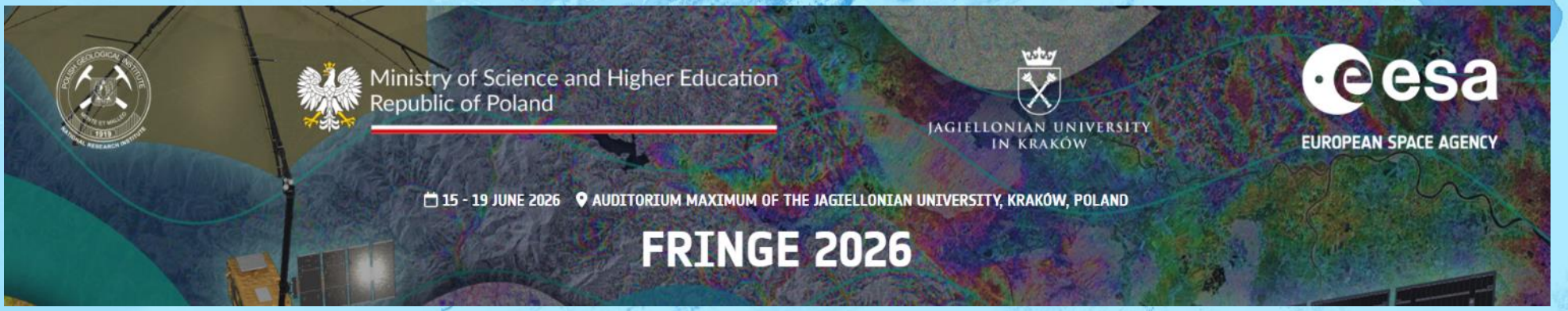
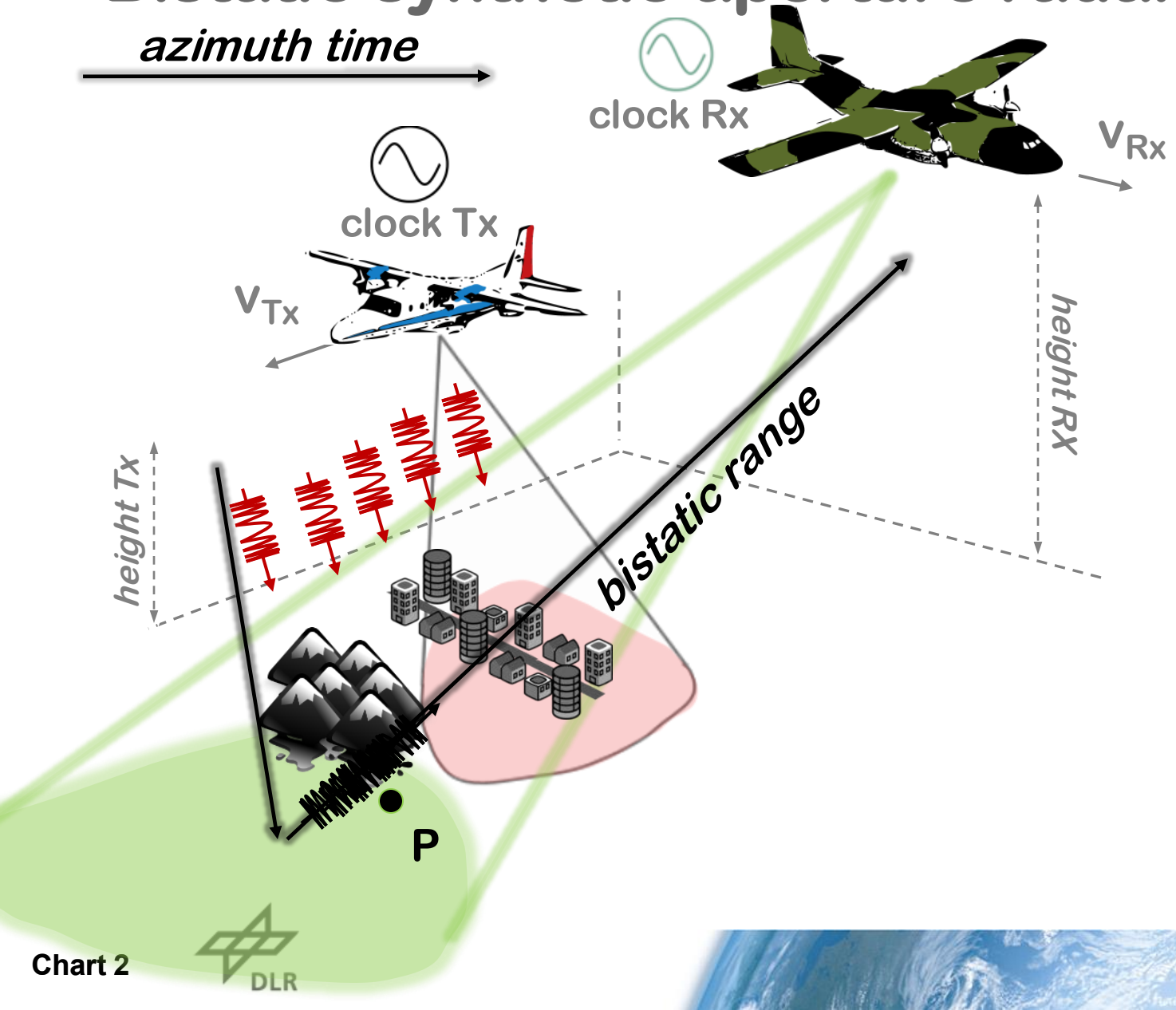
A Robust Data-based Phase Synchronisation Approach for the Harmony Mission

Marc Rodriguez-Cassola, Pau Prats-Iraola, Eduardo Rodrigues-Silva

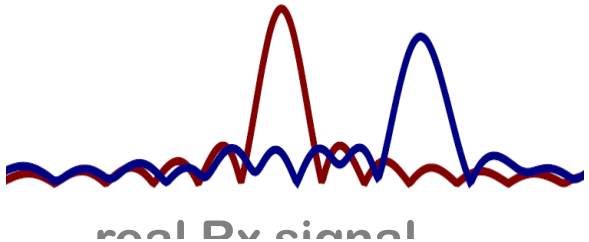


DLR

Bistatic synthetic aperture radar



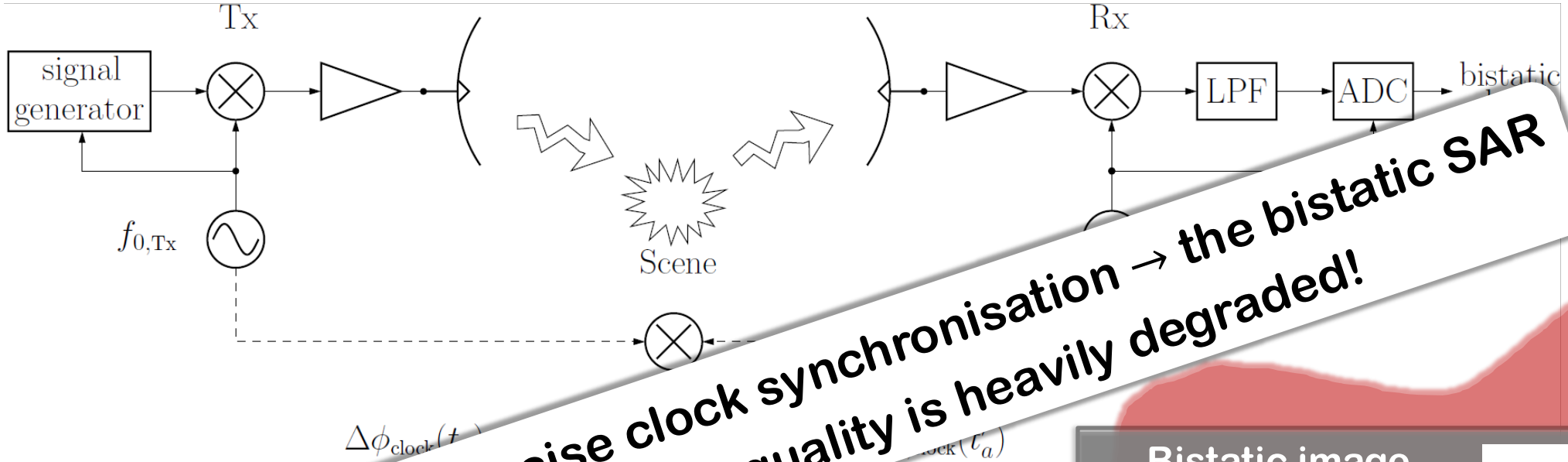
Bistatic Data Synchronisation



real Rx signal

DLR

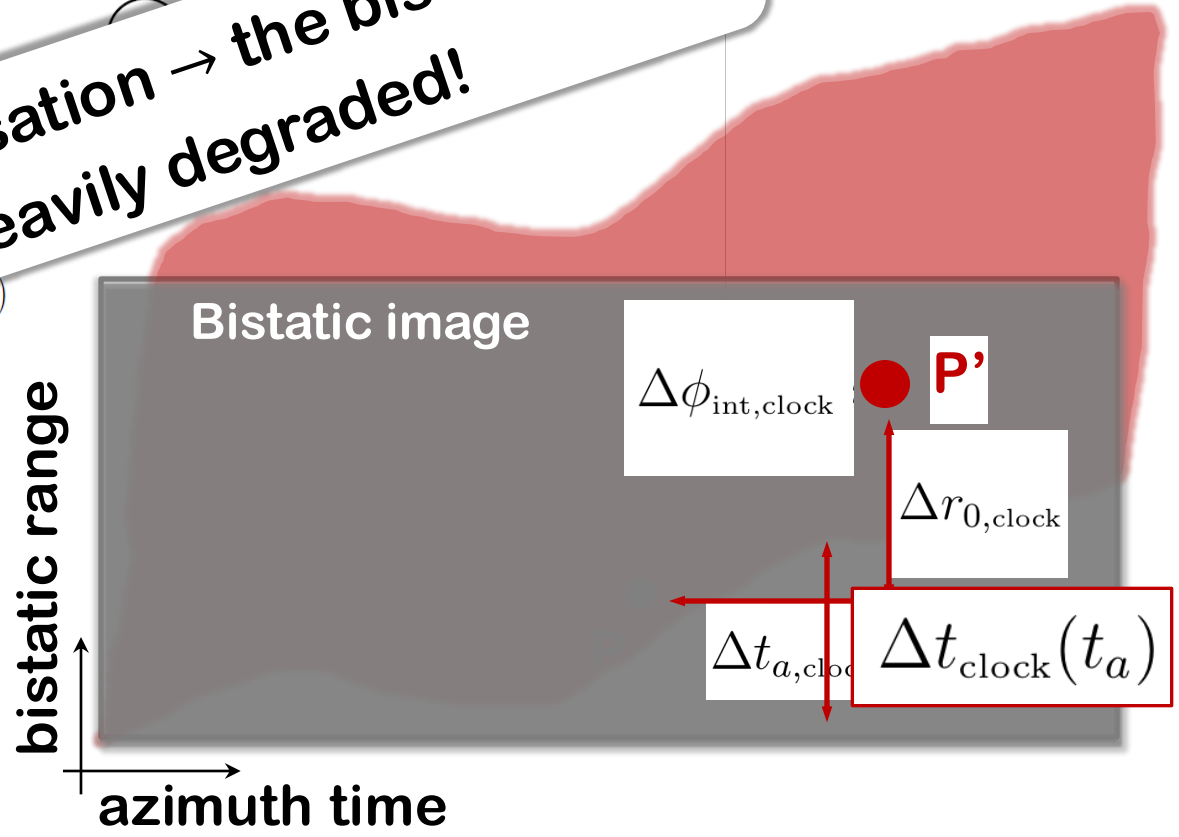
Lack of synchronisation in bistatic SAR systems



No precise clock synchronisation → the bistatic SAR image quality is heavily degraded!

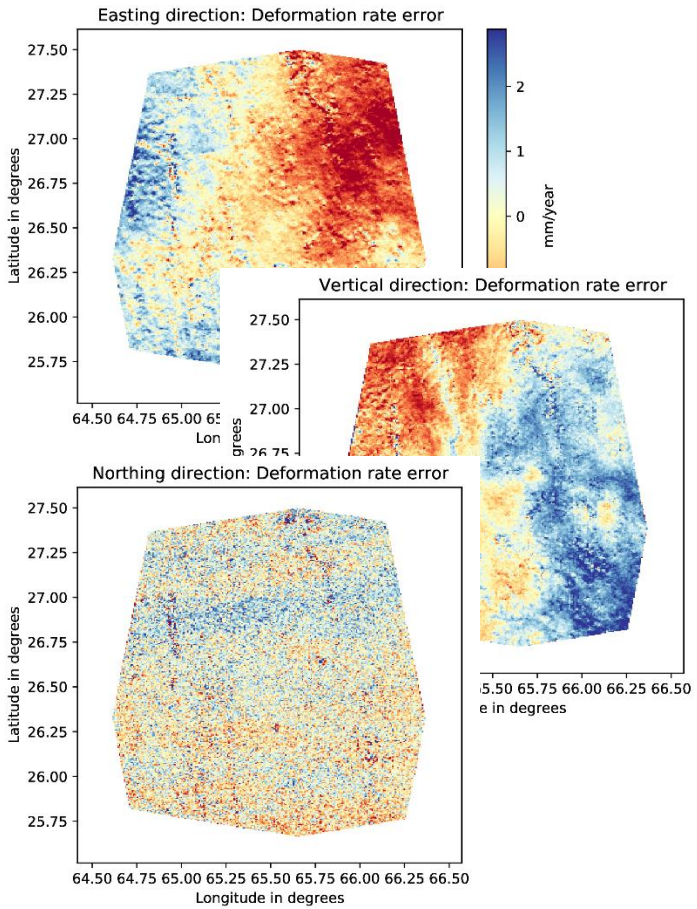
Appar… …ge history

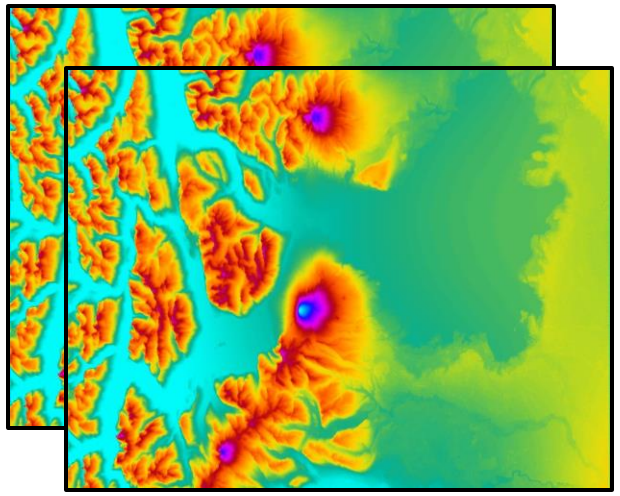
$$r(t_a) \rightarrow r(t_a) + \lambda \cdot \int_{t_{a,0}}^{t_a} \mathrm{d}t'_a \cdot \Delta f_{0,\mathrm{clock}}(t'_a)$$

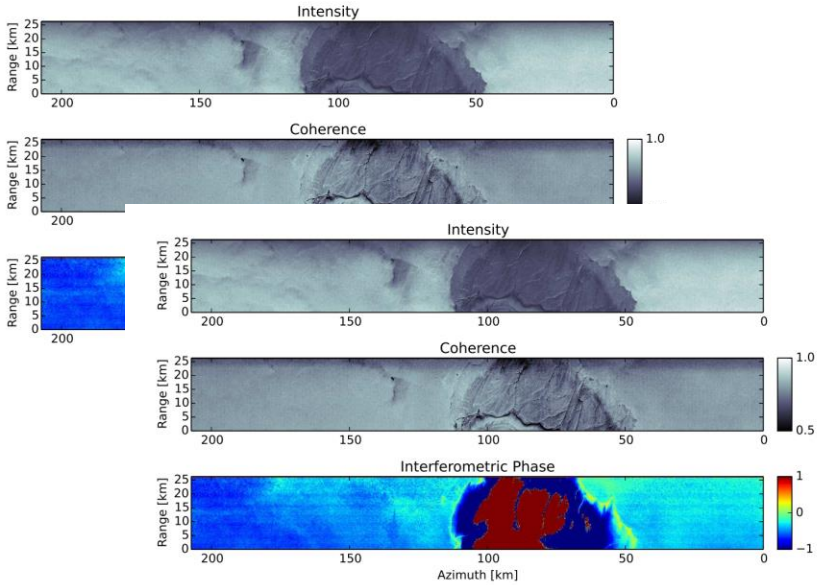


DLR

Harmony Sync Requirements Overview





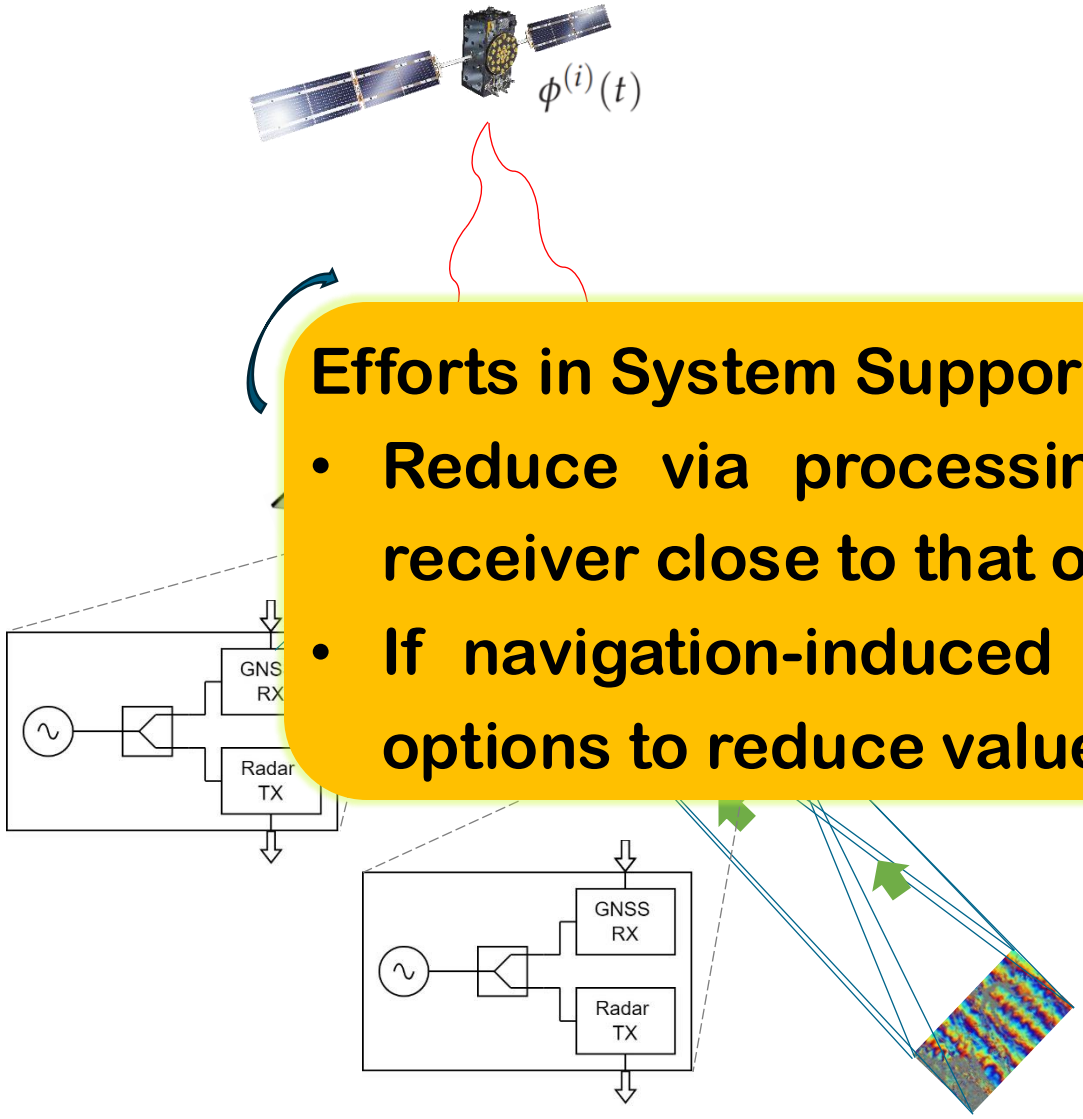


TDV – RPI
~10 deg

TOC – SP-XTI
~1 deg

OC – SP-ATI
>10 deg

Harmony Sync Subsystem: GNSS-based



Overview

- Identical between the Harmonies
- Different wrt Sentinel-1

Efforts in System Support (at least on DLR side)

- **Reduce via processing the contribution of the GNSS receiver close to that of thermal noise!!**
- **If navigation-induced ramps properly estimated explore options to reduce values via tailored PBD processing!!**

Observations

- Error (currently) dominated by GNSS receiver contribution ~ 1 order of magnitude!!
- Navigation-induced ramps in close formation account for ~5 deg in 120 s

In the Middle of the Harmony Processor…

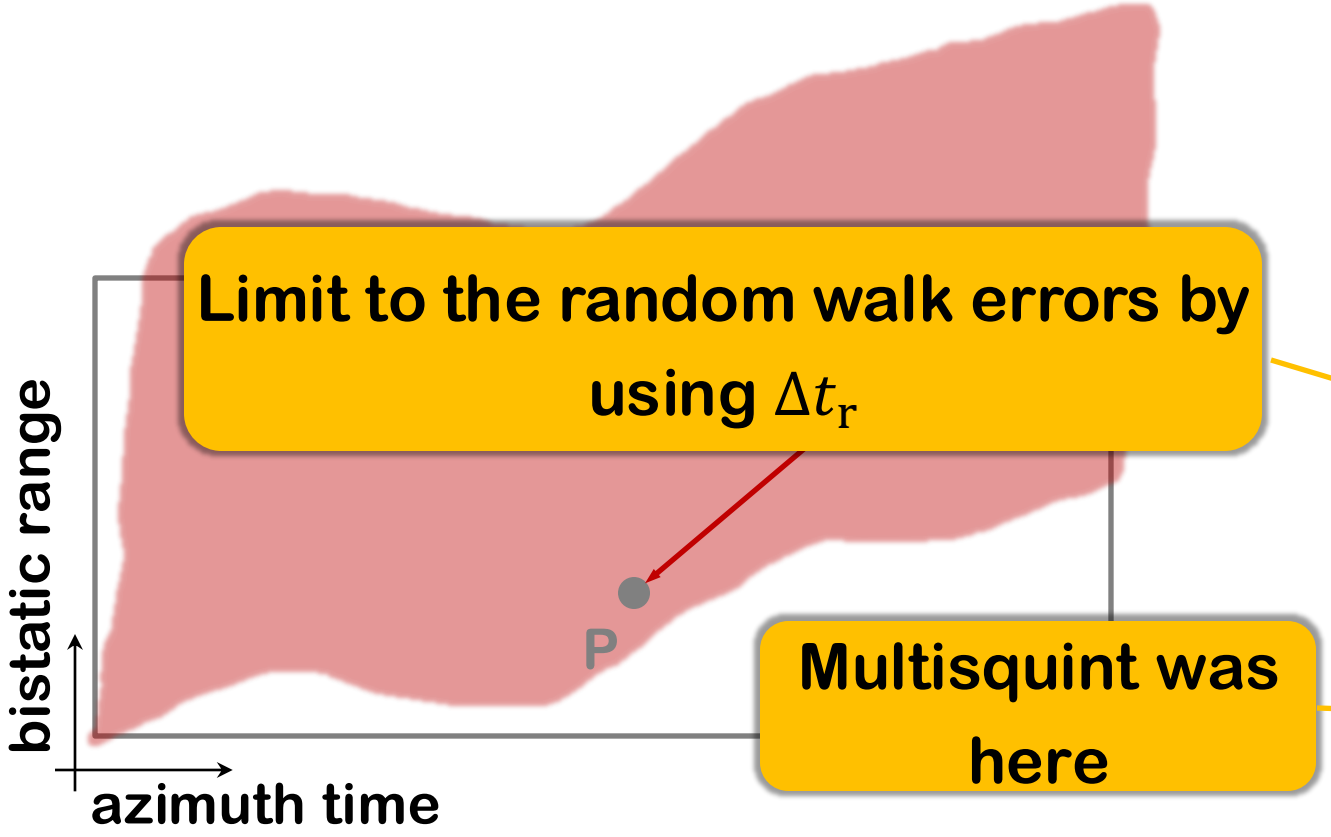
GNSS-based sync is applied always except

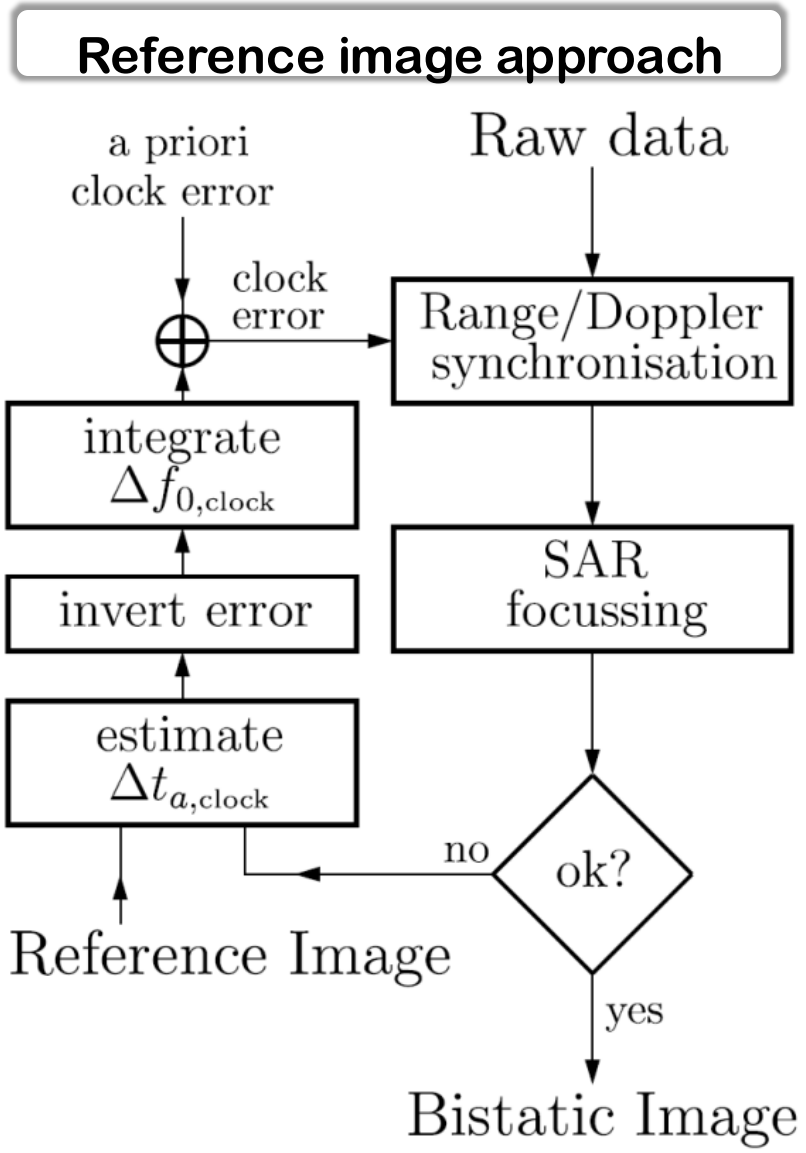
- GNSS-denied (or not usable) scenarios
- Strong turbulent scenarios (?)
- Multipath-contaminated data

Class	Products/observables	GNSS CBE	GNSS BE	Comment	Action
SPI	TOC, topography, WS-altimetry	☹	☺	If BE is achieved, residuals might be quasi-linear/harmonic	Y*
RPI	TDV	😐	😐	If substantial contamination due to different S1 architecture occurs	Y*
Ocean	Currents, winds	☺	☺	Residual geolocation negligible in multilooked products, radiometric biases dominated by external cal	No worries

***But not necessarily what everybody is thinking about**

AutoSync of bistatic SAR data





Inversion model

$$\Delta t_a(t_a, r_0) \approx \frac{\partial \Delta t_a}{\partial \Delta \phi_{\mathrm{clock}}} \cdot \frac{\mathrm{d}\Delta \phi_{\mathrm{clock}}}{\mathrm{d}t_a} \approx \frac{r_0}{v^2} \cdot \frac{\lambda}{2} \cdot \Delta f_{0,\mathrm{clock}}(t_a)$$

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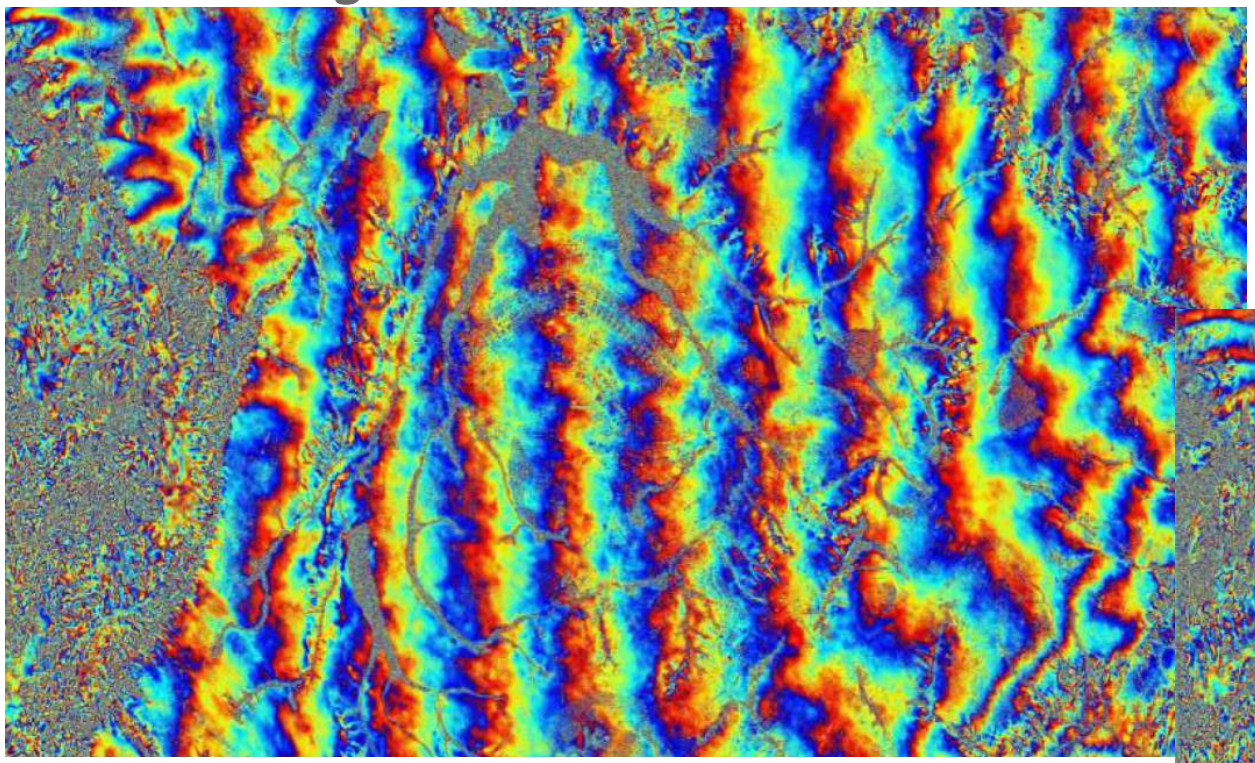
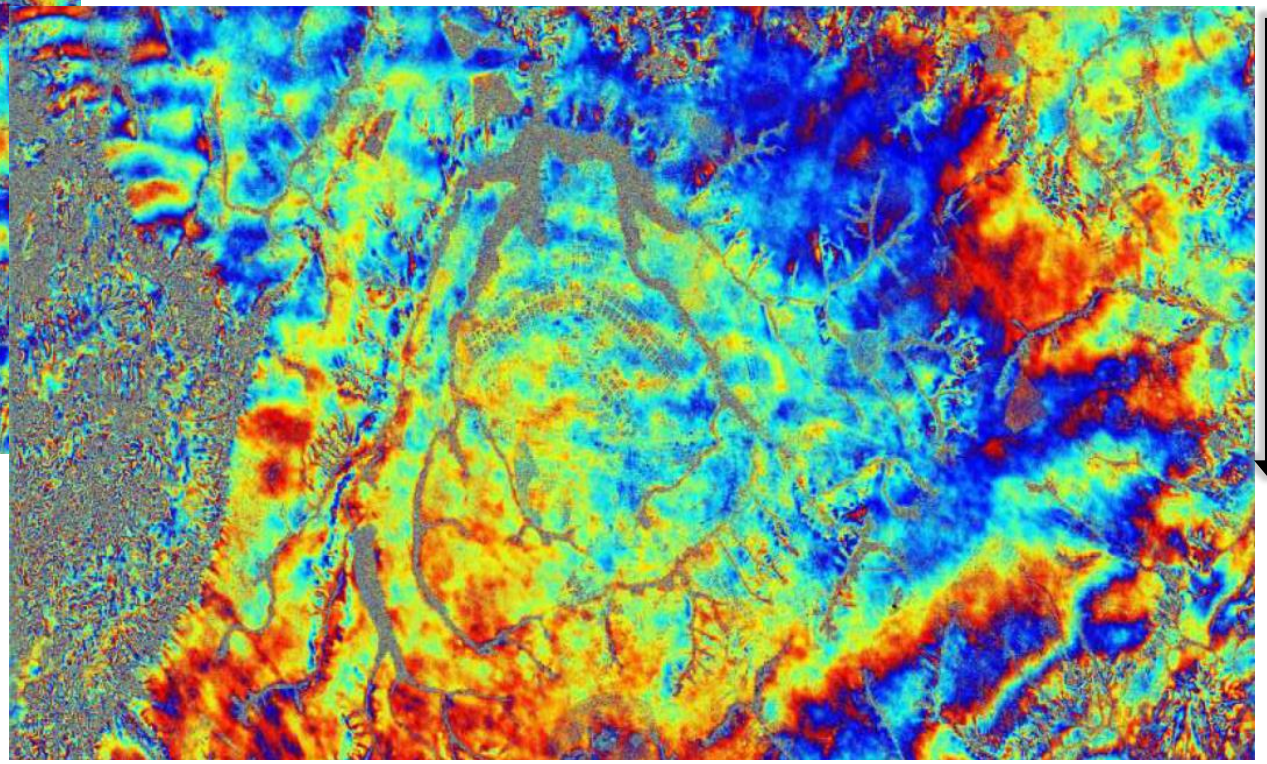
AutoSync with a reference image: TanDEM-X



non-synchronised

1st bistatic repeat-pass interferograms, Brasilia area



bistatic range

synchronised with AutoSync

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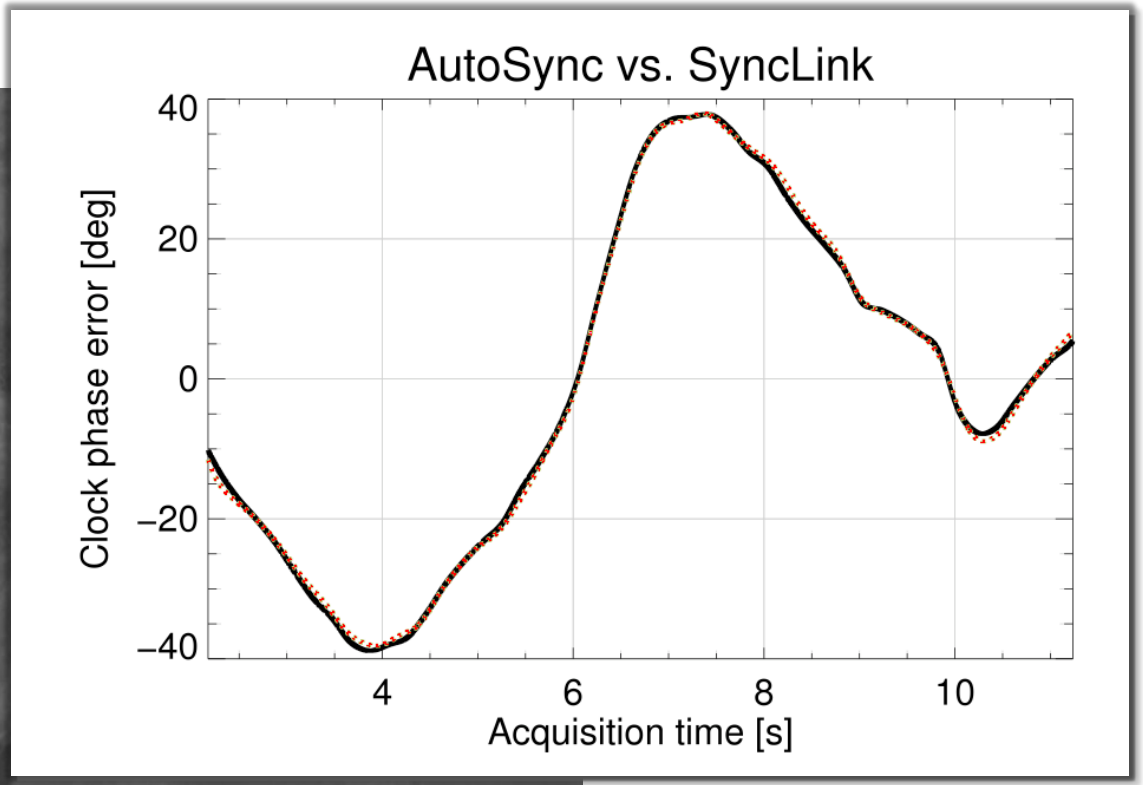
AutoSync validation with TanDEM-X SyncLink



- TanDEM-X SyncLink
- AutoSync

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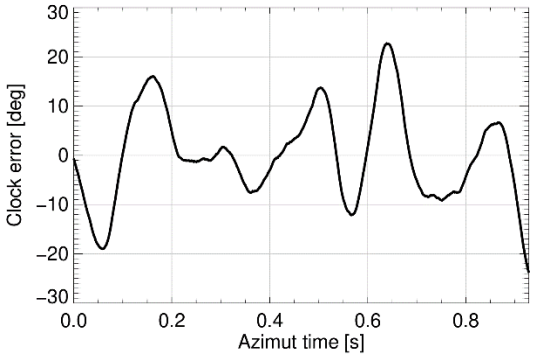
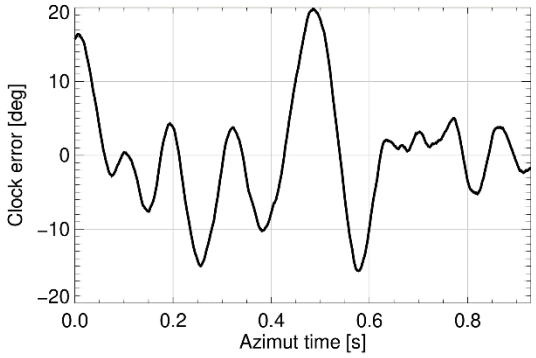
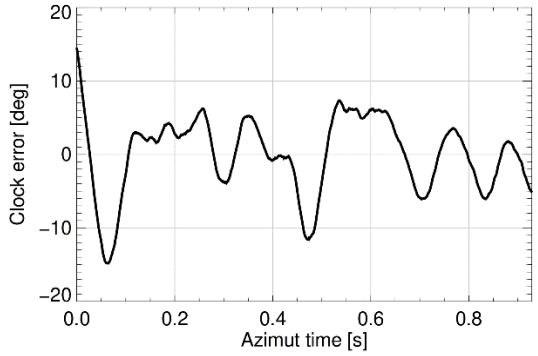
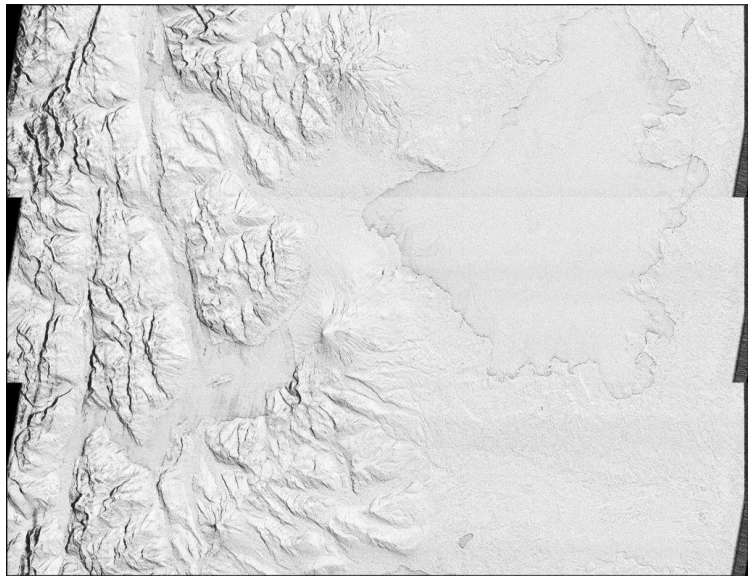
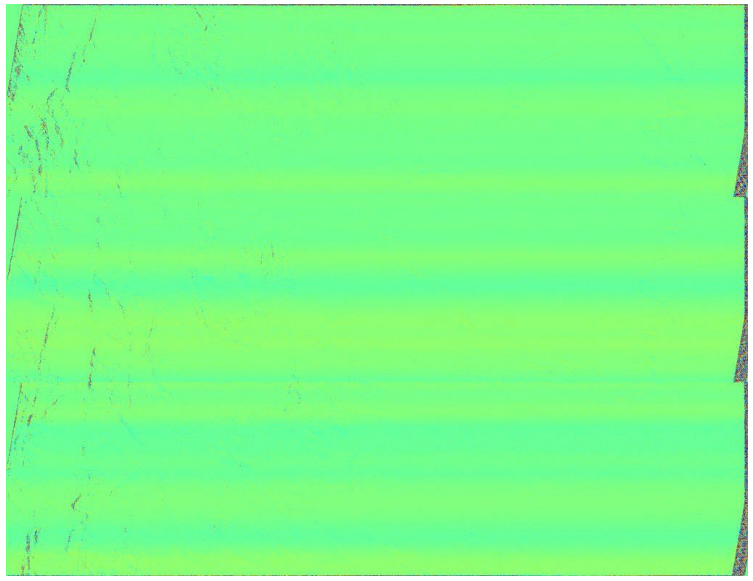
Clock Synchronisation with Harmony Simulated Data

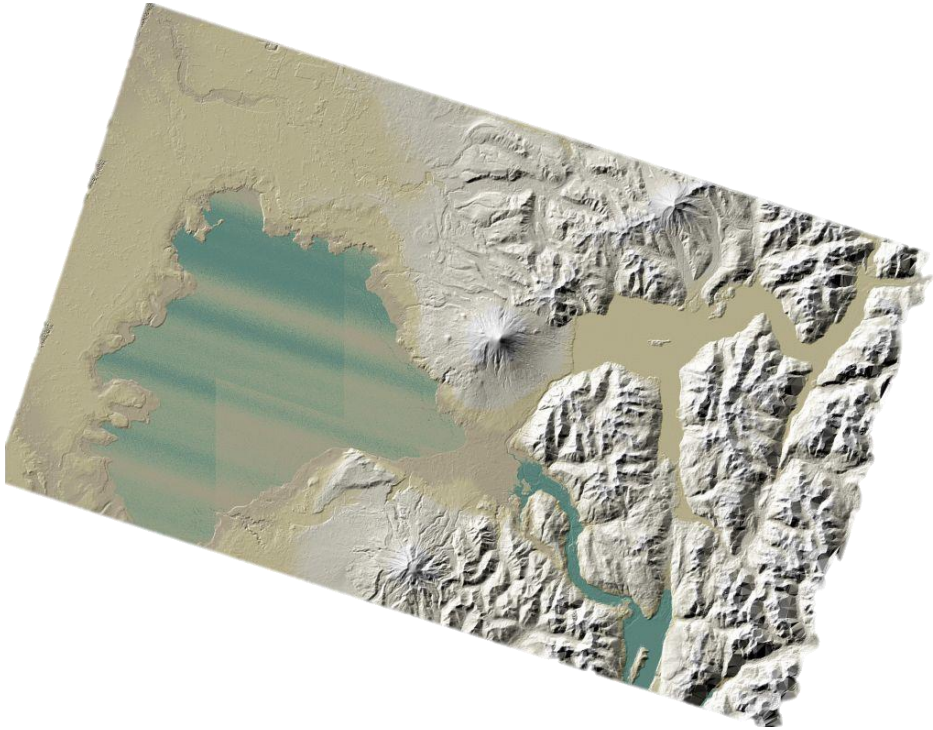












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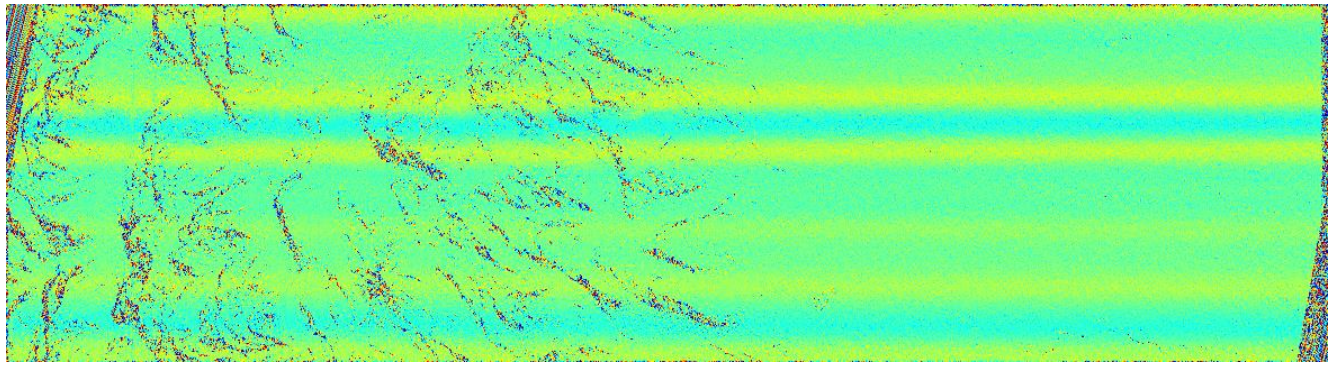

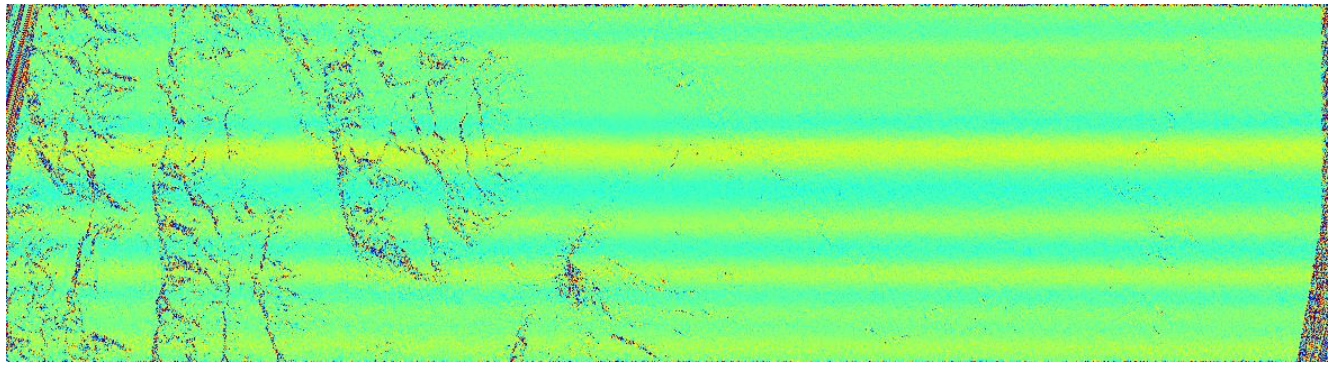

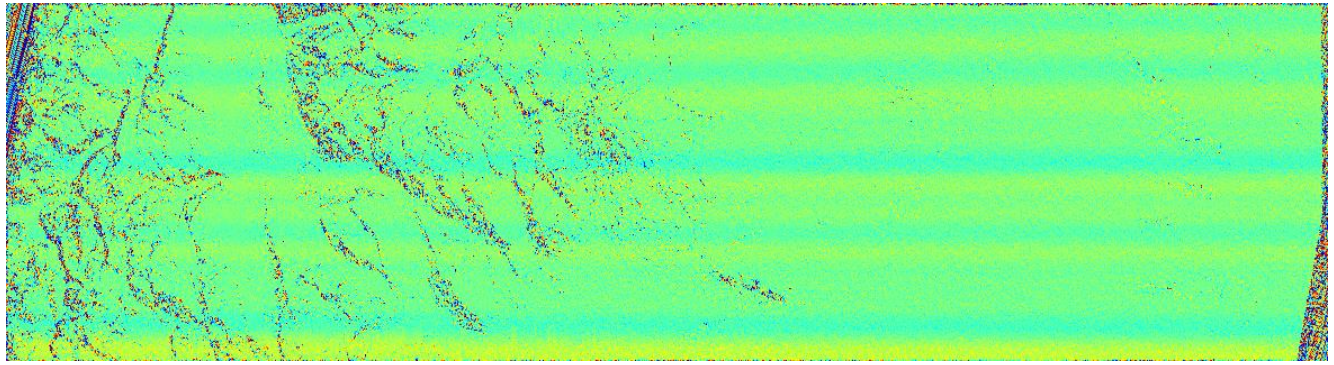

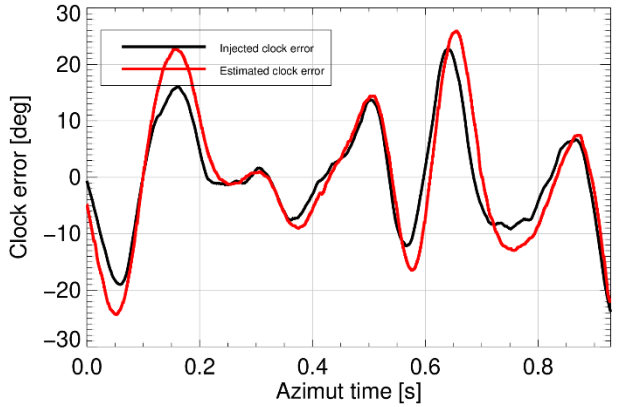

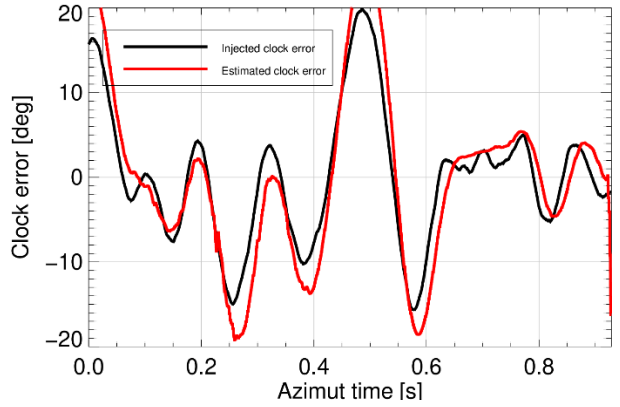

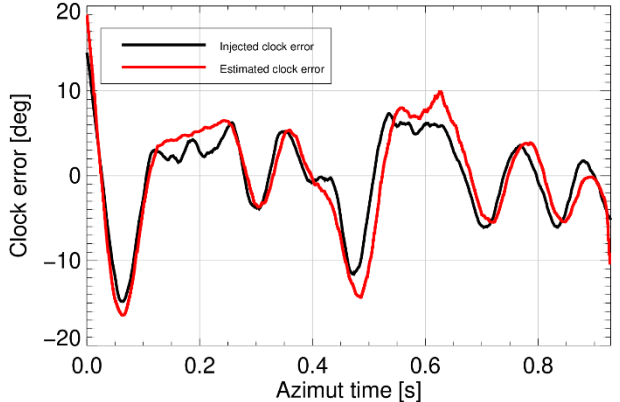

Revisiting the Previous Table…

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SPI	TOC, topography, WS-altimetry	☹	☺	If BE is achieved, residuals might be quasi-linear/harmonic	Y*
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Ocean	Currents, winds	☺	☺	Residual geolocation negligible in multilooked products, radiometric biases dominated by external cal	No worries

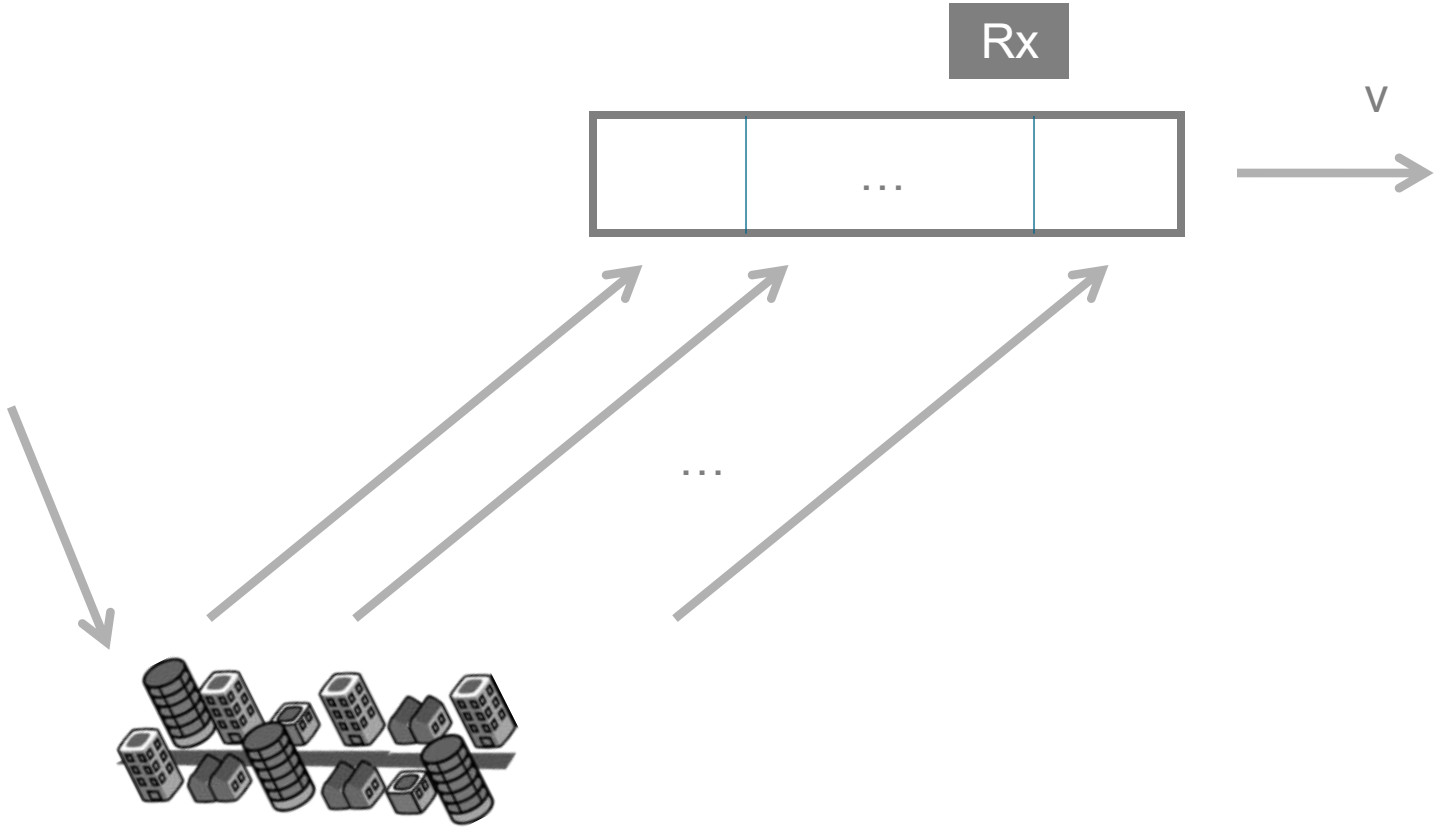
- In its more or less conventional form AS/MS can only be used in SPI cases where residuals of the GNSS-based sync are too large
- If the GNSS-based sync is tuned to its expected performance residual sync can be effected in a less sophisticated and computationally expensive way (based on drifts or phase) by averaging over larger areas
- A dedicated algorithm for RPI considering the stacks may be needed in case we want to clean up the interferograms

How to Use Data-based Sync Afterwards?

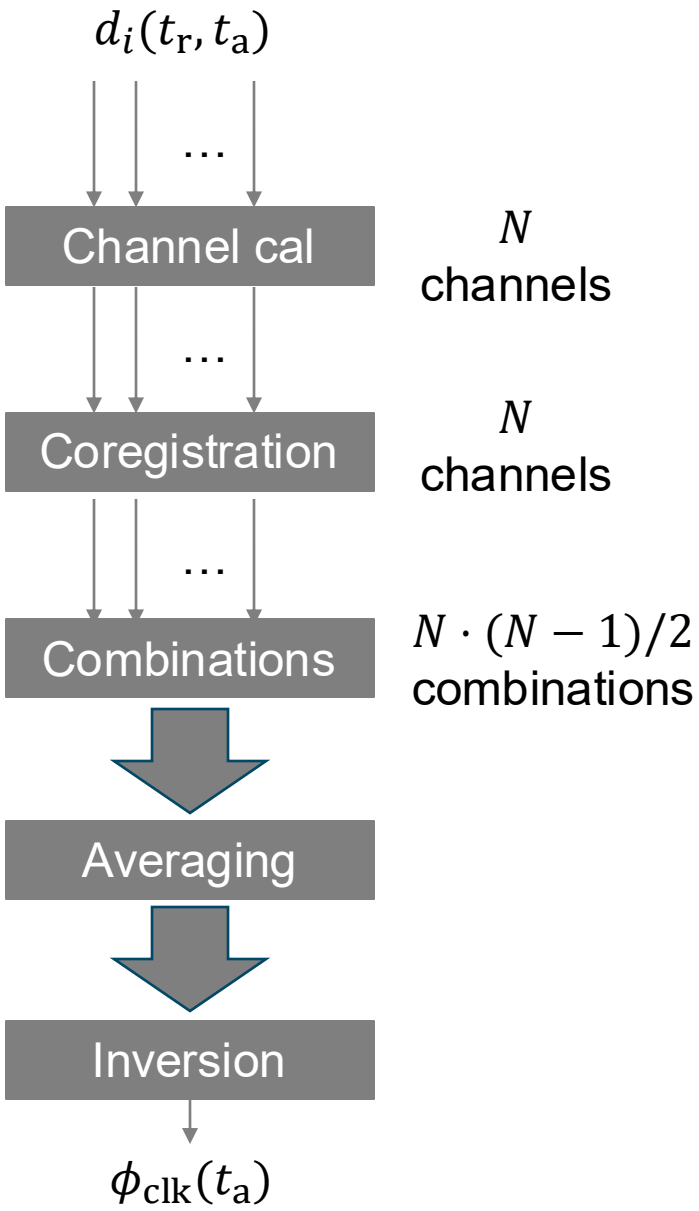
- Assumption is that non-coherent AutoSync will not meet performance → Finger weg!!
- Estimation in SPI between Harmony 1 and Harmony 2 is differential
- Estimation in RPI with a stack of Harmony 1/Harmony 2 images → potential to separate individual contributions
- Best case for AS/MS is with monostatic reference image → sensitivity to geometric errors?
- Interferograms might be cleaner, but still distorted, plus should the correction go into the CoSLCs?

So because of the problems above + the possibility that some GNSS solutions are bad, we suggest to complement the approach in the following manner!!

Suggested Approach



Processing Flow



- Channel calibration to avoid systematic signatures (e.g., internal cal, delays, phase errors)
- Coregistration mostly in azimuth.
- Inter-channel temporal lags depend on squints and attitude
- Averaging across the swath
- Averaging up to inverse of clock bandwidth (~1 to 5 Hz)
- Inversion using weighted linear model (e.g., WLMS)
- Calibration of residual signatures using external reference (e.g., GNSS)