML by 4 and 20)



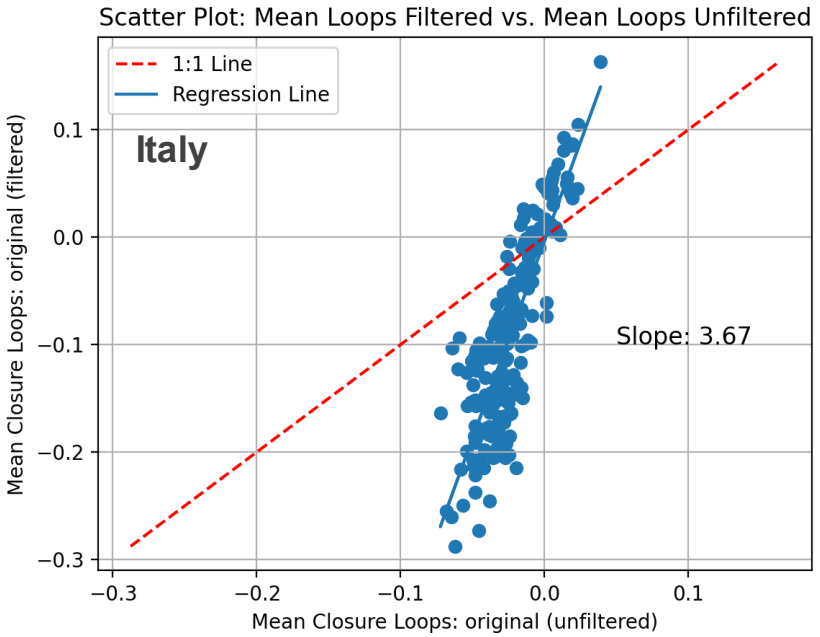
Filtered vs. Unfiltered

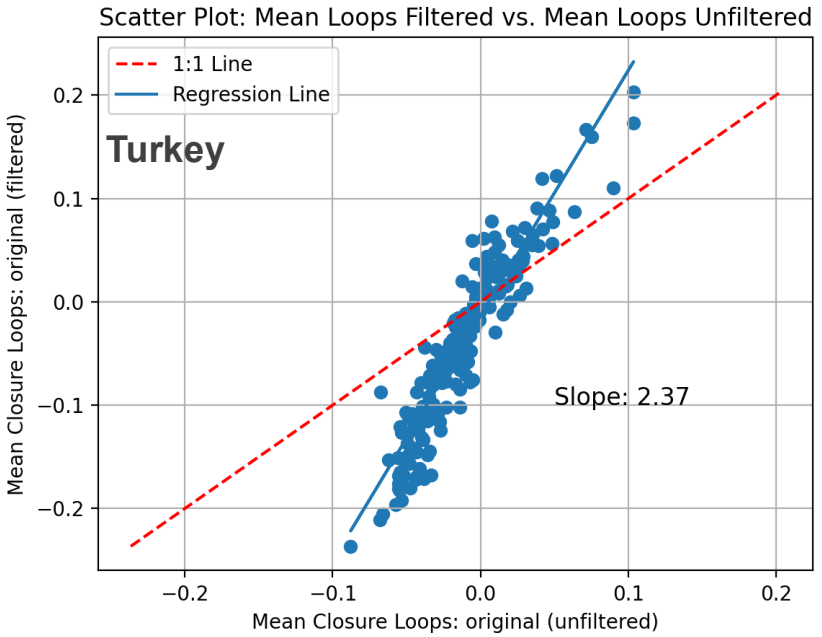


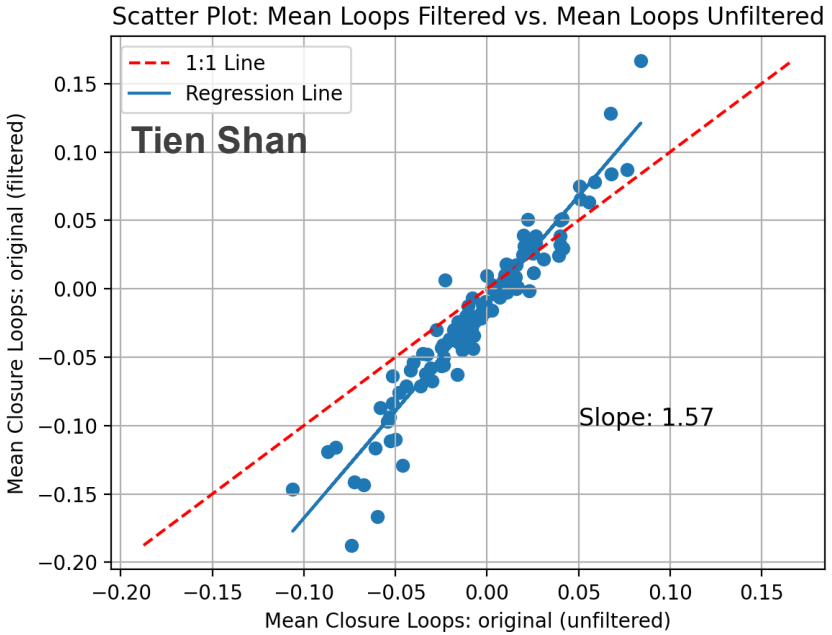




Filtered vs. Unfiltered

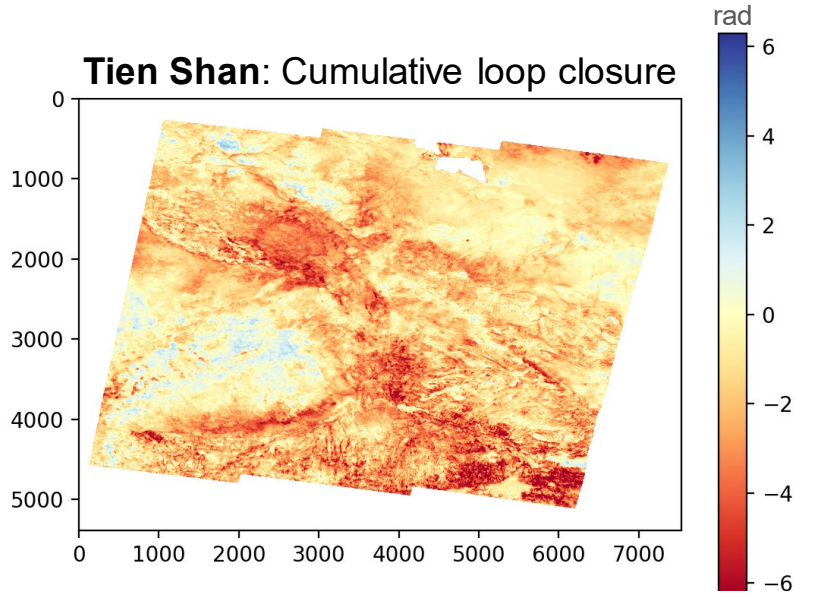


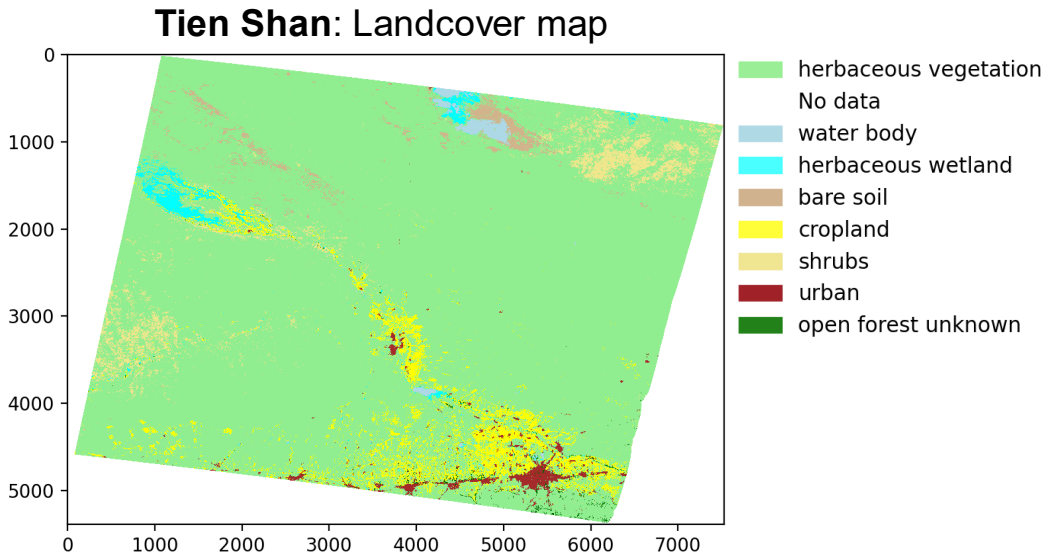


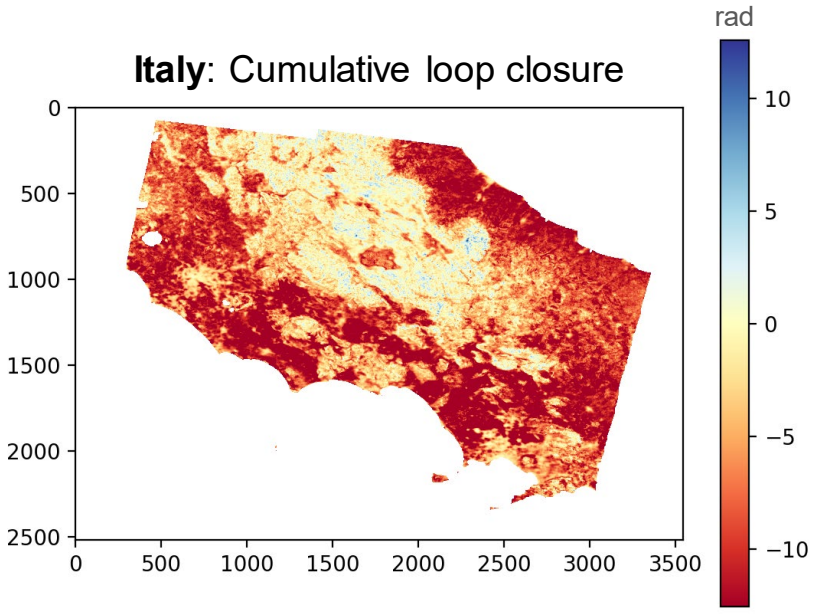


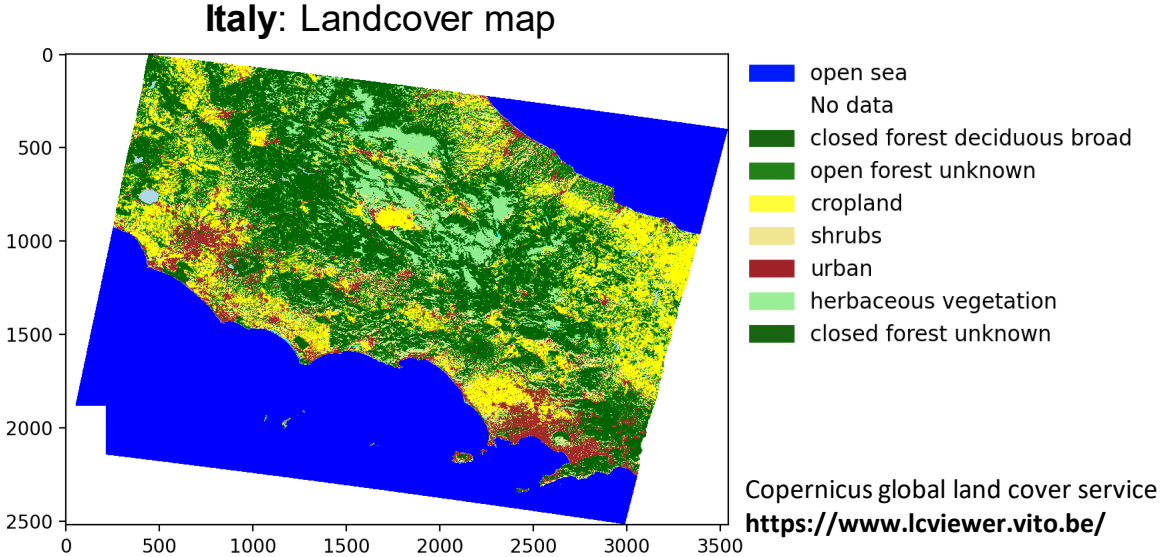
Cumulative Loop Closures and Landcovers

UNIVERSITY OF LEEDS





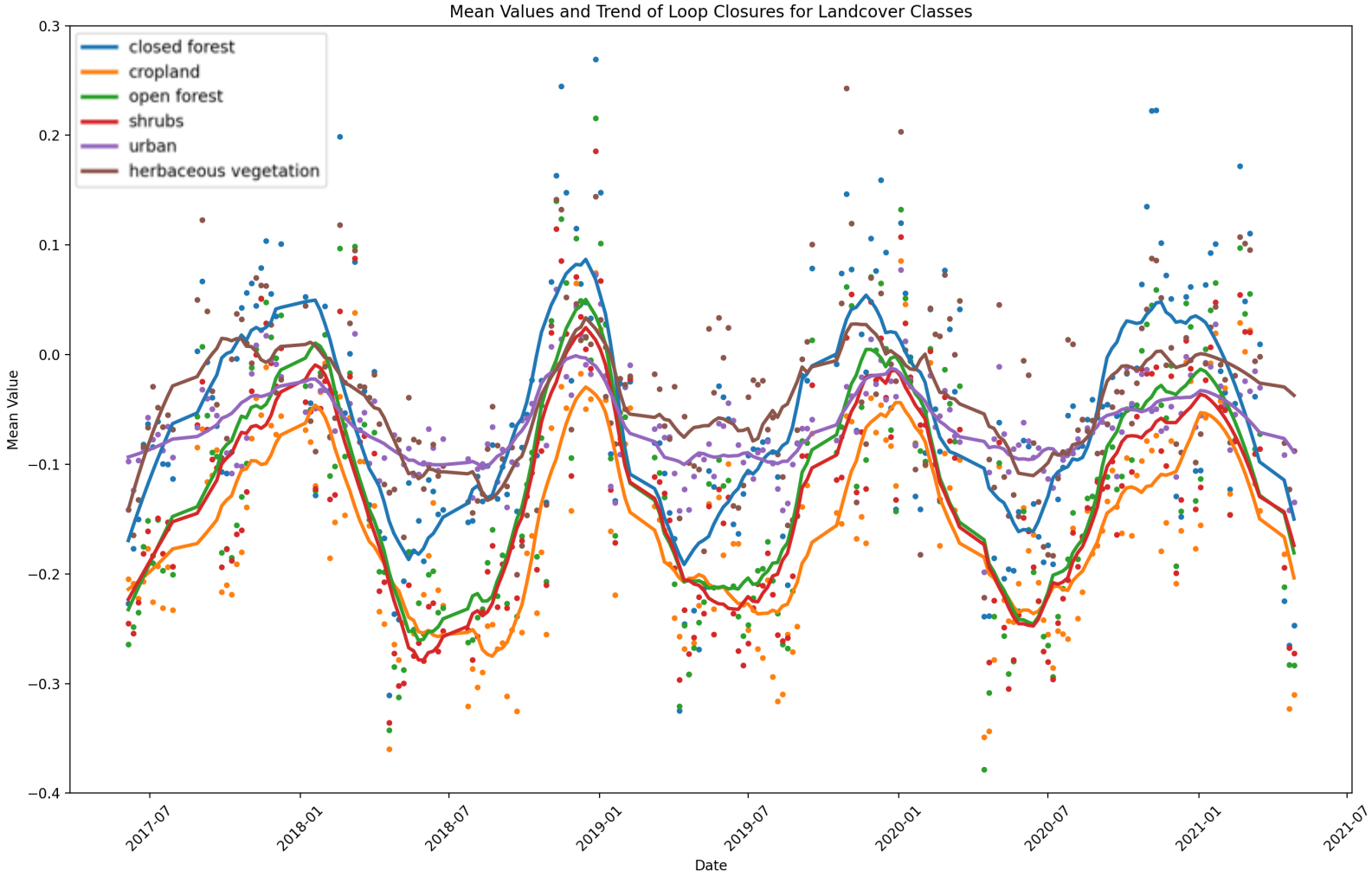


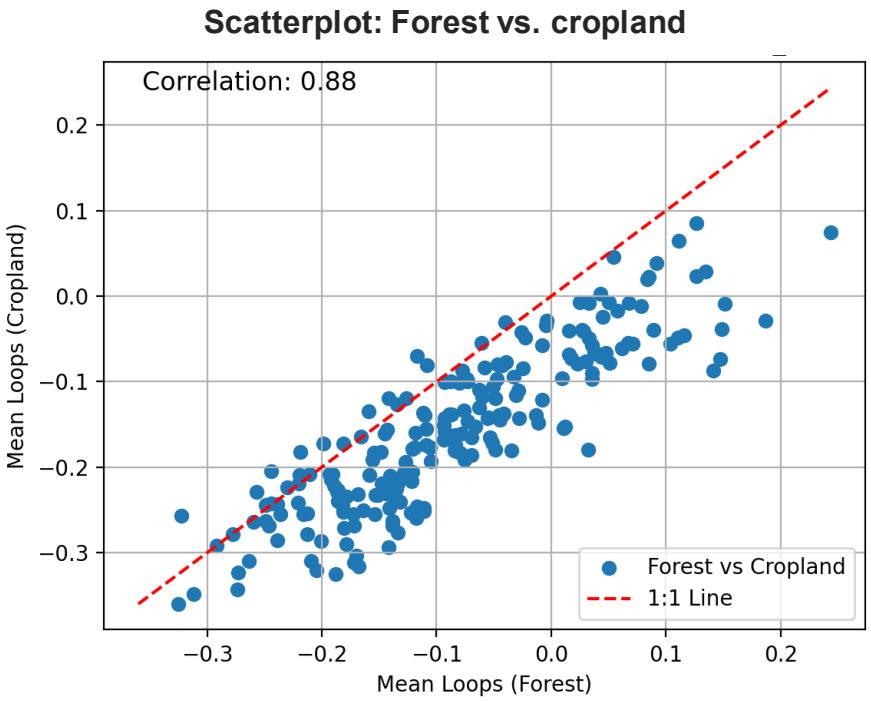


Copernicus global land cover service
https://www.lcviewer.vito.be/

Loop closures in different landcovers

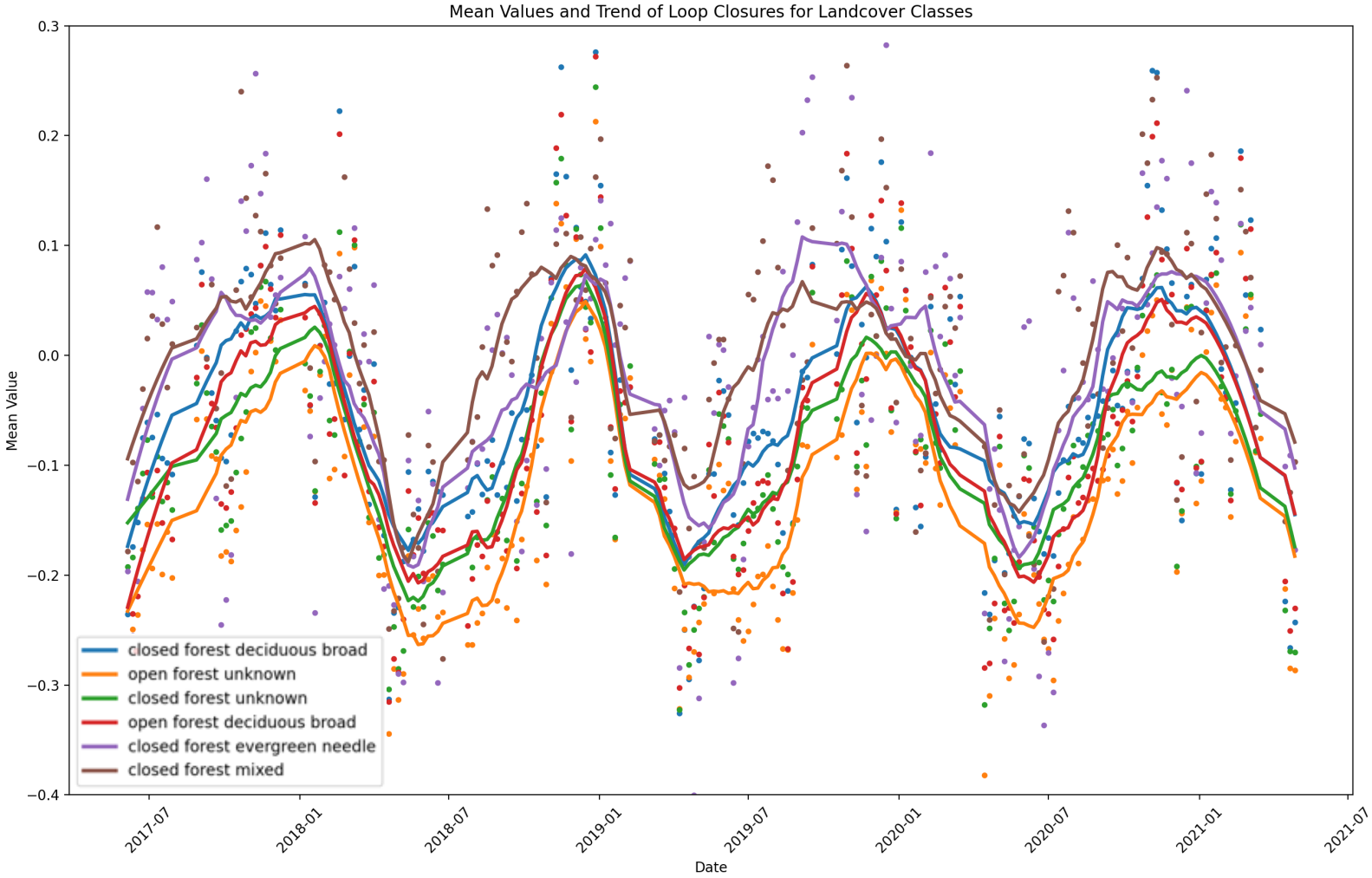
- Mean values of loop closures in different landcovers in Italy





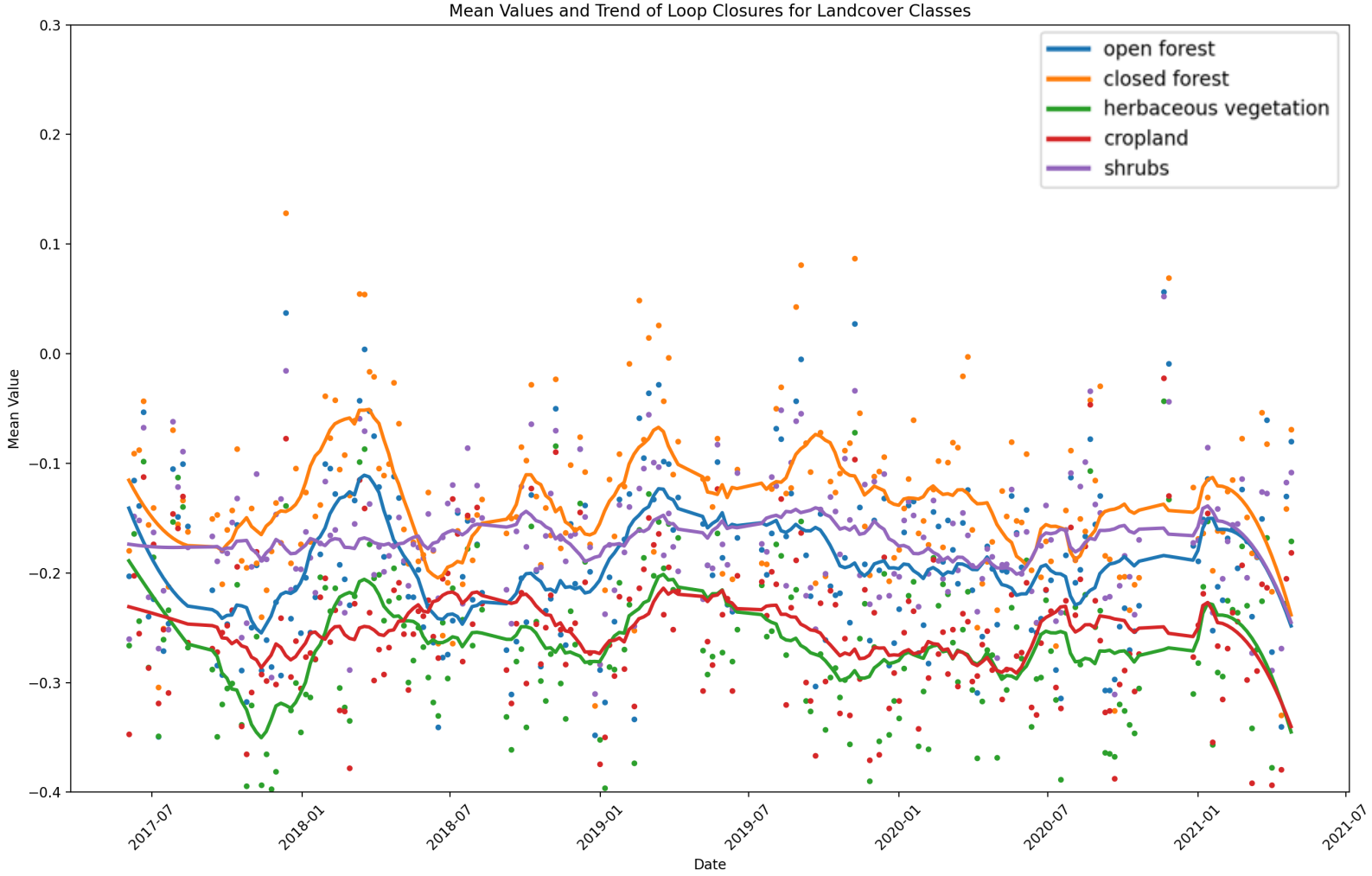
Loop closures in different landcovers

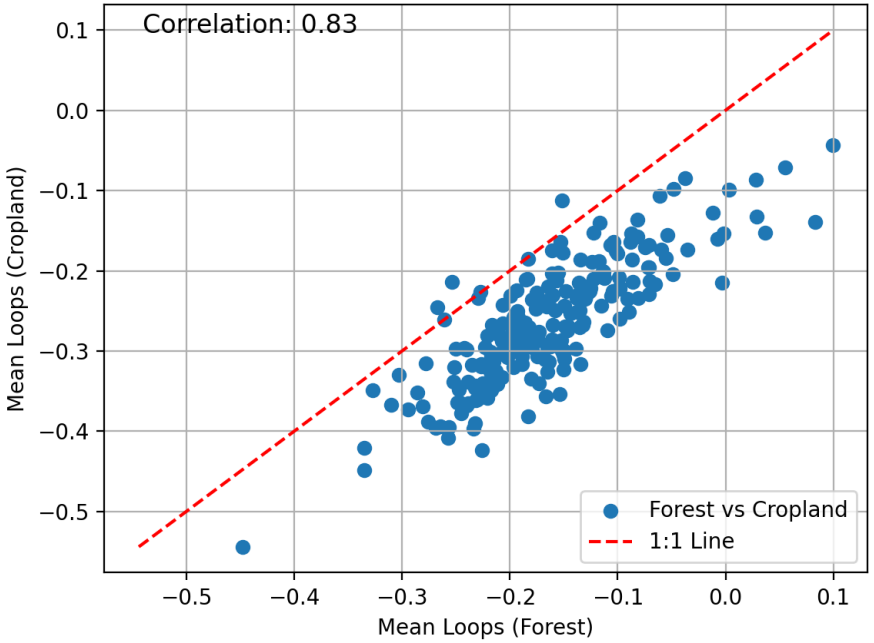
- Mean values of loop closures in different forest classes in Italy



Loop closures in different landcovers

- Mean values of loop closures in different landcovers in Azores





Loop closures in different landcovers

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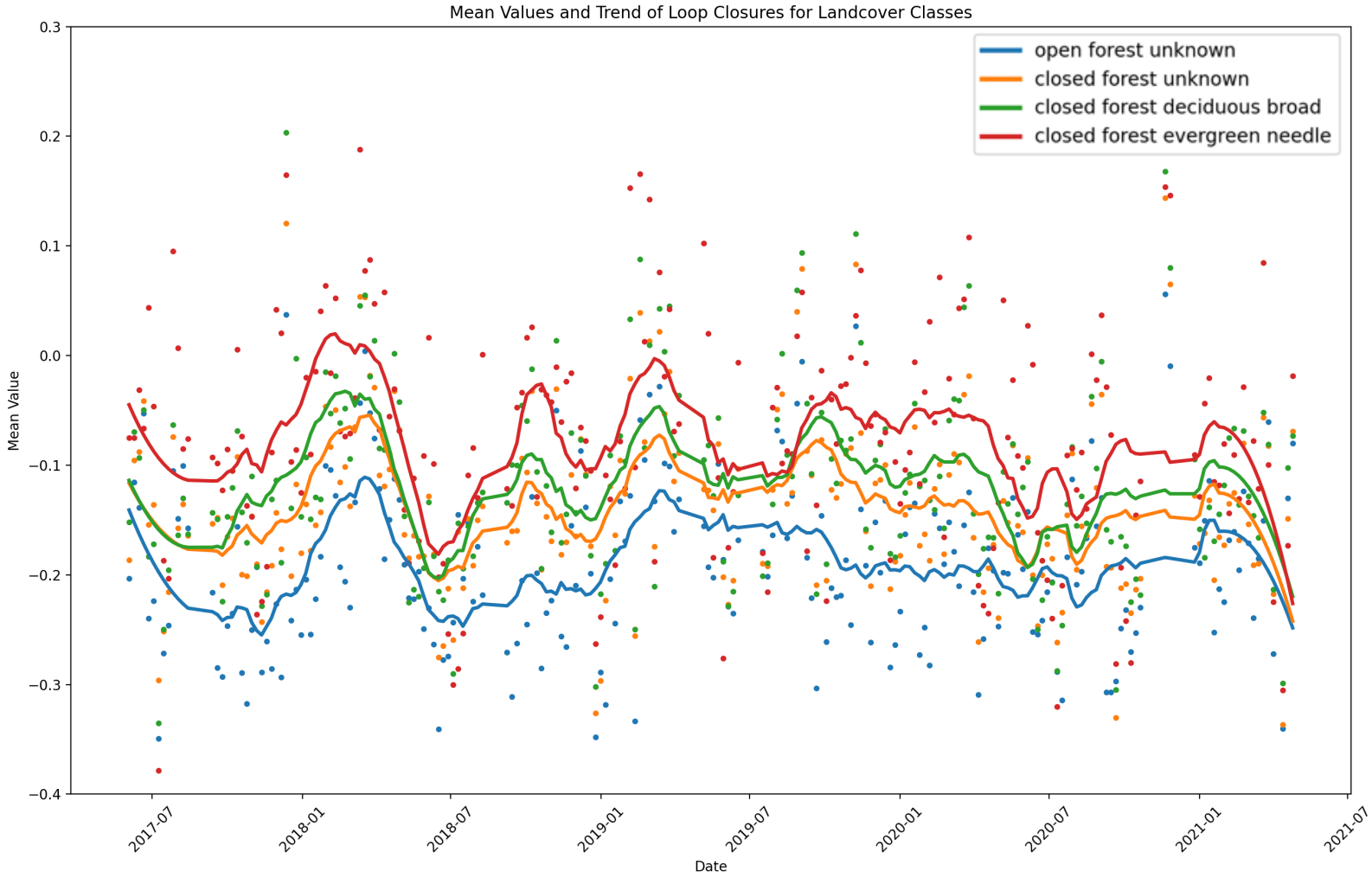
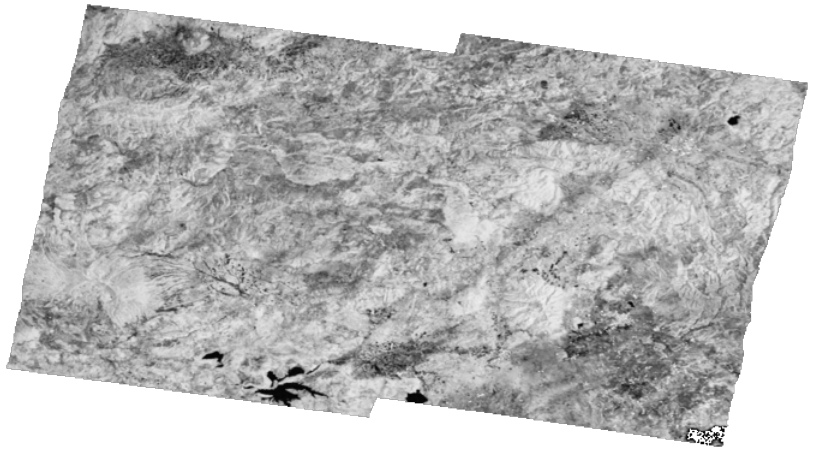
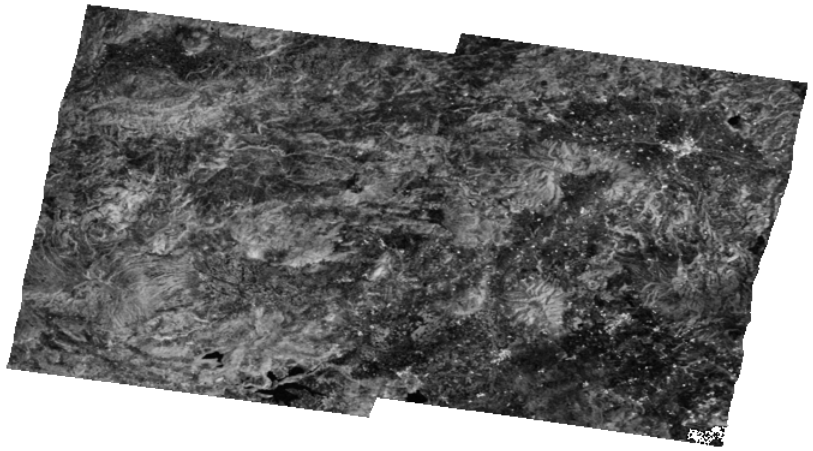


Loop closures time-series: VV vs. VH

Coherence image: VV vs. VH

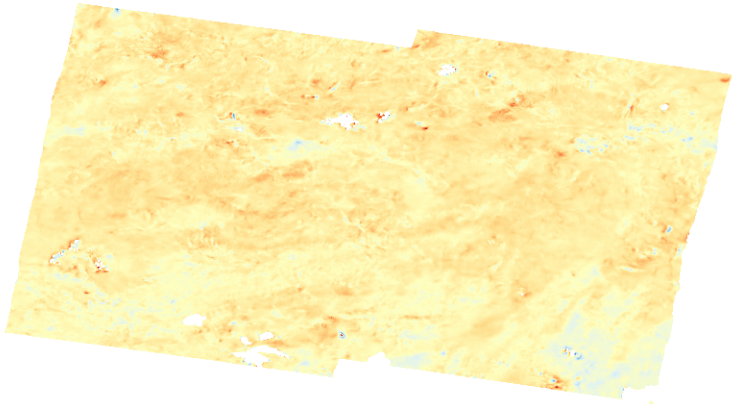


Coherence (VV): 20181006_20181012

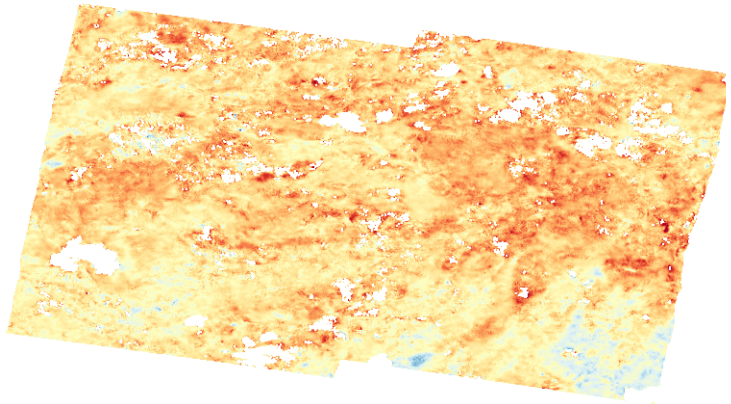


Coherence (VH): 20181006_20181012

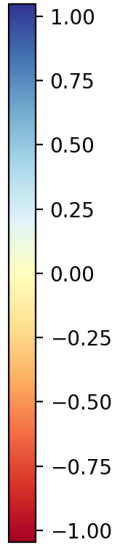
A single loop closure in VV and VH

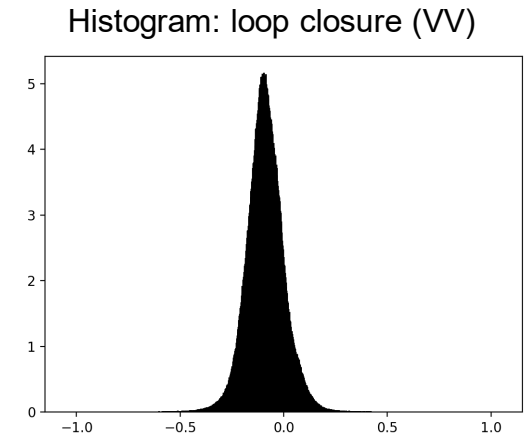


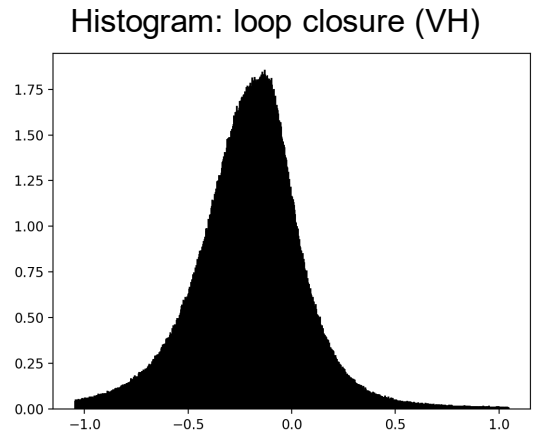
Loop closure (VV)



Loop closure (VH)

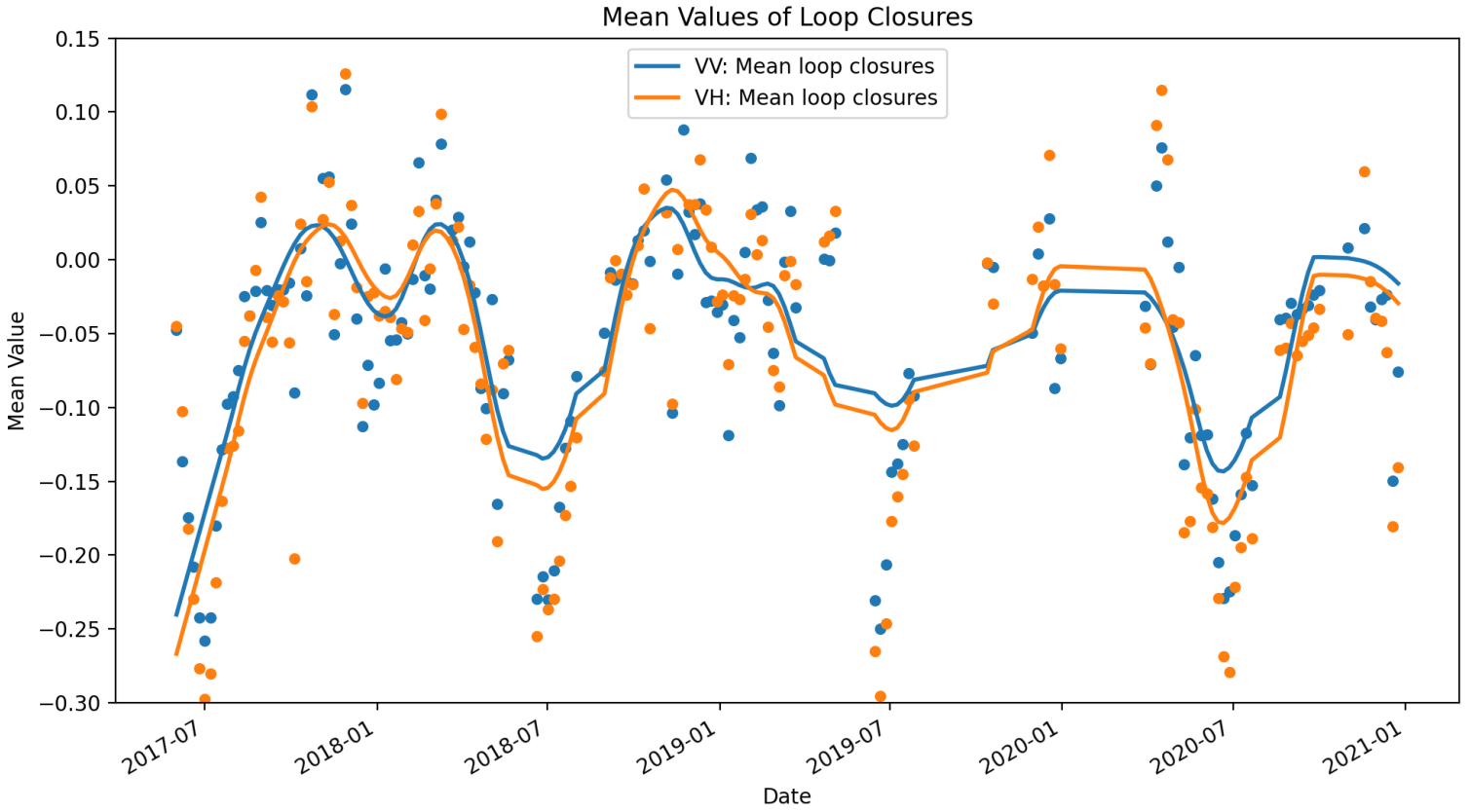


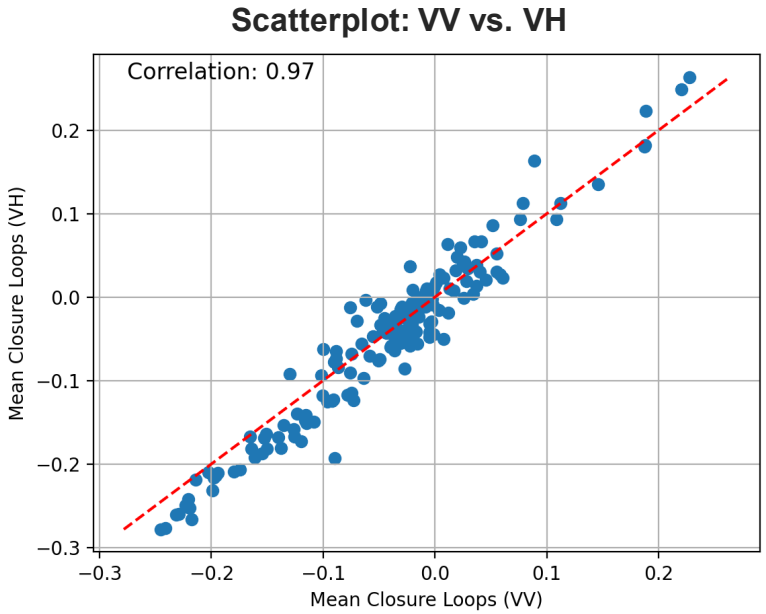




Loop closures time-series: VV vs. VH

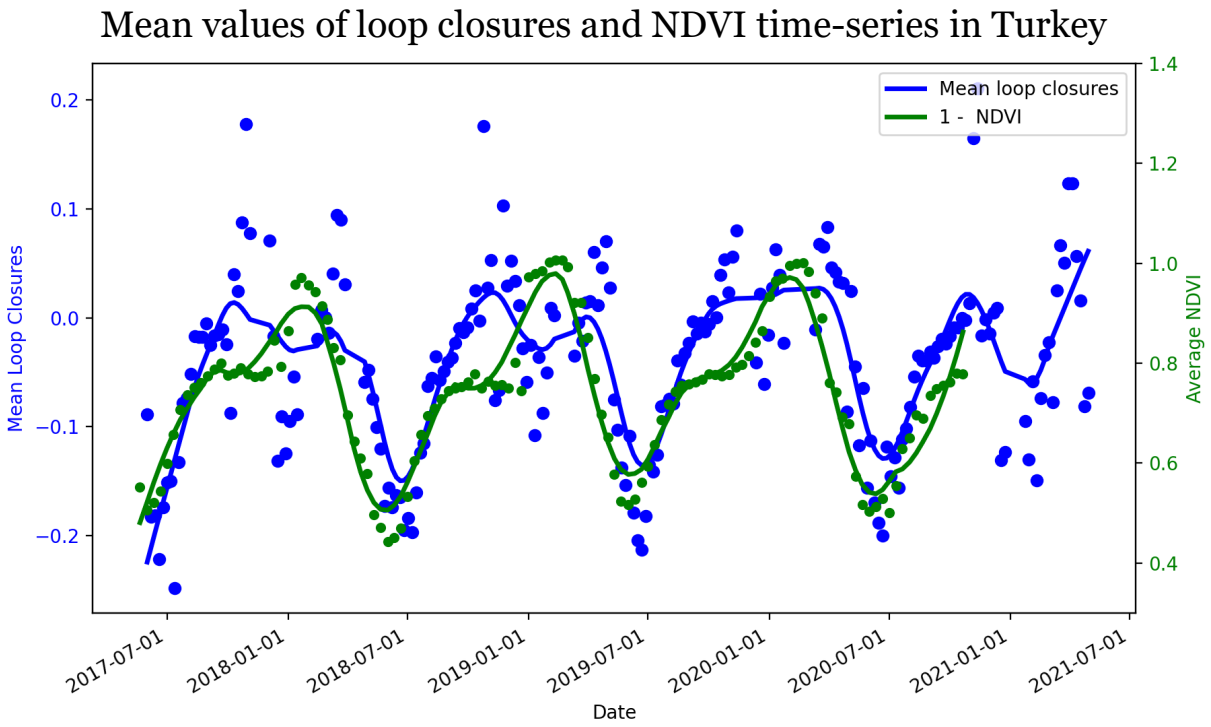
- Mean values of loop closures in VV and VH in Turkey frame:

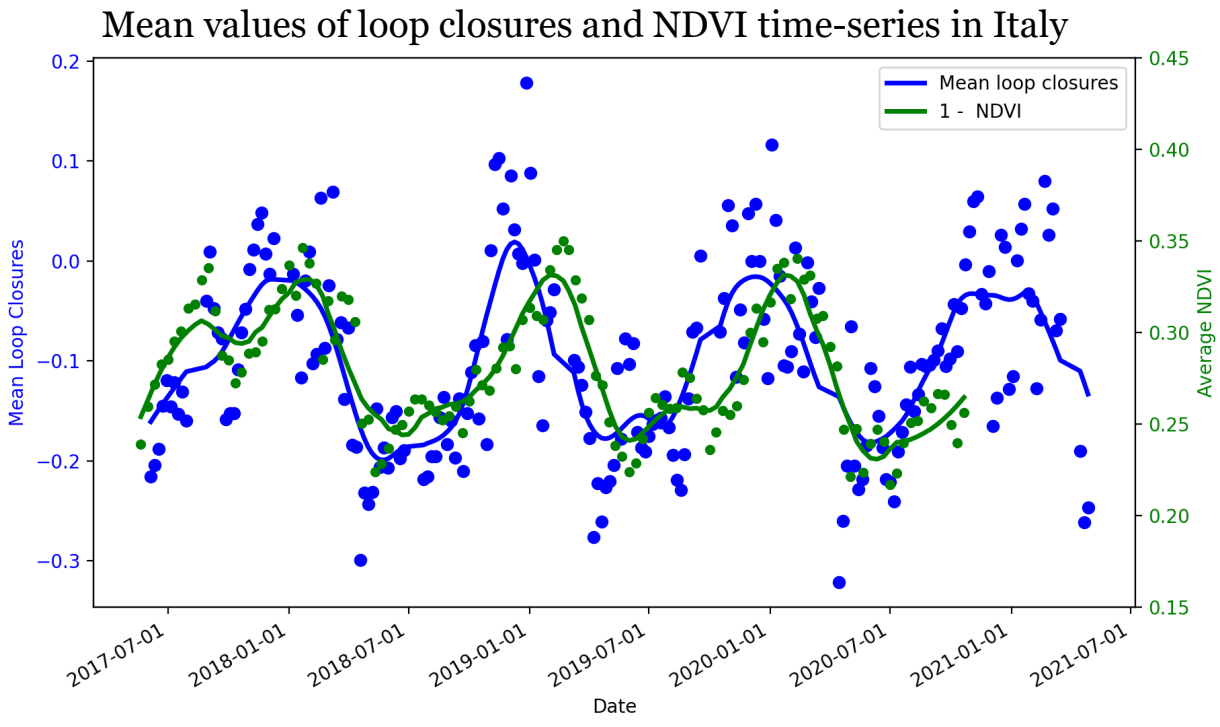




Loop closures time-series vs NDVI

- NDVI: a widely-used metric for quantifying the health and density of vegetation
- Obtained from Copernicus Global Land service (every 10 days using SPOT-VEGETATION Collection)

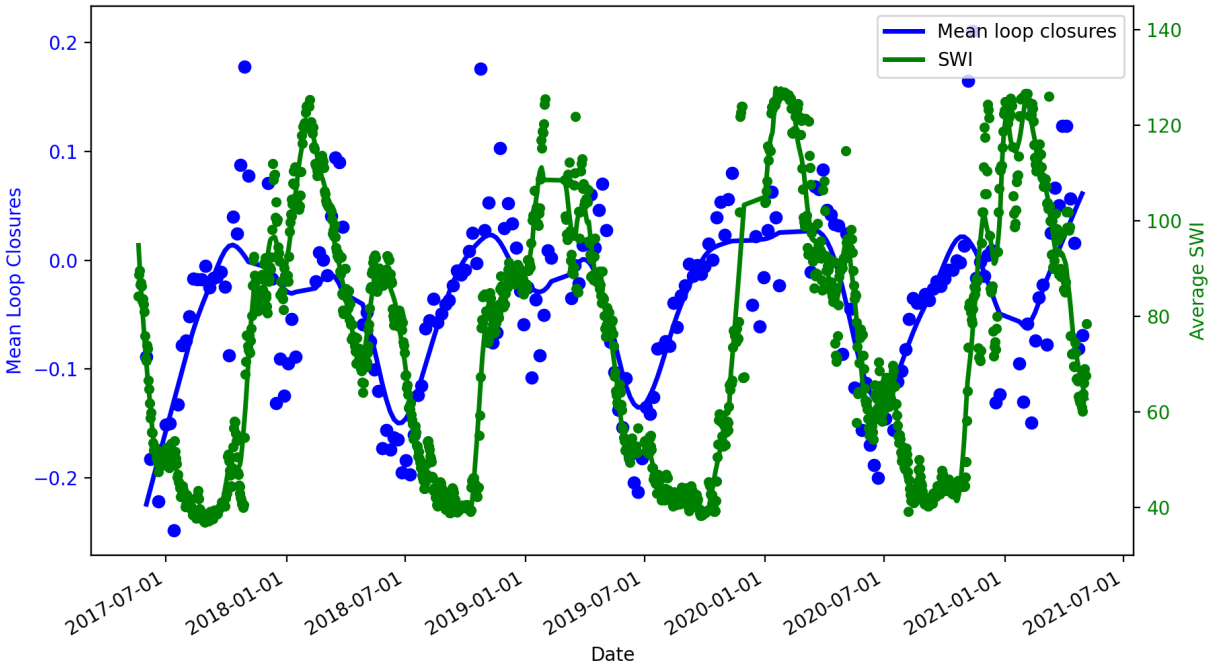




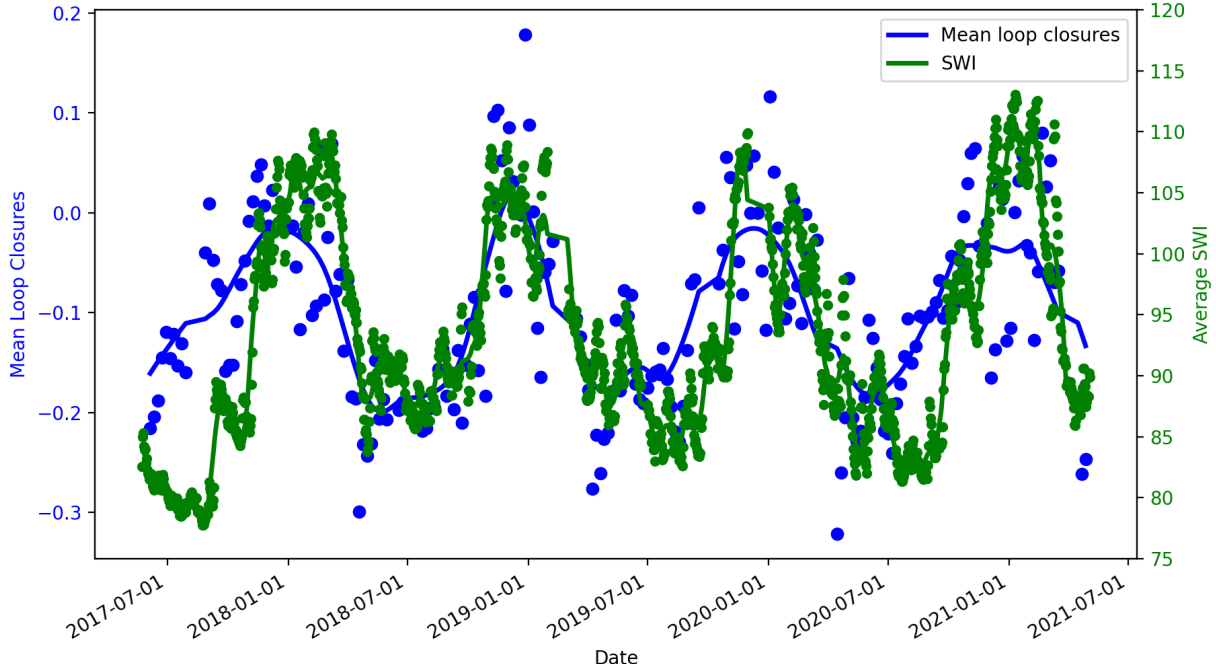
Loop closures time-series vs SWI

- SWI: It shows water content in the soil profile
- Obtained from Copernicus Global Land service (Based on scatterometer satellite sensors and S-1 backscatter data)

Mean values of loop closures and SWI time-series in Turkey



Mean values of loop closures and SWI time-series in Italy



Take-Home Messages

Loop closure time-series:

- The loop closure time-series has a seasonal trend showing itself with different peaks across different regions.
- The lowest values of closure phase was observed in Tien shan whereas the larges values were in Azores

Ascending vs Descending:

- There was not a significant change of closure phase in ascending and descending which suggests that Phase bias is a lesser concern in the east-west velocities but more importance when estimating vertical velocities.

Effect of filtering:

- Filtering (whether Goldstein or boxcar) can significantly increase the closure phase values.
- The increase was larger in denser landcovers/larger precipitation

Take-Home Messages

Land cover investigation:

- Cropland has larger phase bias than forest
- Open forest has generally larger phase bias than closed forest

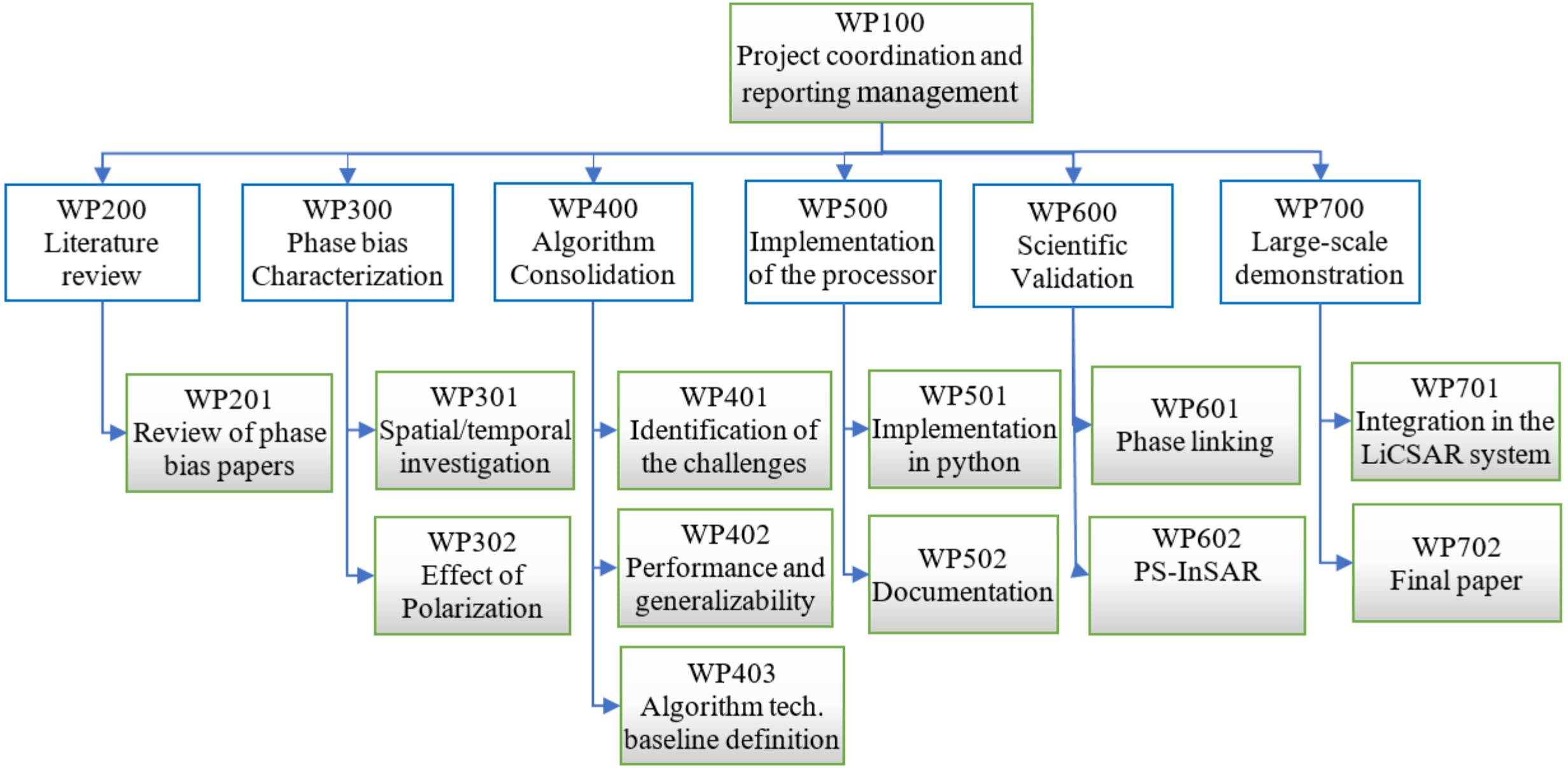
Polarization dependency:

- VH in general ended up with larger values of loop closures than VV

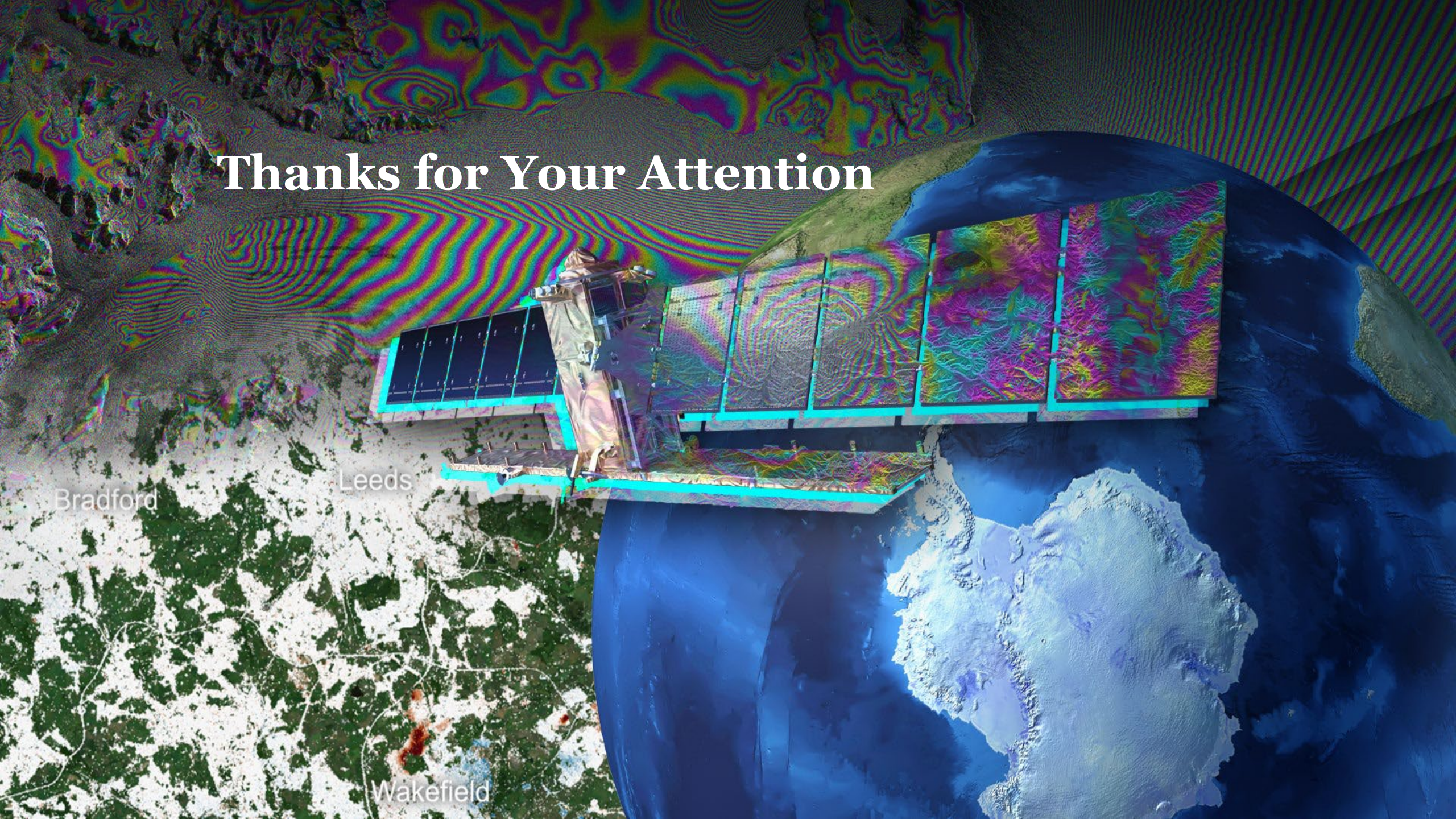
Environmental proxies:

- A good match was observed between the vegetation growth (NDVI) and closure phase time-series
- The closure phase time-series agrees well with surface soil moisture (SWI)

Outlook


WP100
Project coordination and reporting management
WP200
Literature review
WP300
Phase bias Characterization
WP400
Algorithm Consolidation
WP500
Implementation of the processor
WP600
Scientific Validation
WP700
Large-scale demonstration
WP201
Review of phase bias papers
WP301
Spatial/temporal investigation
WP302
Effect of Polarization
WP401
Identification of the challenges
WP402
Performance and generalizability
WP403
Algorithm tech. baseline definition
WP501
Implementation in python
WP502
Documentation
WP601
Phase linking
WP602
PS-InSAR
WP701
Integration in the LiCSAR system
WP702
Final paper

Thanks for Your Attention



Future works

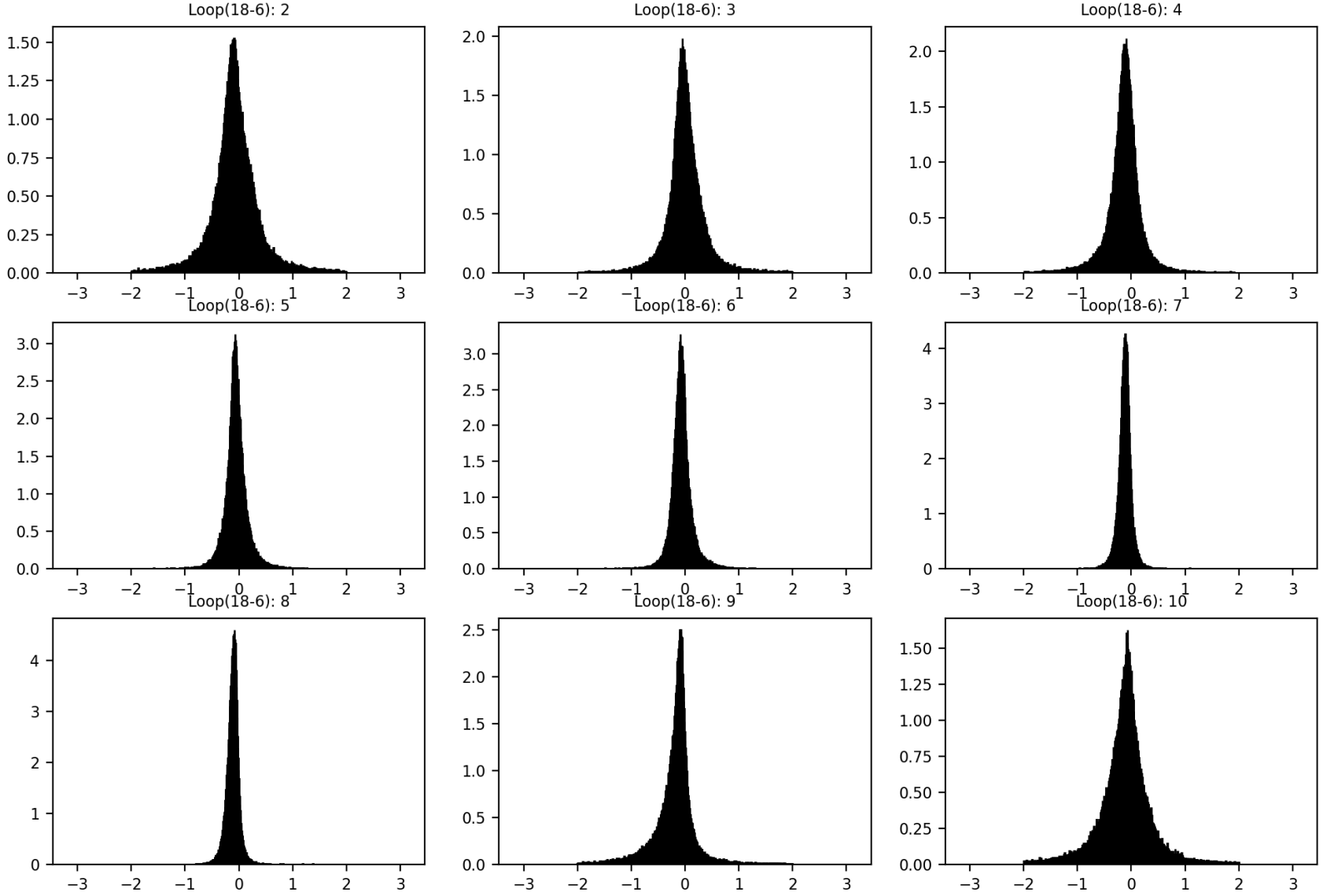
- Investigate the effect of phase closure wrapping
- Investigate the minimum temporal baseline required to fulfil the “zero bias” assumption
- Account for small and large gaps in the time series, identifying possible limitations
- Investigate if the coefficients of the assumed linear system vary in time and/or space (either pixel by pixel or for different land covers)
- Investigate the necessity of including smoothing constraints to the system of equations
- Investigate the benefits of having more than three connections per epoch, and the upper limits in terms of temporal baselines and number of connections
- Investigate cases where a mixture of acquisition patterns (e.g., 6 and 12 days) exists in the time series

Outstanding questions

- Do a_1 and a_2 vary in time and space?
- Can a_1 and a_2 be estimated during the inversion?
- Can we account in the algorithm for complete loss of coherence e.g. when a crop is harvested?
- How to do the inversion when there is a gap in the time-series?
- Can we apply a smoothing temporal constraint of the bias in case of a gap?
- How to do the inversion when there are missing interferograms (lack of 3 nearest interferograms)?
- How to expand the idea when having larger than 3 connection per epoch?
- Can we split the time-series and run the inversion in subsets?

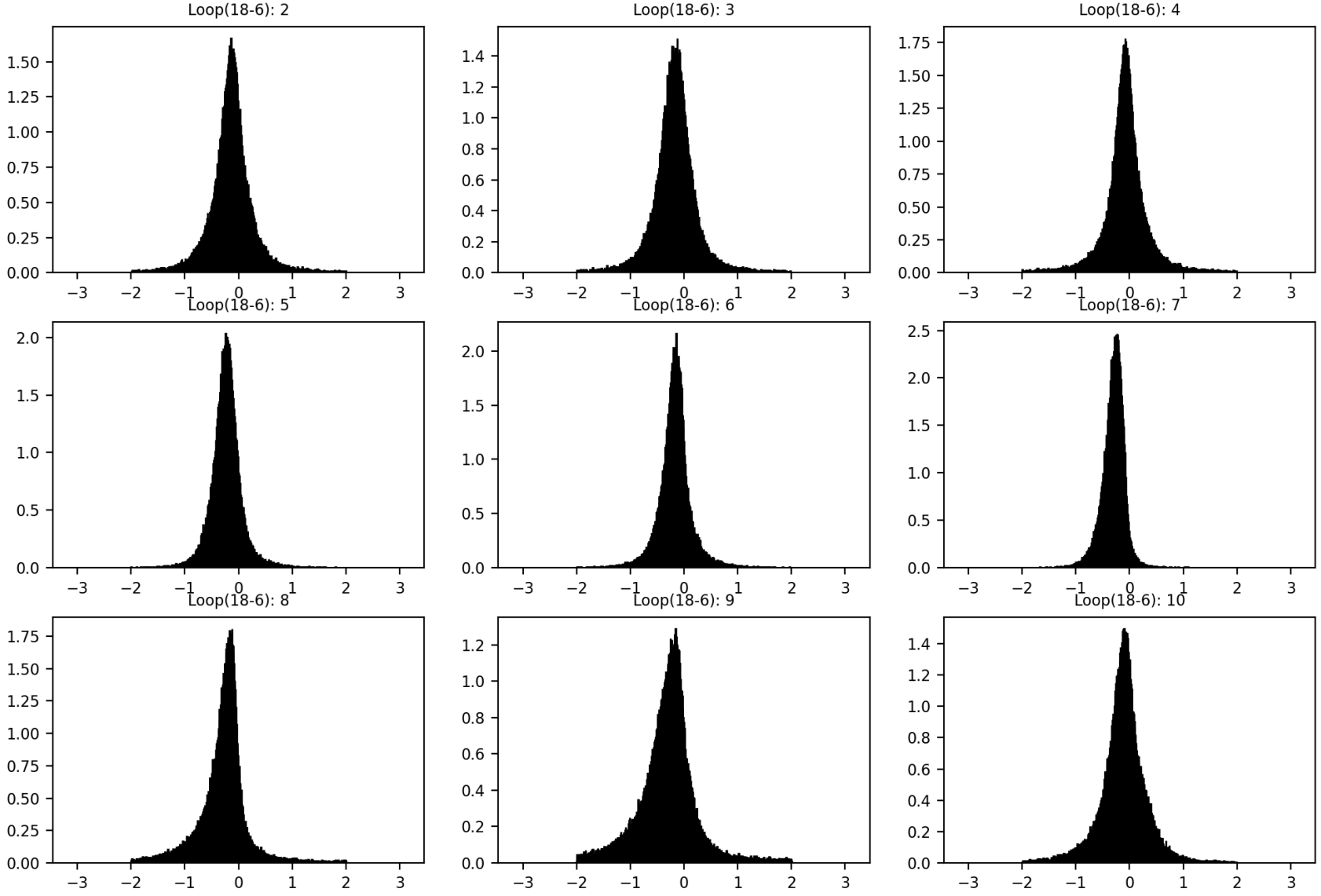
Future works

$$12\ day\ -\sum_{1}^{2} 6\ day$$



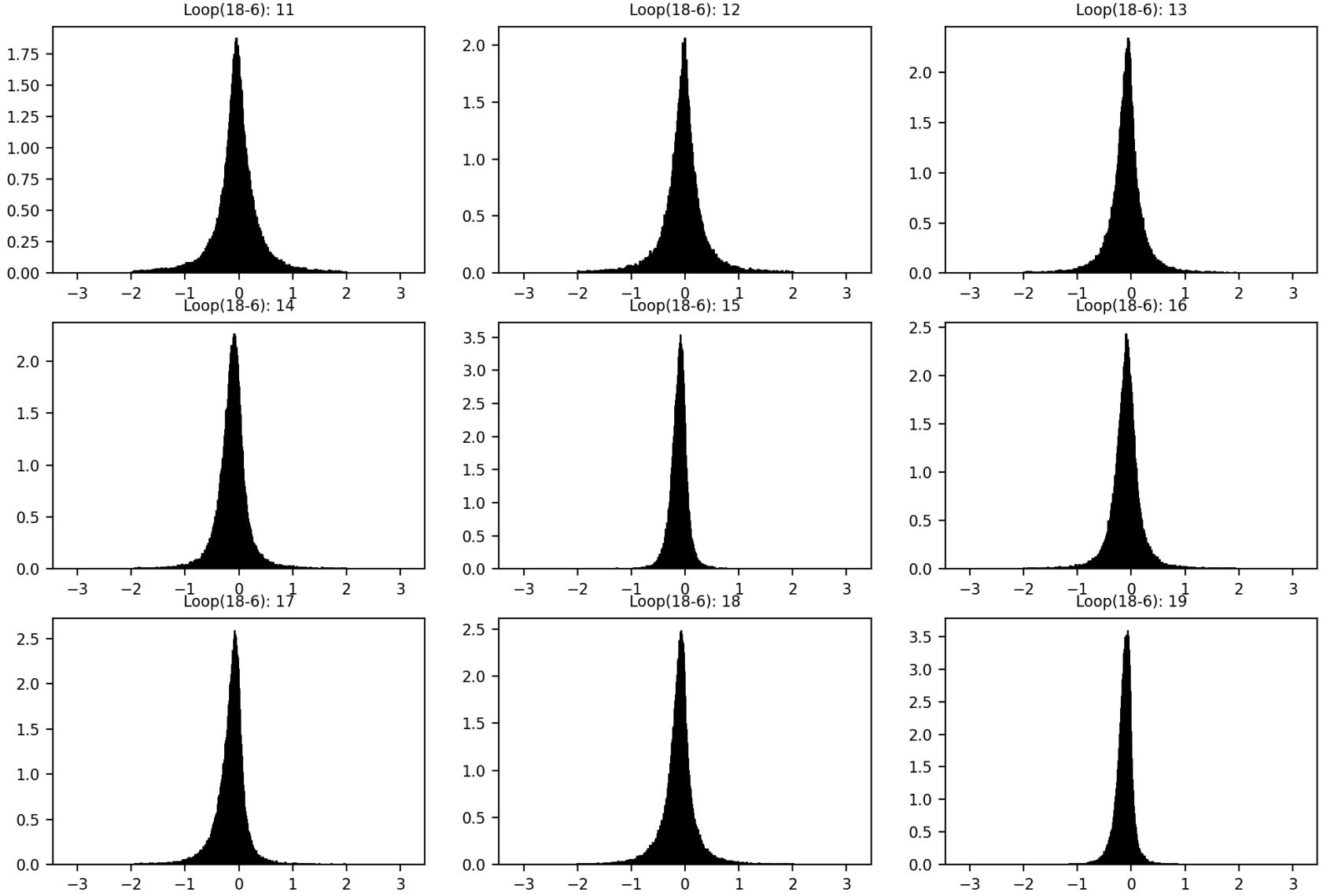
Future works

$$18\ day\ -\sum_{1}^{3} 6\ day$$



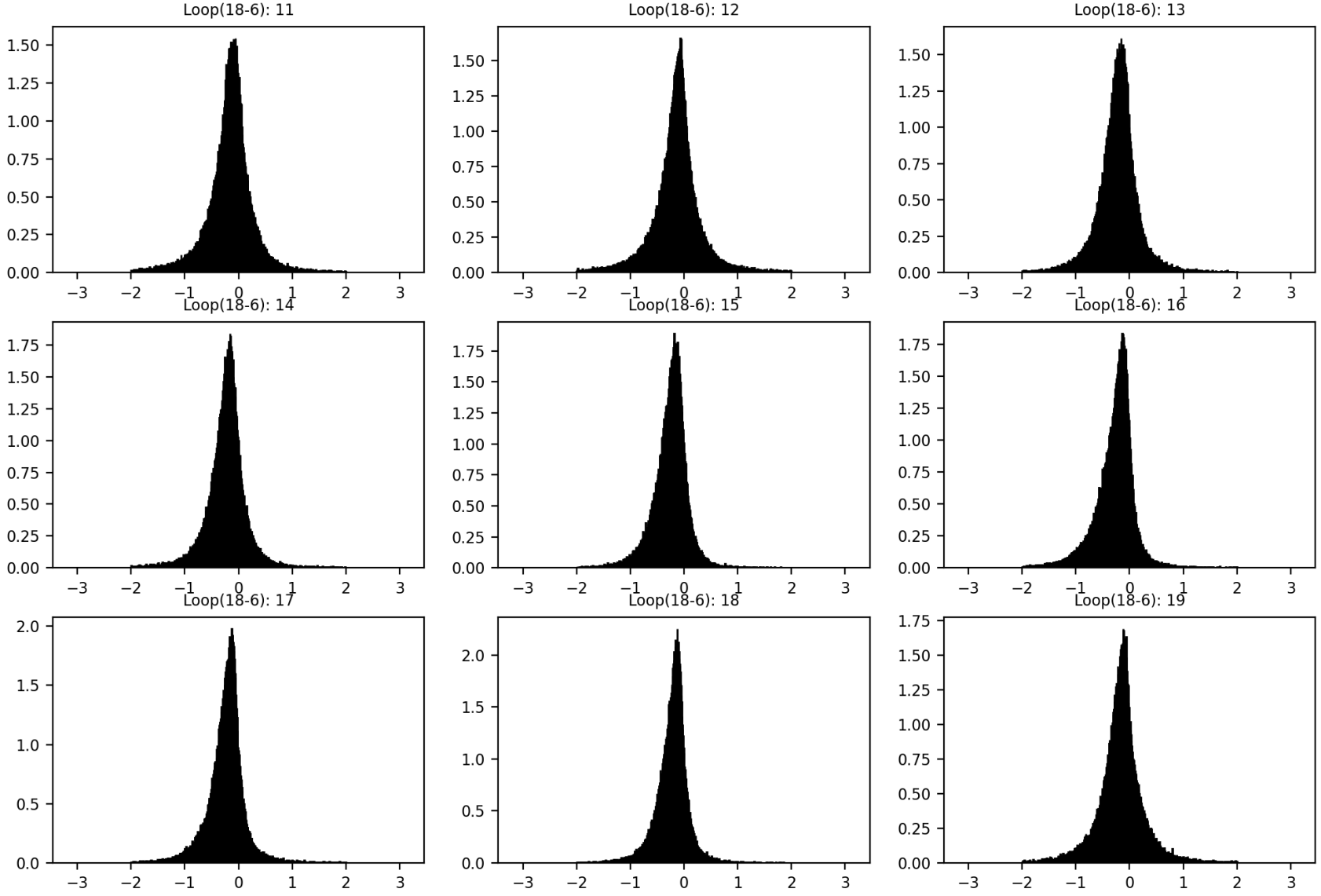
Future works

$$12\ day\ -\sum_{1}^{2} 6\ day$$



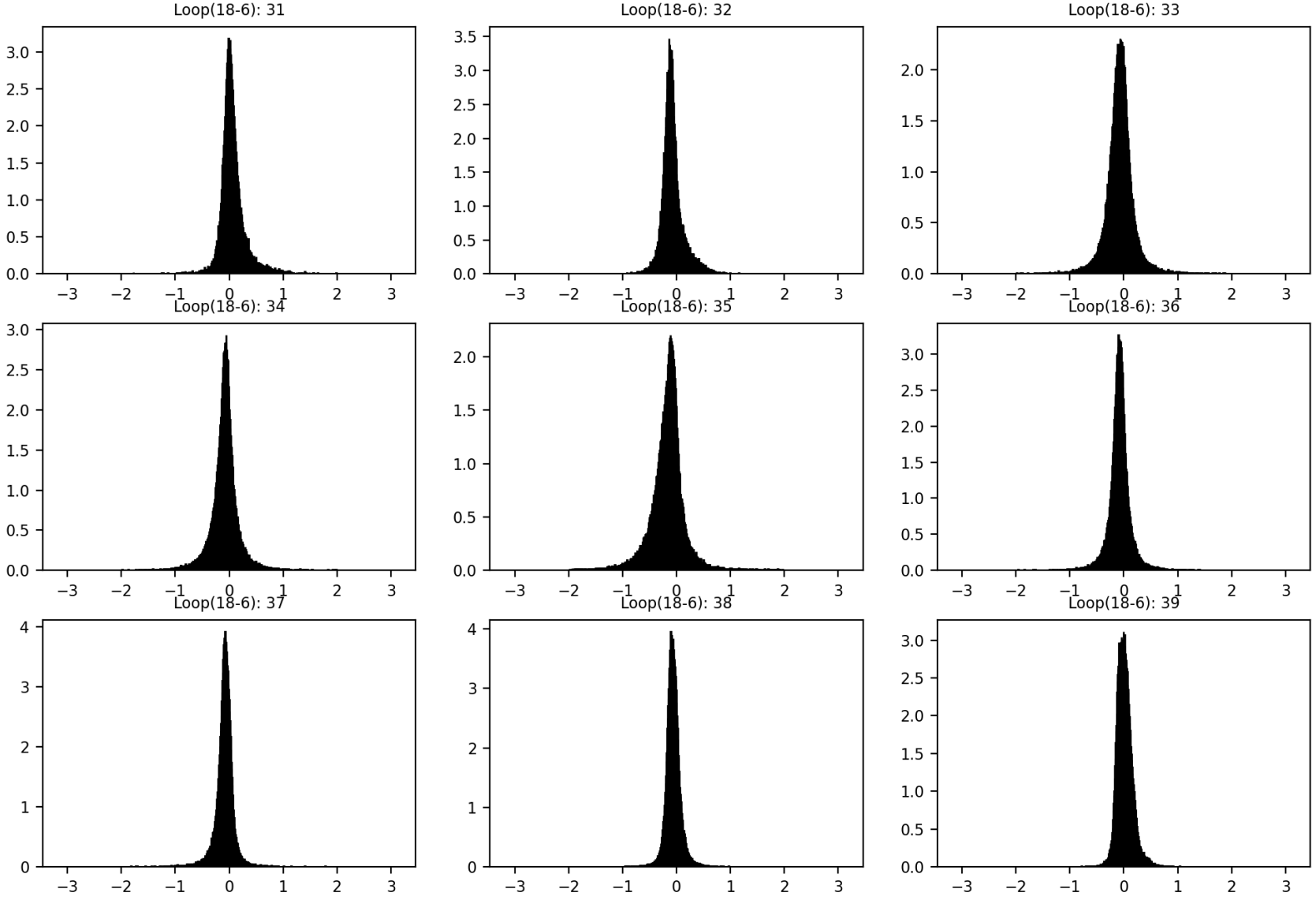
Future works

$$18\ day\ -\sum_{1}^{3} 6\ day$$



Future works

$$12\ day\ -\sum_{1}^{2} 6\ day$$



Future works

$$18\ day\ -\sum_{1}^{3} 6\ day$$