Bistatic Campaigns and Processing with the MetaSAR-L

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MetaSensing, Italy and The Netherlands

Multistatic Radar Workshop,
Politecnico di Milano, Milan
19-20 June 2025

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Outline

- Bistatic Airborne Campaigns Overview:
  - BelSAR
  - TomoSense
  - WaddenSAR
- The MetaSensing Processing Framework:
  - Overall Concept
  - Case Study Results: Bistatic L-Band Interferometry
- Summary & Conclusions

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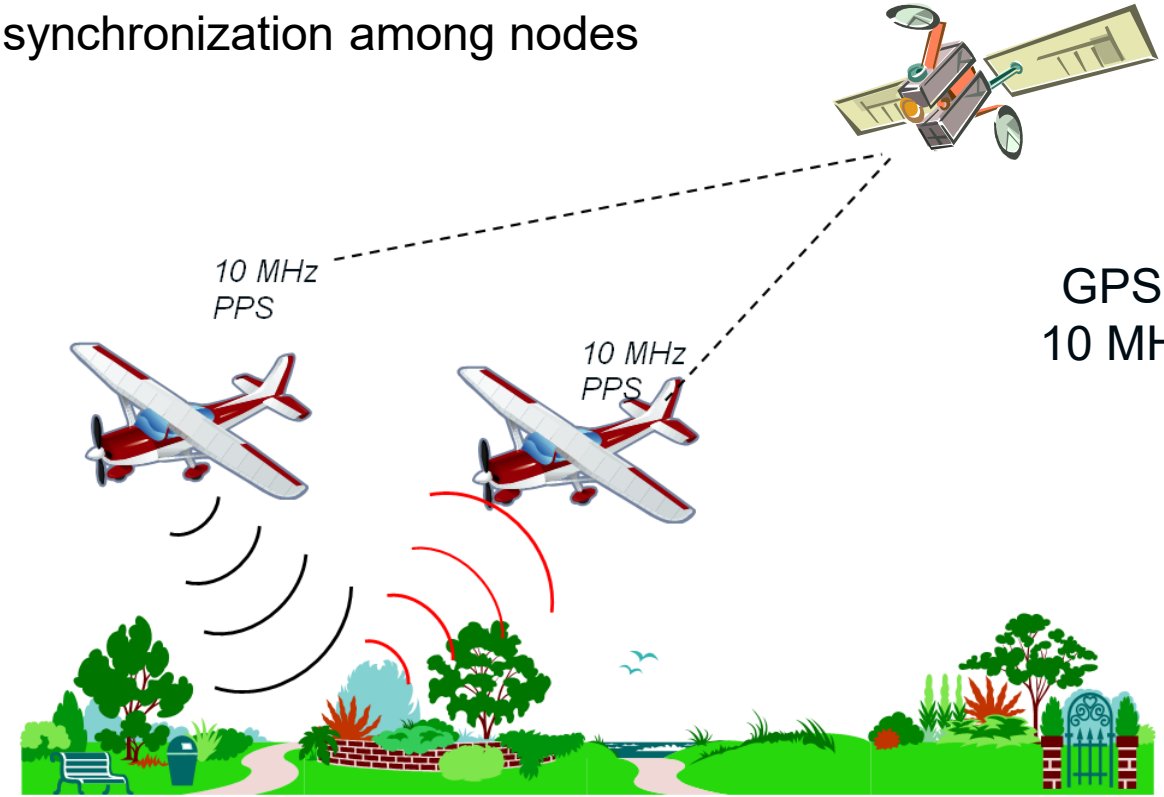
Bisatic Campaigns Overview

Airborne synchronization among nodes



GPS disciplined
10 MHz reference
clock

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BelSAR (2018) Bi. L-band Pol ATI-XTI

BelSAR

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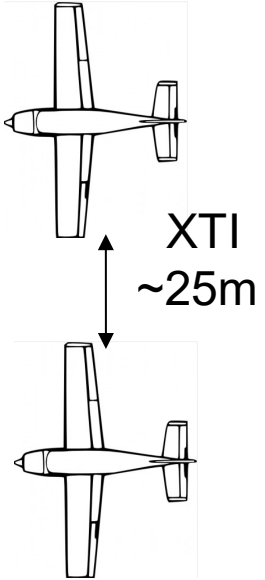
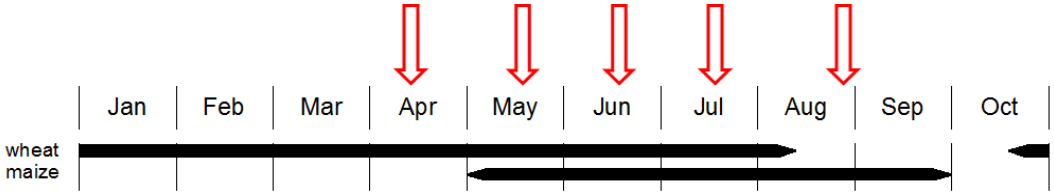
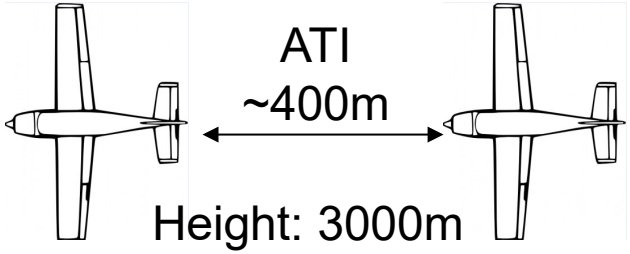
BelSAR (Bi. L-band Pol ATI-XTI)

BelSAR (1st Bistatic L-band Campaign)

- **Interferometric:** Two sensors flying in XTI and ATI configurations
- **Fully polarimetric:** Monostatic and Bistatic acquisitions
- **Multitemporal:** acquisitions between April and September 2018, baseline of about 1 month (5 campaigns)







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BelSAR (Bi. L-band Pol ATI-XTI)

Bistatic full-pol image (May 2018, Belgium)

(Red VV, green HH, blue VH)

← Successfully calibrated

scientific data

OPEN

DATA DESCRIPTOR

The BELSAR dataset: Mono- and bistatic full-pol L-band SAR for agriculture and hydrology

Jean Bouchat[1,6✉], Emma Tronquo[2,5], Anne Orban[3], Karlus A. C. de Macedo[4], Malcolm Davidson[2], Niko E. C. Verhoest[2] & Pierre Defourny[1]

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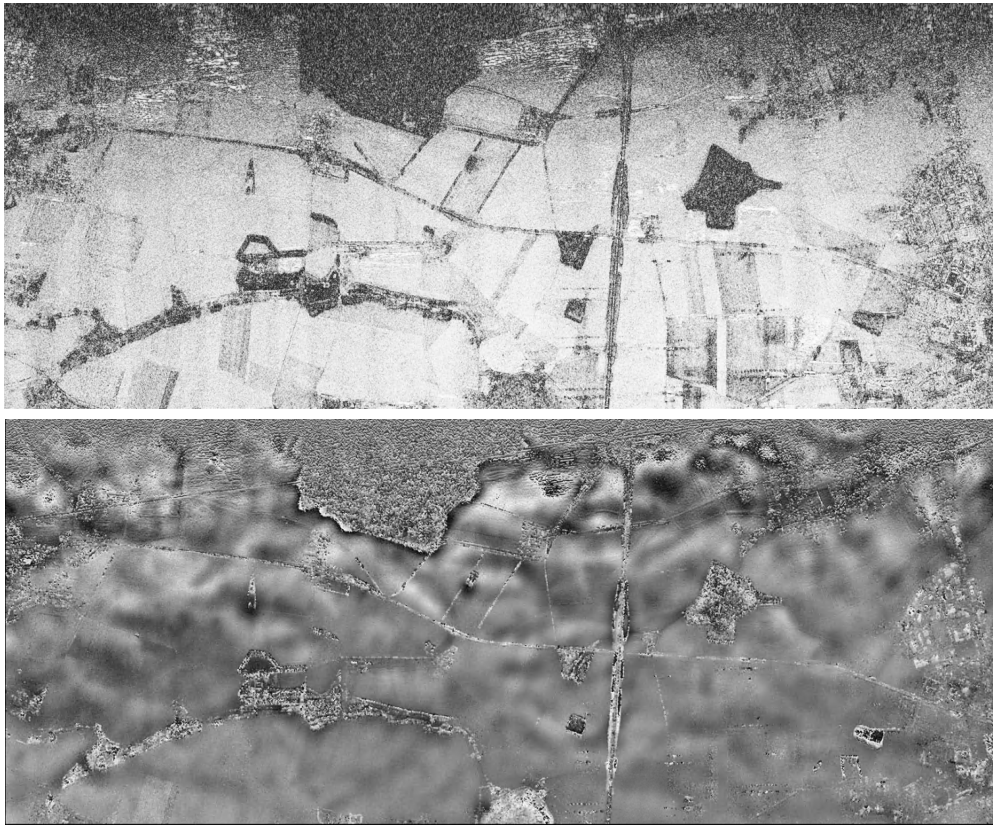
BelSAR (Bi. Multi. Pol. ATI-XTI)

Bistatic Interferogram (XTI, Before & After Residual Mot. & Missyc. filtering)

Flight

Ground Range



Phase free of mis-synchronization and residual motion errors

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TomoSense (Bi. C-L-Band Pol. Tomo.)

TomoSense

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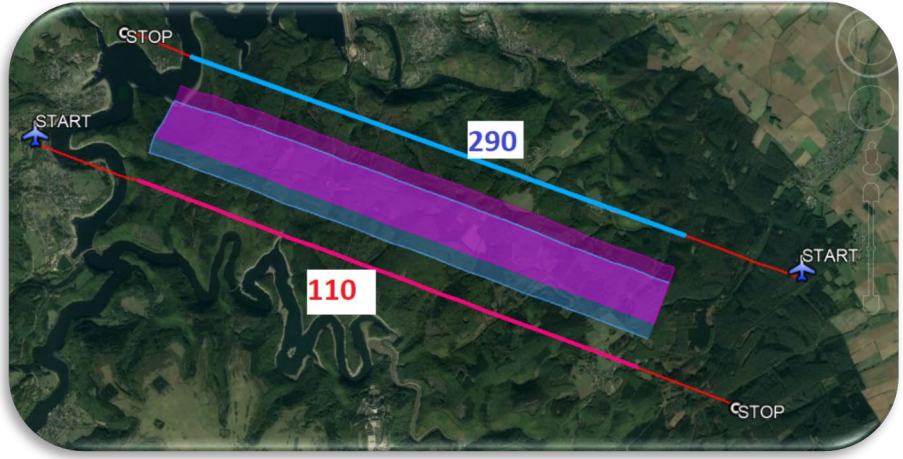
TomoSense (Bi. C-L-Band Pol. Tomo.)

Acquisitions over the Eifel Park, Germany →

- 22 July 2020 for P-band (Mono)
- 14 – 16 Sept. 2020 for L-band **(Bistatic)**
- 24 Nov 2020 for C-band **(Bistatic)**
- 28 Oct 2021 for C-band **(Bistatic**)



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TomoSense (Bi. C-L-Band Pol. Tomo.)

L-band flight geometry

Formation flown in 2020 flights

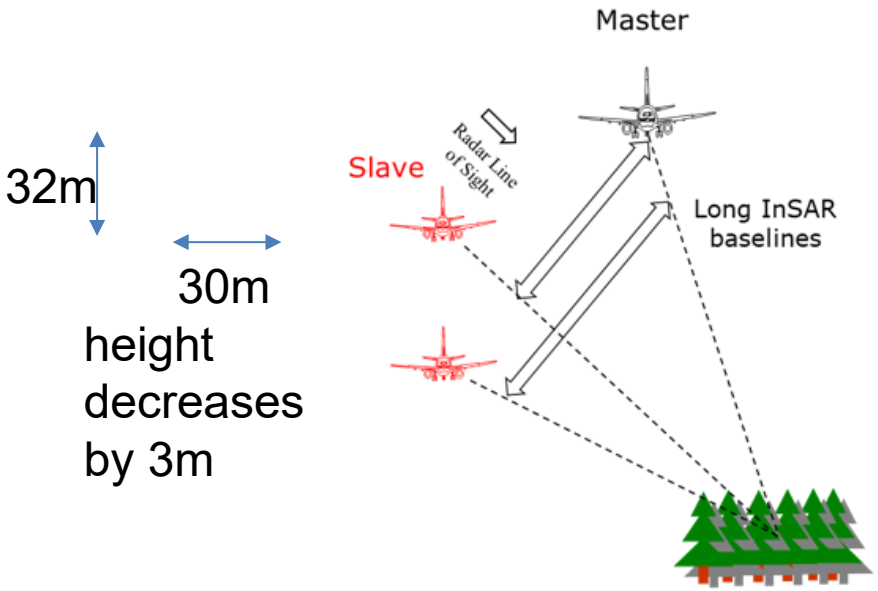
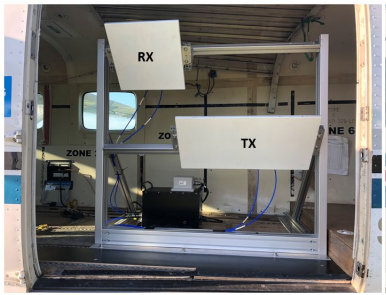


Table 4 - Acquisition parameters at L band	
Look angle	47° (left side)
Center frequency	1.375 GHz
Tx Bandwidth	50 MHz
Sampling frequency	50 MHz
PRF	1.7 KHz
Duty cycle	100% (FMCW)
Nominal flight altitude (MSL)	10.000 ft
Tx power: L1, L2	35, 40 [dBm]
Pol	Full-pol



L1 on OO-SEX

L2 on PH-SWP

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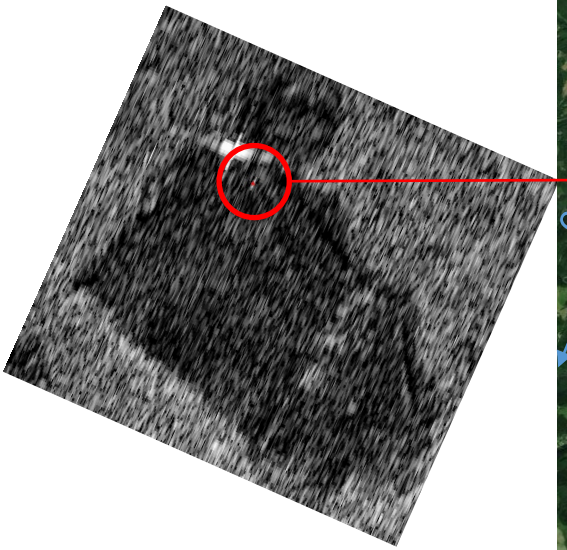
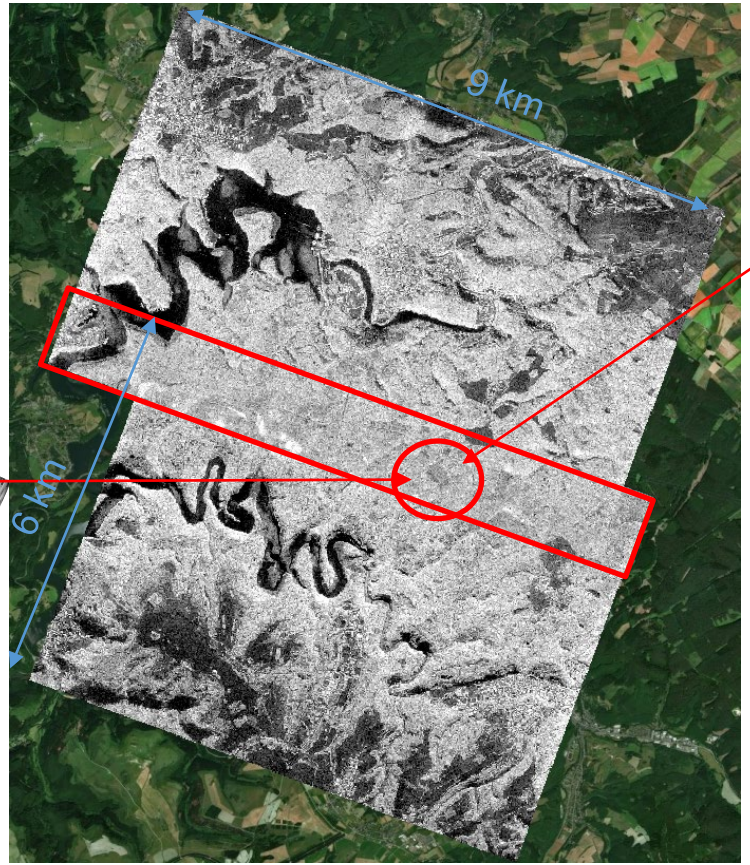
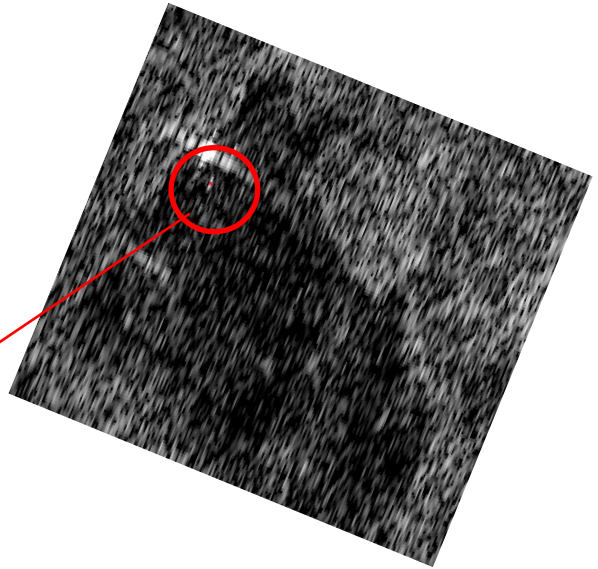
TomoSense (Bi. C-L-Band Pol. Tomo.)

- 58 acquisitions
- 29 for each direction
- 3 x 1 m res
- 18º to 68º look angle





L-band Images



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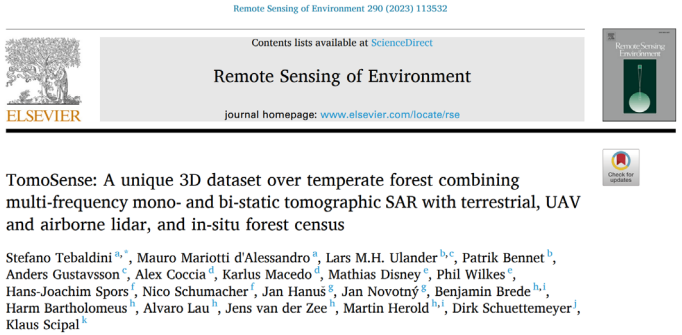
TomoSense (Bi. C-L-Band Pol. Tomo.)

1) The TomoSense Data (Bistatic and Monostatic) have been made available by MetaSensing as:

- SLC SAR data and metadata (NetCDF format)
- geometric and radiometric calibrated (at level 1)
- coregistered within the navigation accuracy (in the order of 5 cm)

2) The TomoSense Data have been further processed by POLIMI (Tomography)

- Mis-synchronization (phase) compensatic
- Residual motion (phase) compensation
- Calibrations
- Tomography



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Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

TomoSense: A unique 3D dataset over temperate forest combining multi-frequency mono- and bi-static tomographic SAR with terrestrial, UAV and airborne lidar, and in-situ forest census

Stefano Tebaldini [a,*], Mauro Mariotti d'Alessandro [a], Lars M.H. Ulander [b,c], Patrik Bennet [b], Anders Gustavsson [c], Alex Coccia [d], Karlus Macedo [d], Mathias Disney [e], Phil Wilkes [e], Hans-Joachim Spors [f], Nico Schumacher [f], Jan Hanuš [g], Jan Novotný [g], Benjamin Brede [h,i], Harm Bartholomeus [h], Alvaro Lau [h], Jens van der Zee [h], Martin Herold [h,i], Dirk Schuettemeyer [j], Klaus Scipal [k]

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WaddenSAR (Bi. C-band Dual Pol.)

WaddenSAR

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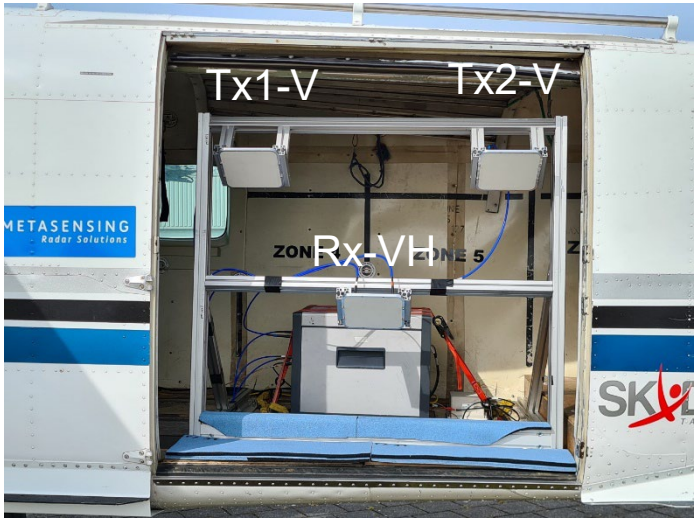
WaddenSAR

Only Rx (Bistatic node, Passive)

2Tx + Rx (Monostatic node)



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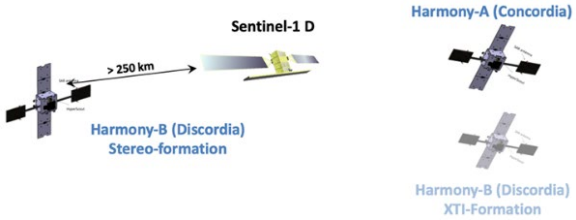
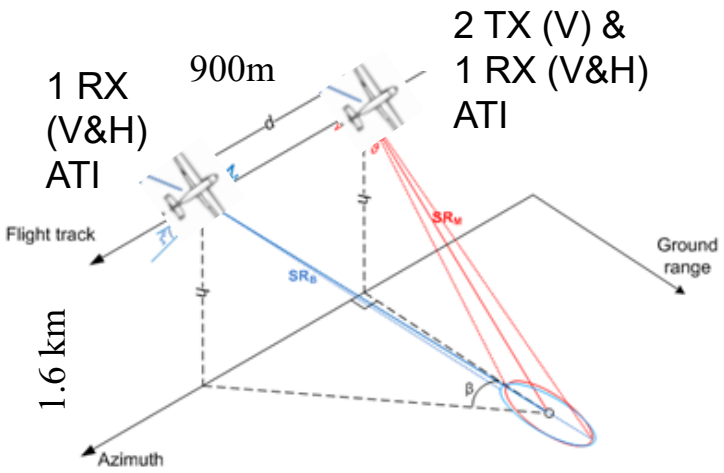
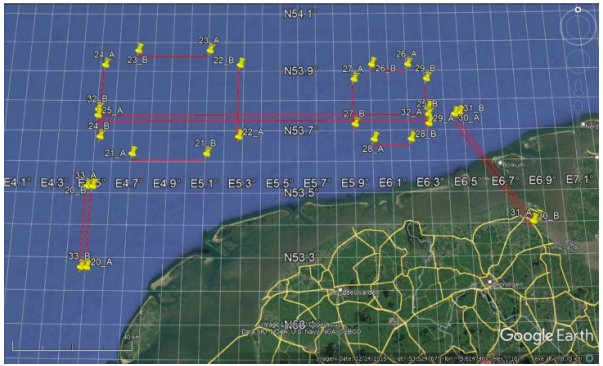
WaddenSAR (Bi. C-band Dual Pol.)

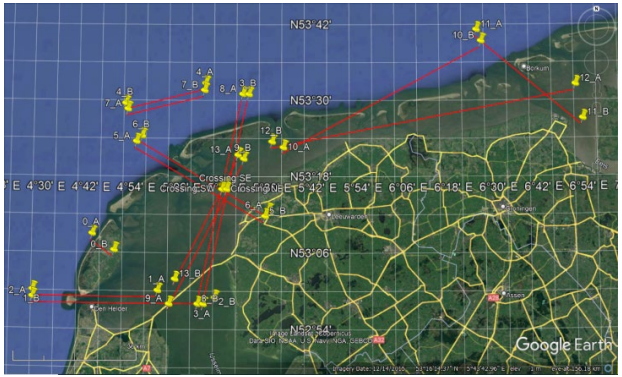
Mimic Harmony





Flight tracks





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WaddenSAR (Bi. C-band Dual Pol.)

Monostatic Image

Bistatic Image

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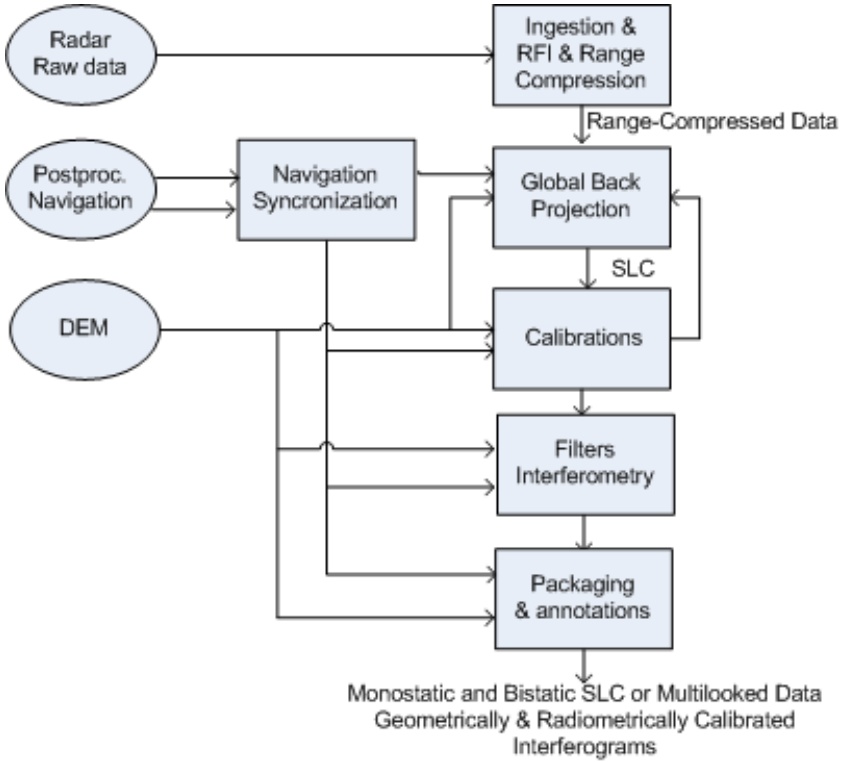
Processing: Overall Concept

Processing Chain



- Processor is based on the Global-Back projection Algorithm for SAR focusing

- The same processing chain Generates: Mono and Bistatic Data as well already Coregistered SAR data (Interferograms)

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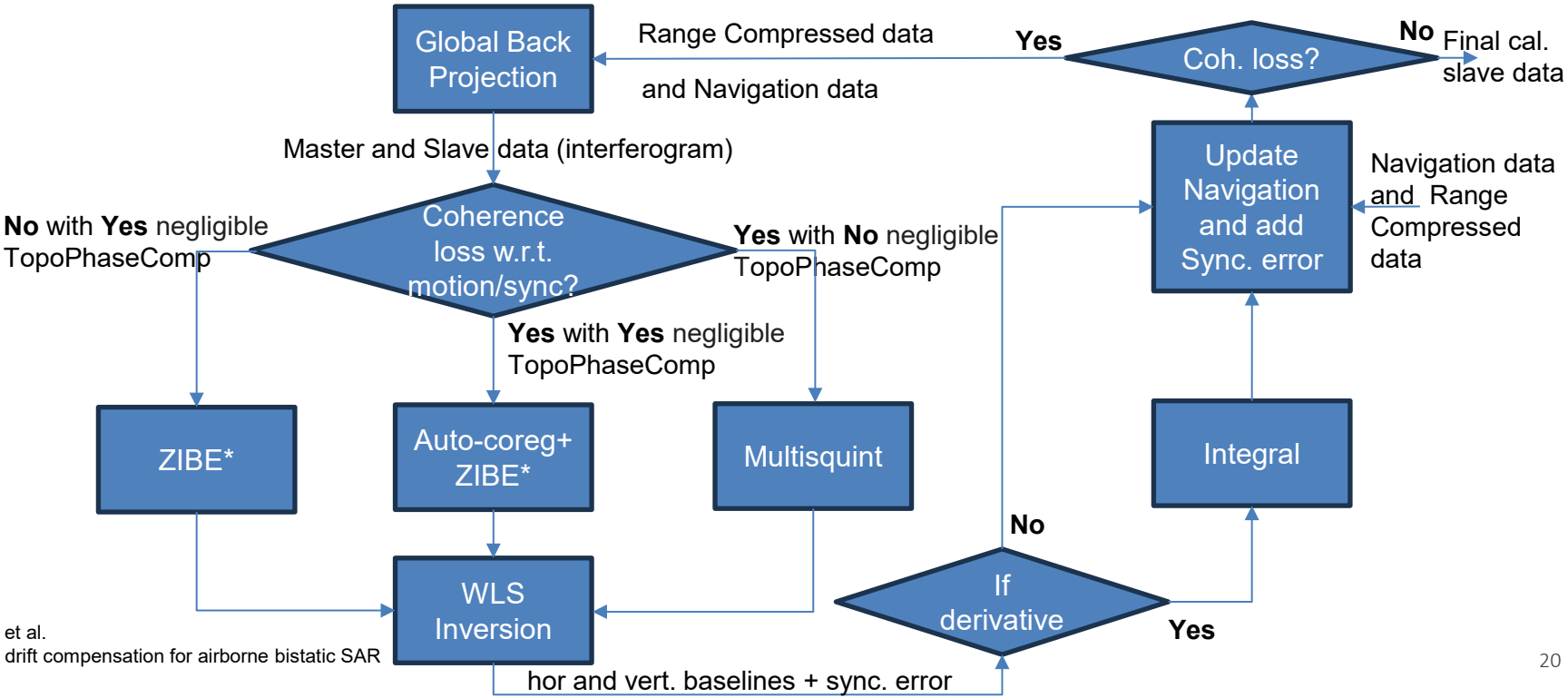
Processing: Overall Concept

Bistatic Autonomous (Phase) Calibration

The same processing chain is meant for Single-Pass, Repeat-Pass and Bistatic interferometry



*KAC de Macedo et al.
Data-driven clock drift compensation for airborne bistatic SAR
EUSAR, 2020

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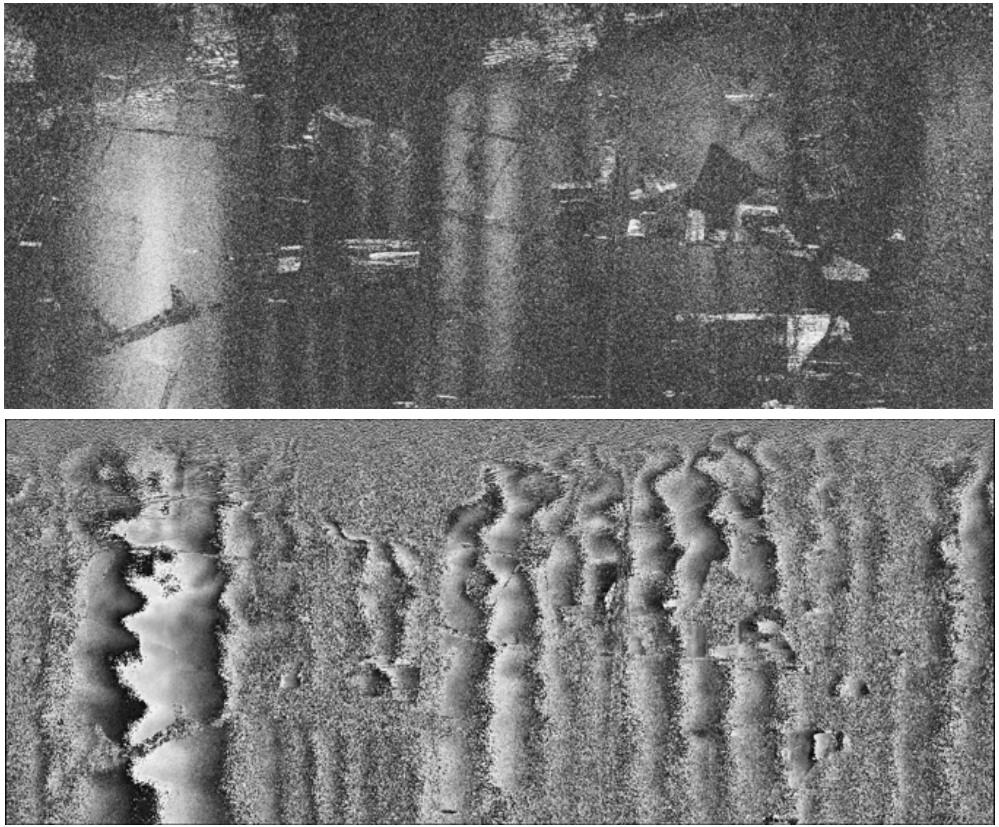
BelSAR (Bi. L-band Pol ATI-XTI)

Bistatic Interferogram (XTI, Before Autonomous Calibration)

Flight

Ground Range



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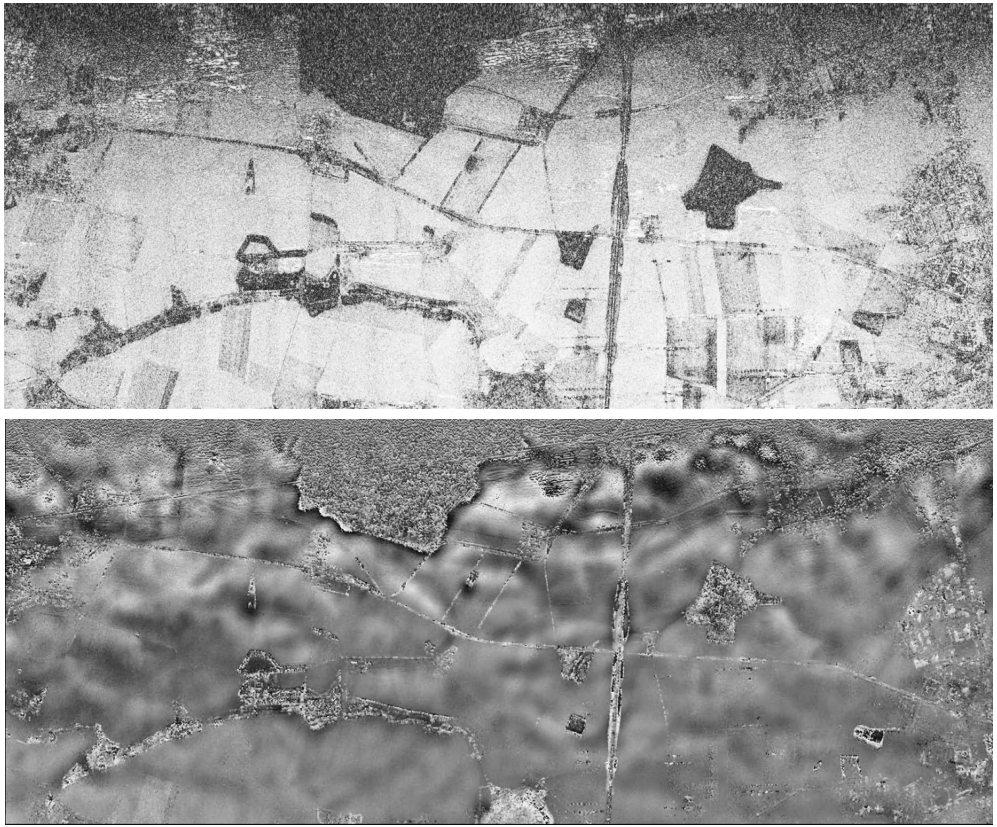
BelSAR (Bi. L-band Pol ATI-XTI)

Bistatic Interferogram (XTI, After Autonomous Calibration using Multisquint)

Flight

Ground Range



Phase free of mis-synchronization and residual motion errors

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Summary & Conclusions

- We presented the Bistatic Campaigns carried out by MetaSensing.

- We showed that we can generate bistatic sigma-0 images and interferograms between two non-cooperative airborne systems.

- We presented our latest processing concept currently implemented to calibrate the baselines and remove the phase mis-synchronization. .

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