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INVERTING CLOSURE PHASE PROBLEMS WITH MULTIPLE-REFERENCE SAR INTERFEROMETRY
Francesco De Zan - delta phi remote sensing

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Inversion problems



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Closure phases are there...

How to retrieve the information they carry?

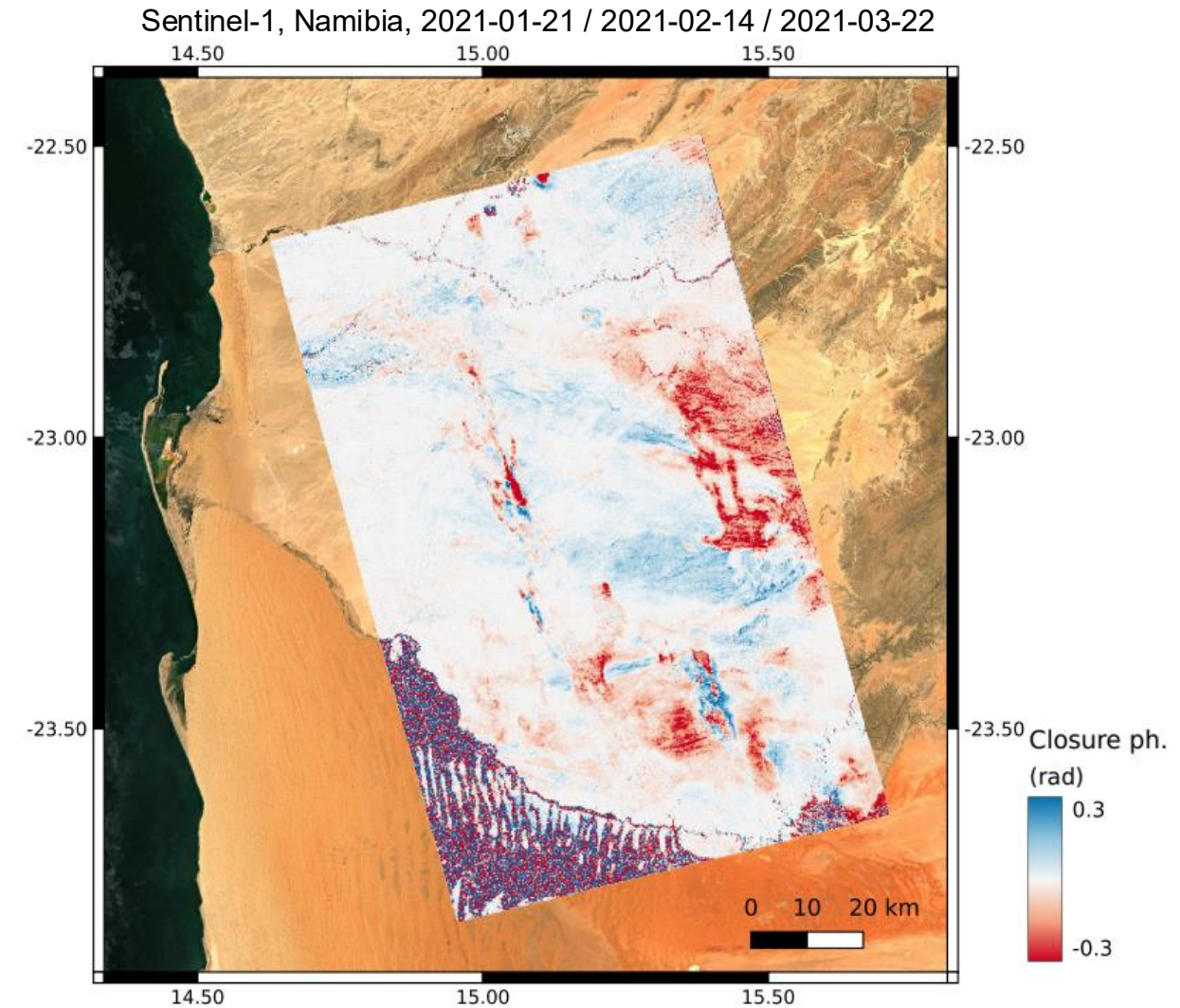
In particular: how to invert soil moisture?

Simple model-inversion starting from closure phases is not very easy

- independent closure phases grow quadratically with the size of the dataset
- modeling is not perfect

I am trying to work from a “processing” perspective rather than an “inversion” perspective:

- Closure phases imply the existence of different scattering contributions
- Can we identify those contributions?



2

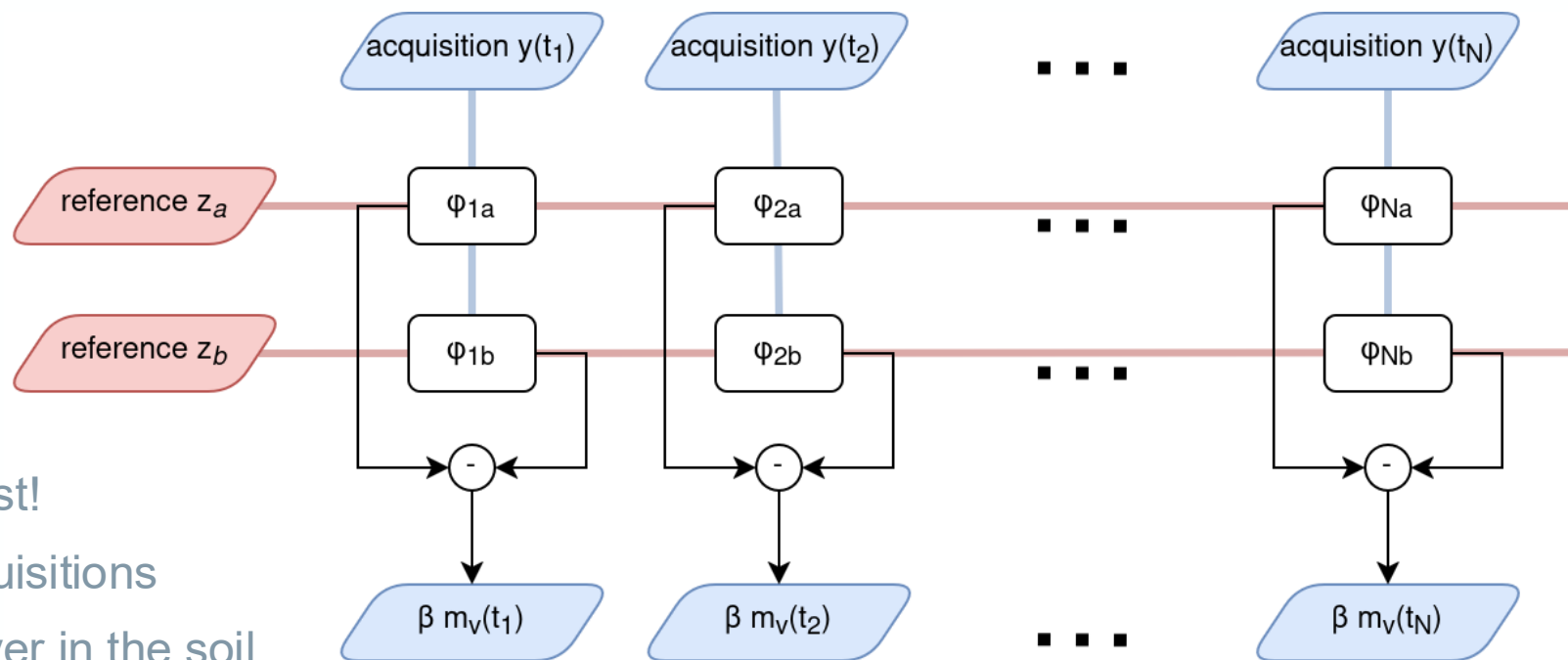
Two reference interferometry



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- Two references yield two series of interferometric phases
- The difference of the two phase times series carries some closure phase information (a soil moisture index)
- Each difference can be seen as a closure phase itself



The processing is elementary and fast!

It is possible to process 100's of acquisitions

Each reference could represent a layer in the soil

F. De Zan, P. Filippucci, L. Brocca, *Validation of high-resolution surface soil moisture time series retrieved by means of SAR interferometry*, Remote Sensing of Environment, Volume 335, 2026, 115266, ISSN 0034-4257, <https://doi.org/10.1016/j.rse.2026.115266>.

How to generate the references



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The linear combination of three acquisitions can be steered to yield any phase history when interfered with those same acquisitions.

1) Select a triplet (t_m, t_n, t_k) with a large closure phase

2) We are going to target two different phase histories

- a series corresponding to phase linking

$$\varphi_a(t_m), \varphi_a(t_n), \varphi_a(t_k)$$

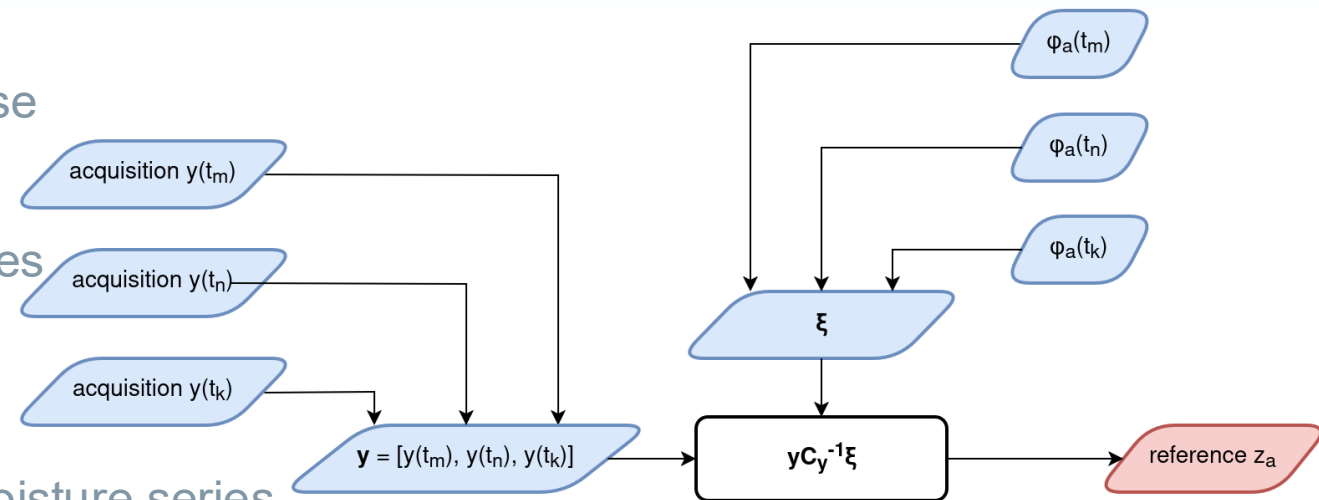
- a “delta” series incorporating a rudimentary soil moisture series

$$\varphi_b(t_m) = \varphi_a(t_m) + \beta \hat{m}_v(t_m)$$

$$\varphi_b(t_n) = \varphi_a(t_n) + \beta \hat{m}_v(t_n)$$

$$\varphi_b(t_k) = \varphi_a(t_k) + \beta \hat{m}_v(t_k)$$

We could make use of
only two acquisitions
(instead of three)



3) We are going to generate two references, one for each phase history

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Solution: sign change for some time series before averaging



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Simple phase estimation



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Similar to phase linking, EMI etc. (retrieving a consistent multi-looked phase time series) but...

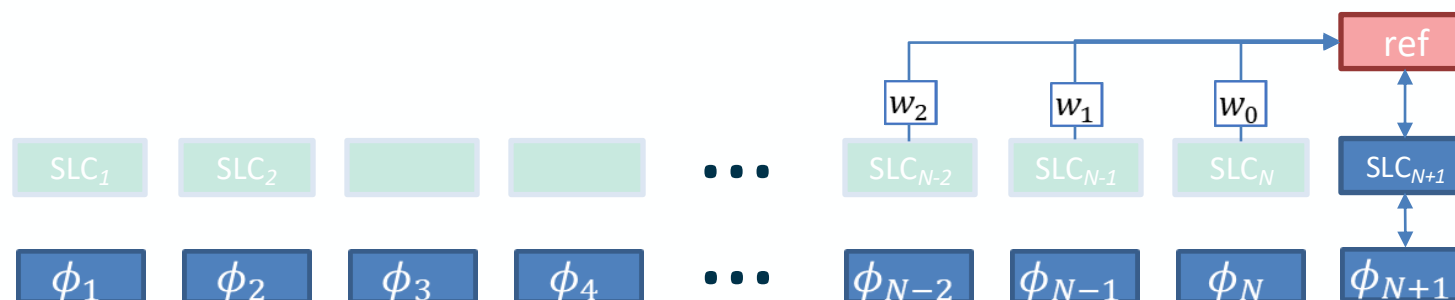
- it is progressive: one new multi-looked phase for each acquisition
- there is no matrix inversion

Filtering the past in a coherent way to maximize interference with scatterers which are coherent over time

Idea: filtering could dampen vegetation contributions (relatively to stable scatterers)

Before coherent filtering it is necessary to restore phase coherence, since the original phase is basically random

An additional, important long-term calibration step is not shown here

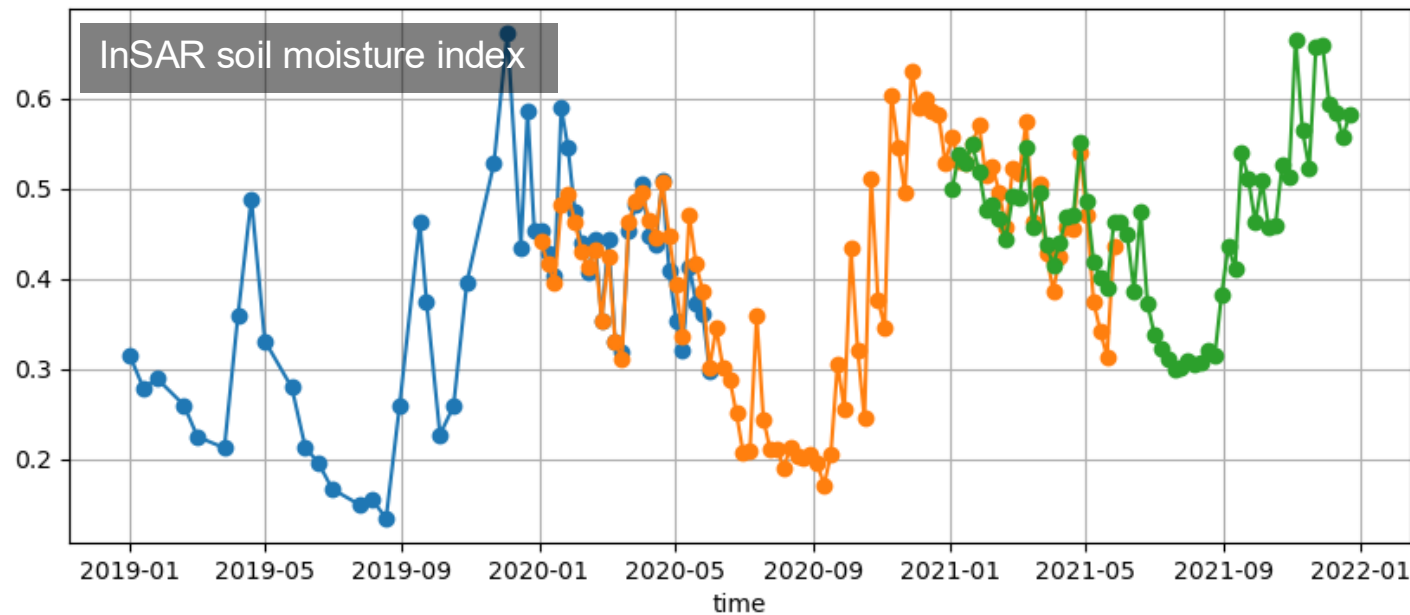


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Unwanted trends appear when simply stitching soil moisture results (vegetation bias?)

How to filter the desired components (soil) and minimize the rest (vegetation)?



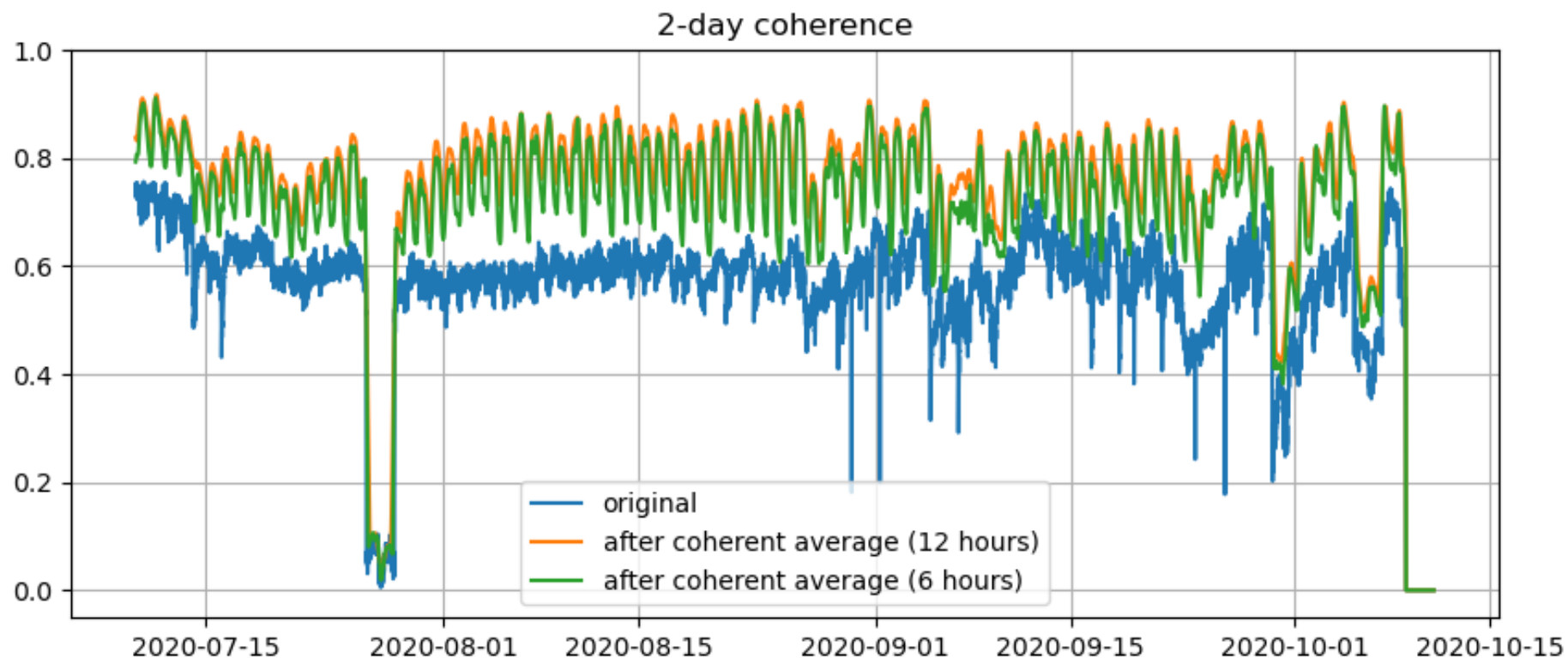


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But: No obvious improvement in the soil moisture inversion over vegetation



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