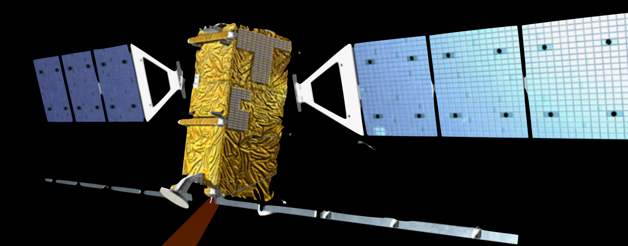
Deformation Estimation on Low Coherence Areas by Means of Polarimetric Differential SAR Interferometry



Stéphane Guillaso[1] Franck Garestier[2]

[1]Computer Vision and Remote Sensing, Technische Universität Berlin, Germany
[2]M2C, University of Caen, France

Overview

I. Context: Survey of the permafrost environment

II. The Yakutsk Region
- Temporal backscattering variation / temperature
- The differential interferometry processing chain
- Investigation of the Data

III. Phase estimation in low coherence area: Preliminary study
- Presentation of the problem
- Phase estimation based on ESPRIT approach
- Preliminary results: masked areas, mean deformation velocity, DEM correction

IV. Conclusions & Perspectives

SAR Potential for Survey of the Permafrost Environment

20% of the continental surface: freezing/thaw cycles

- Need to quantify the carbon emissions (CO_2 and CH_4) for climate modelling

- Predominant physical parameters:
  - ➜ Active layer thickness
  - ➜ Moisture Variation
  - ➜ Type of soil
  - ➜ Vegetation (type and biomass)

Use of Differential SAR Interferometry

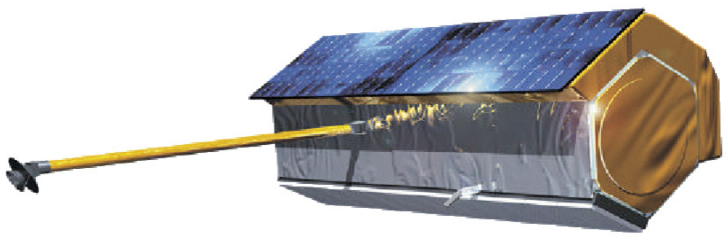
- cm/mm ground movement estimation
  - ➜ Subsidence due to hydrology (water state), heat transfer, ice thickness variation

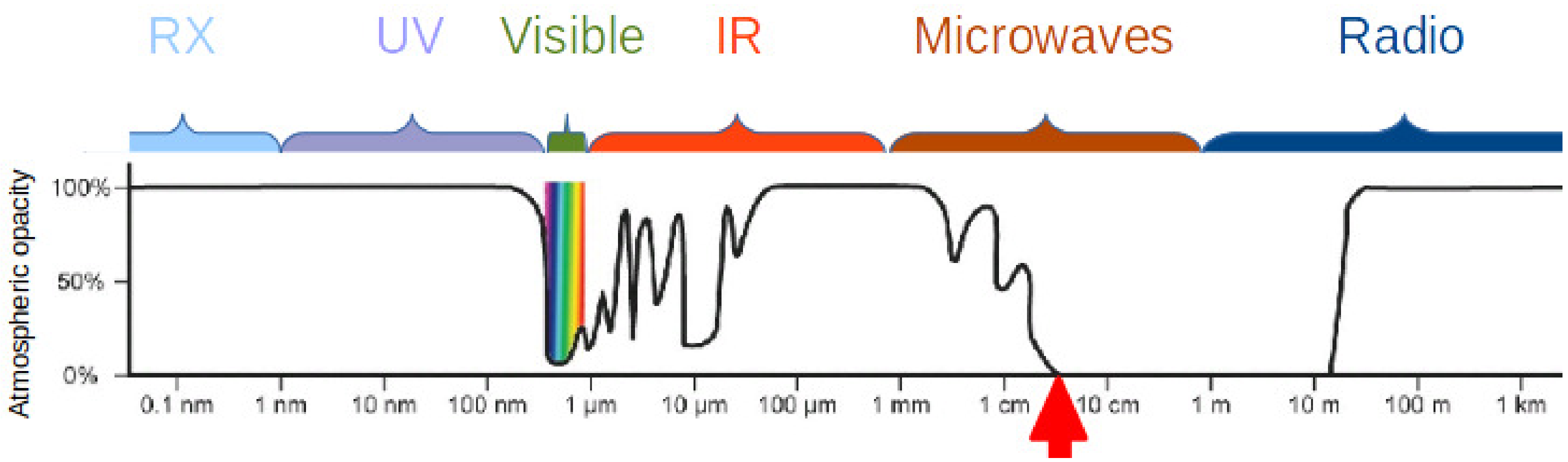
☟

Possibility to inverse the active layer thickness

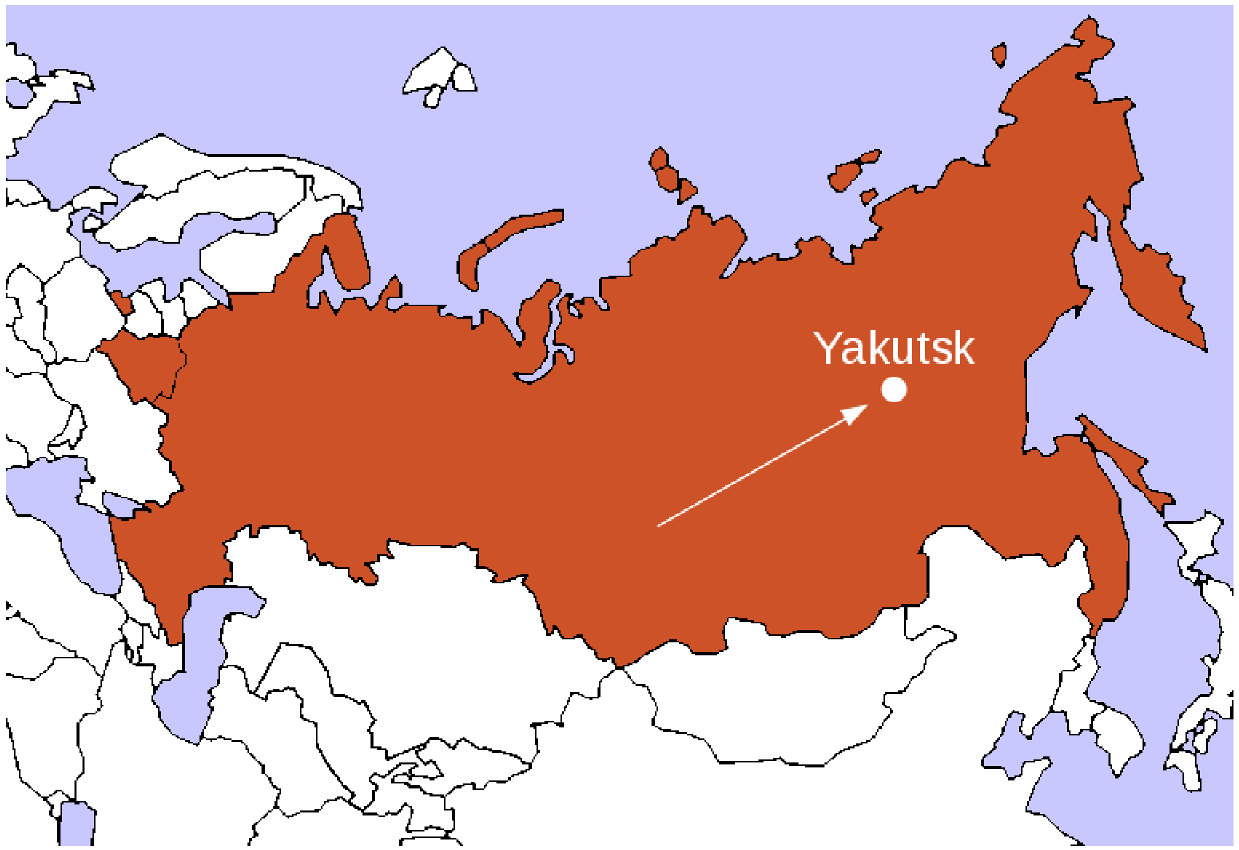
SAR Data Acquisition over the Yakutsk Region

TerraSAR-X

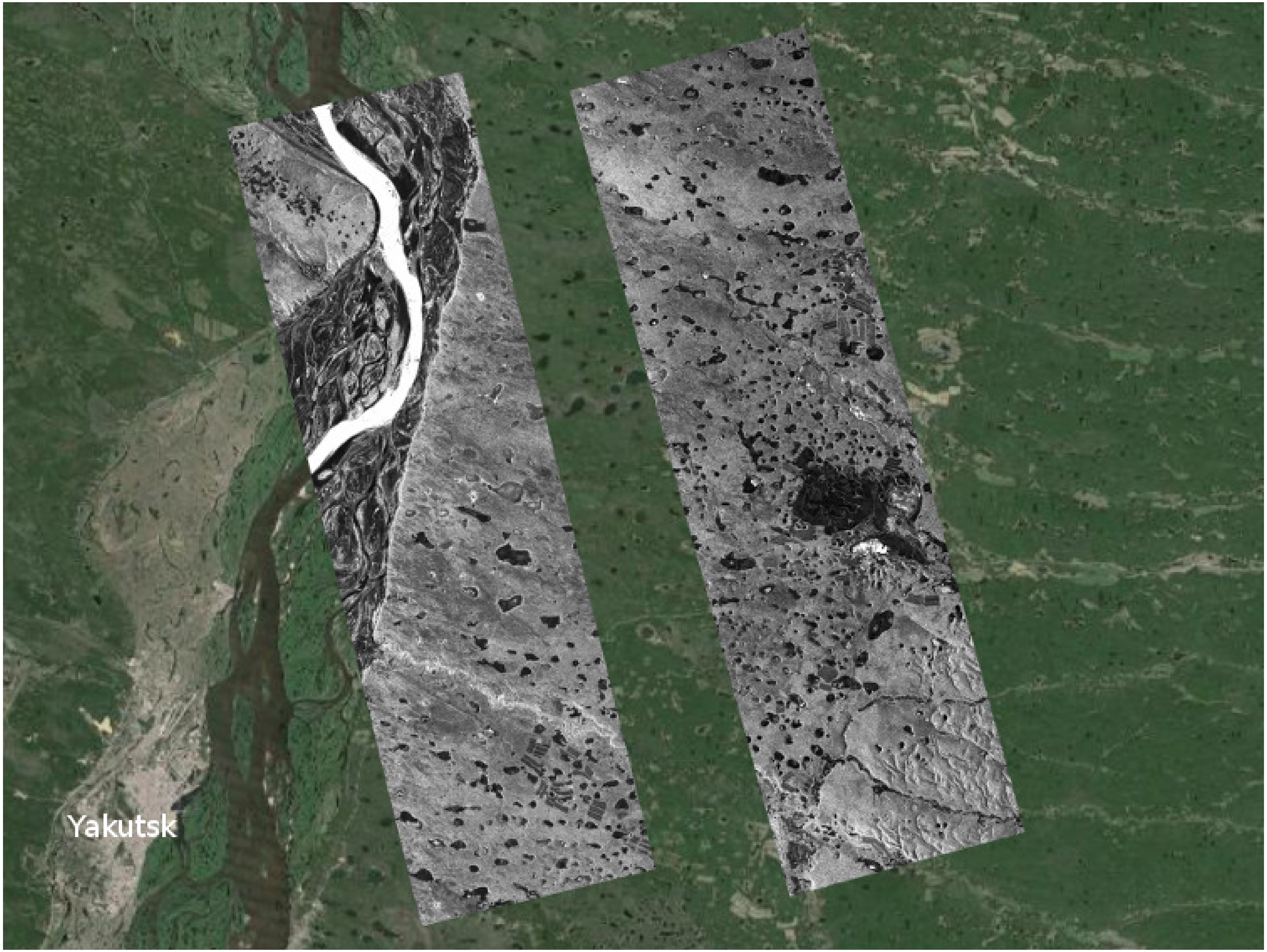




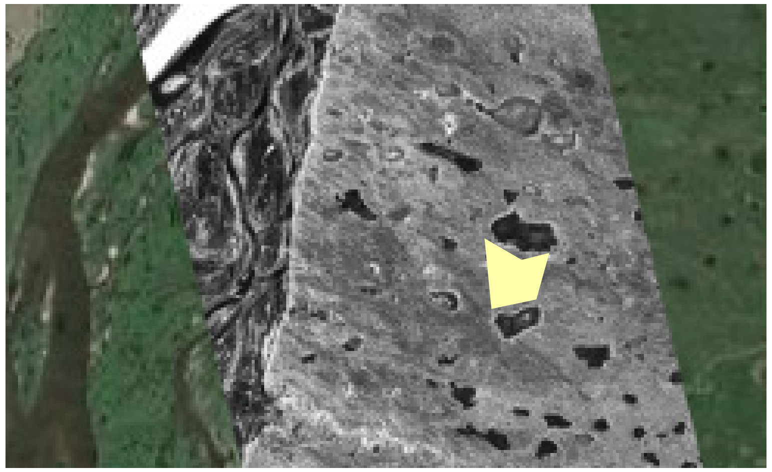
- Emitting frequency: 9.65 GHz (λ ~ 3 cm)
- Ground resolution: ~ 6 m
- Coverage: 2 sites of 30 × 70 km
- Revisit time: 11 days
- Acquisition during 1 years

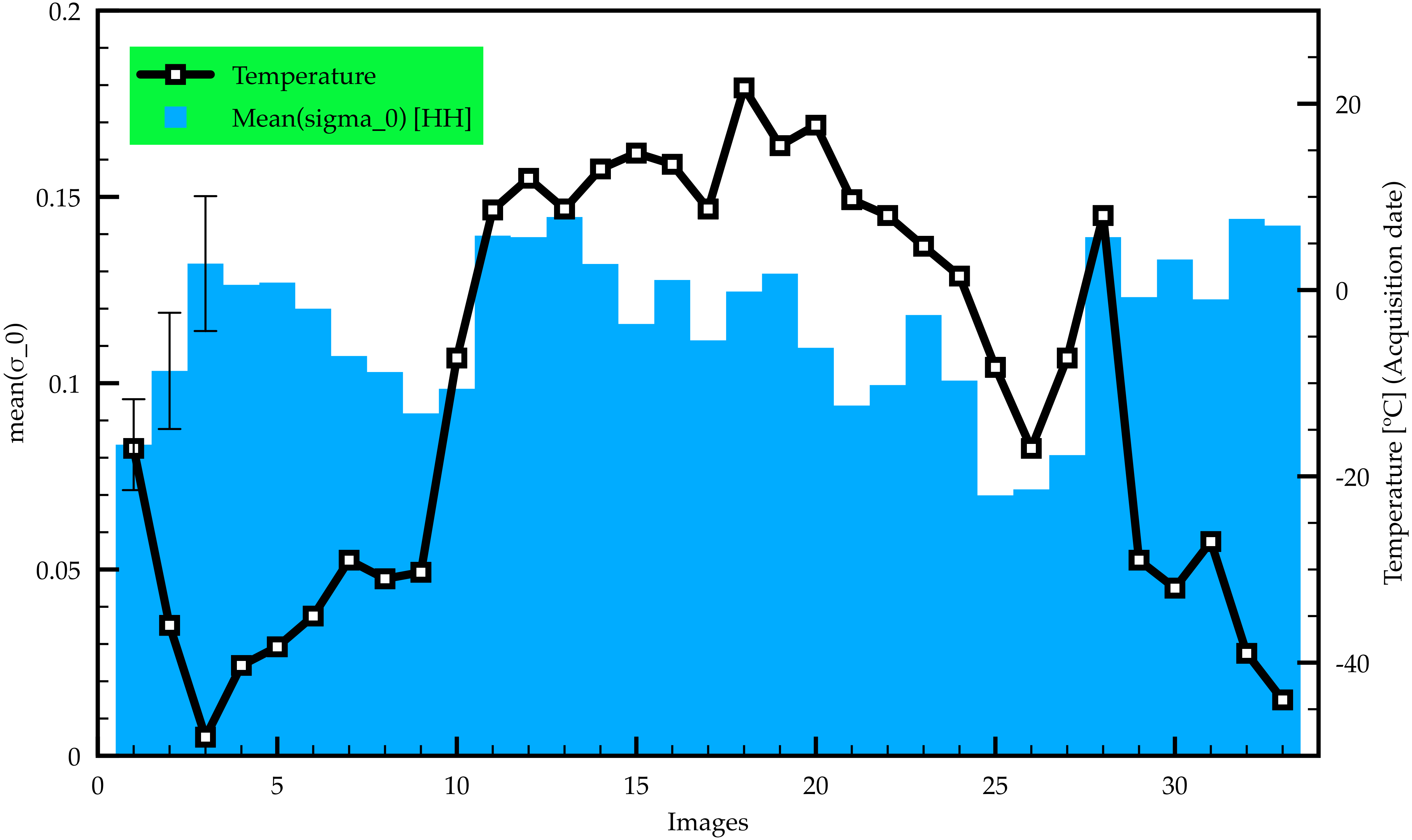


SAR Data Acquisition over the Yakutsk Region

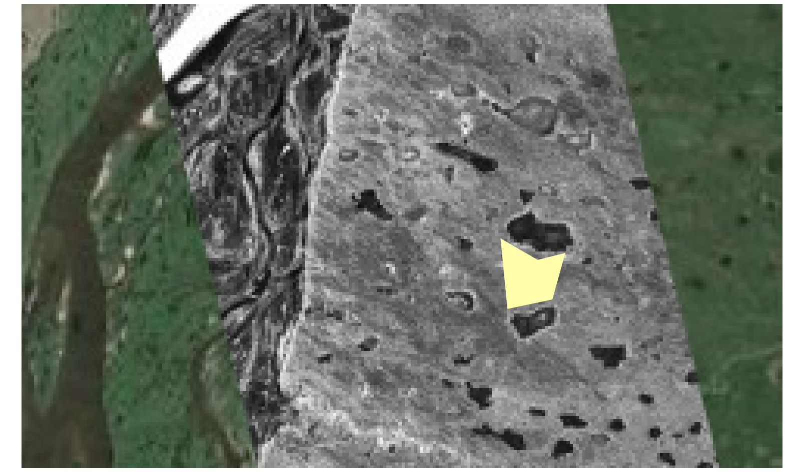


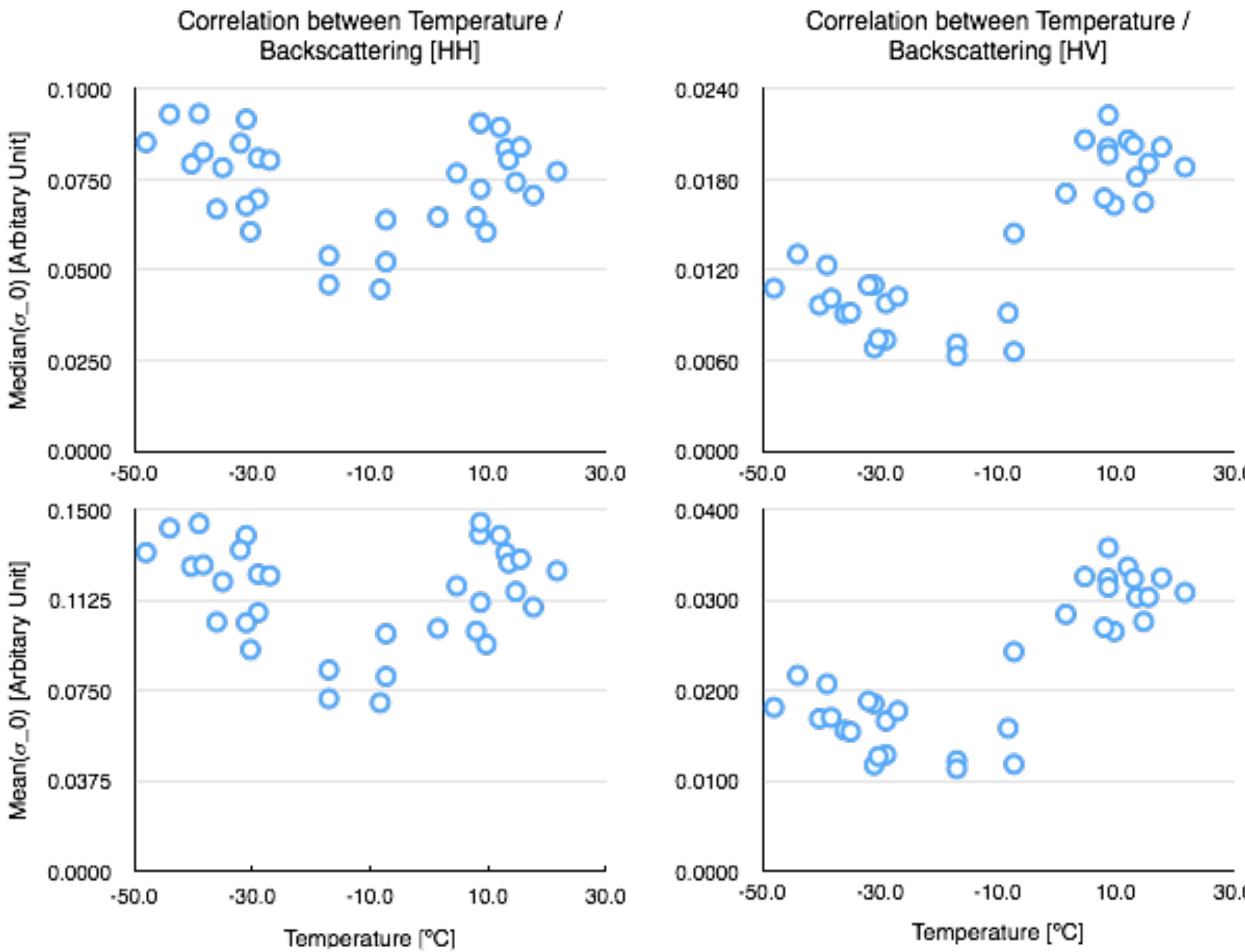
Temporal Backscattering Evolution





Temporal Backscattering Evolution

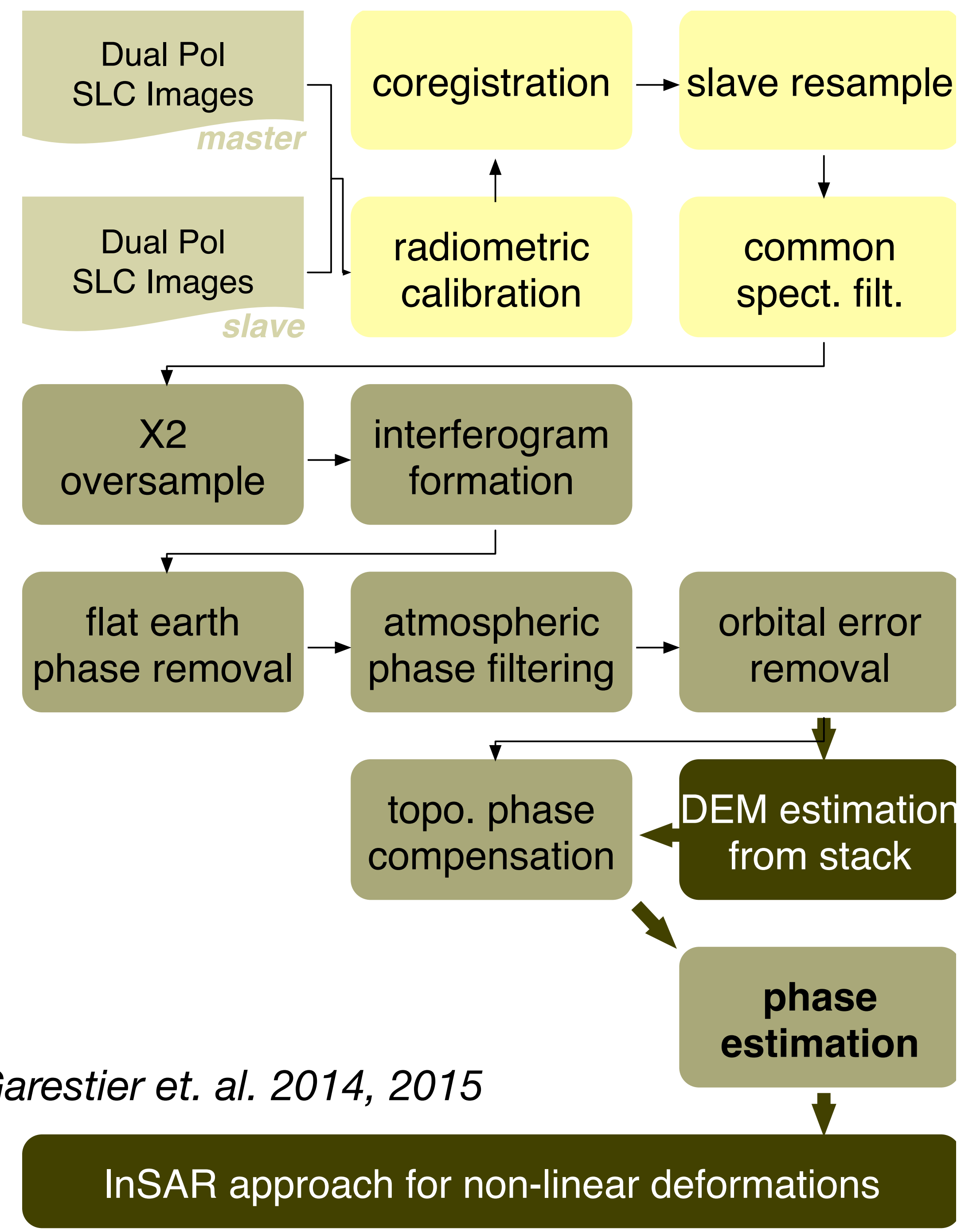




New method to characterise permafrost soil

Development of an interferometric processing chain (SBAS type)

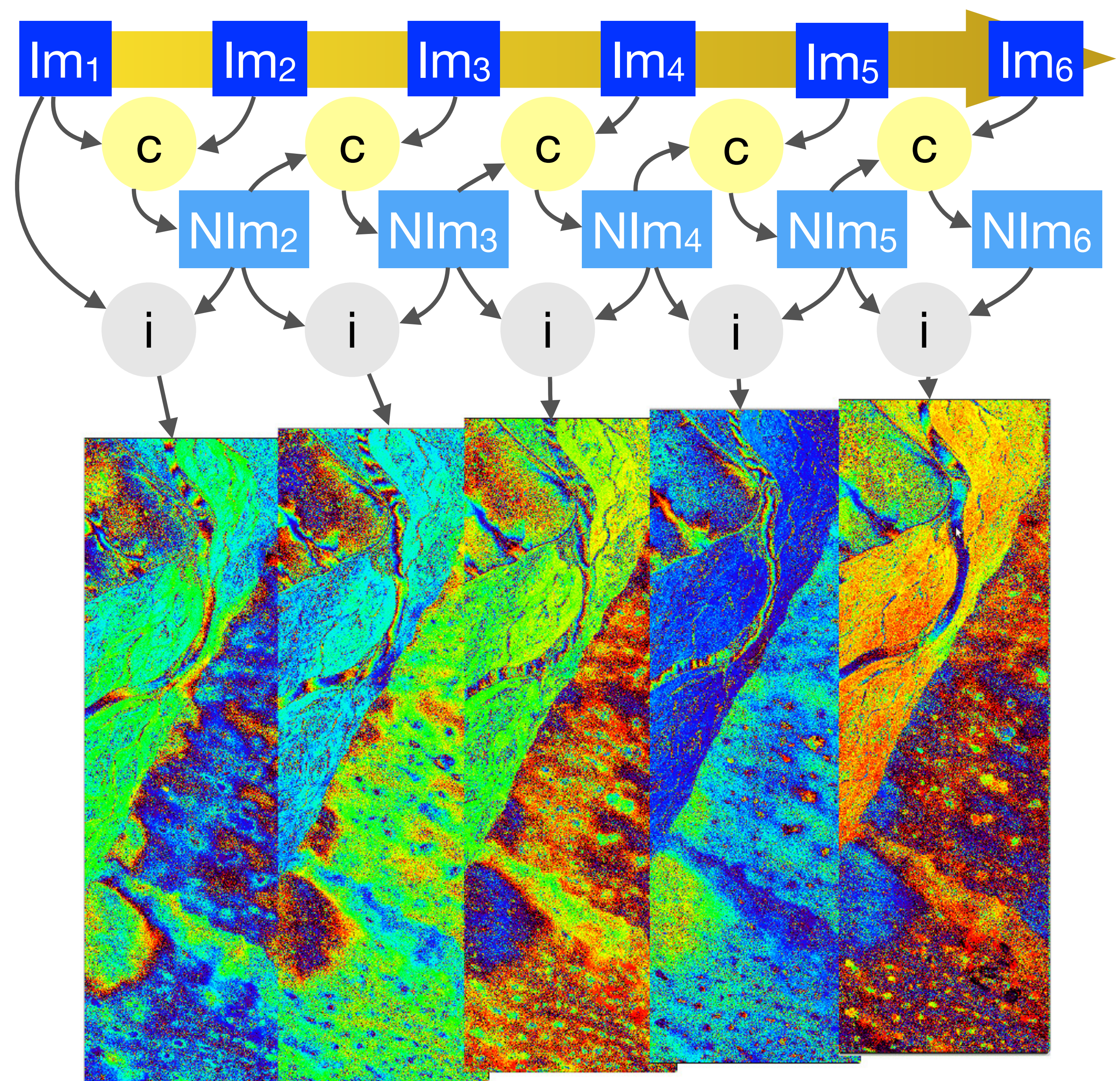
- ➜ Images are co-registered 2 by 2, successively, to keep a good coherence.
- ➜ DEM generated directly from the stack



Garestier et. al. 2014, 2015

TerraSAR-X: Temporal baseline of 11 days

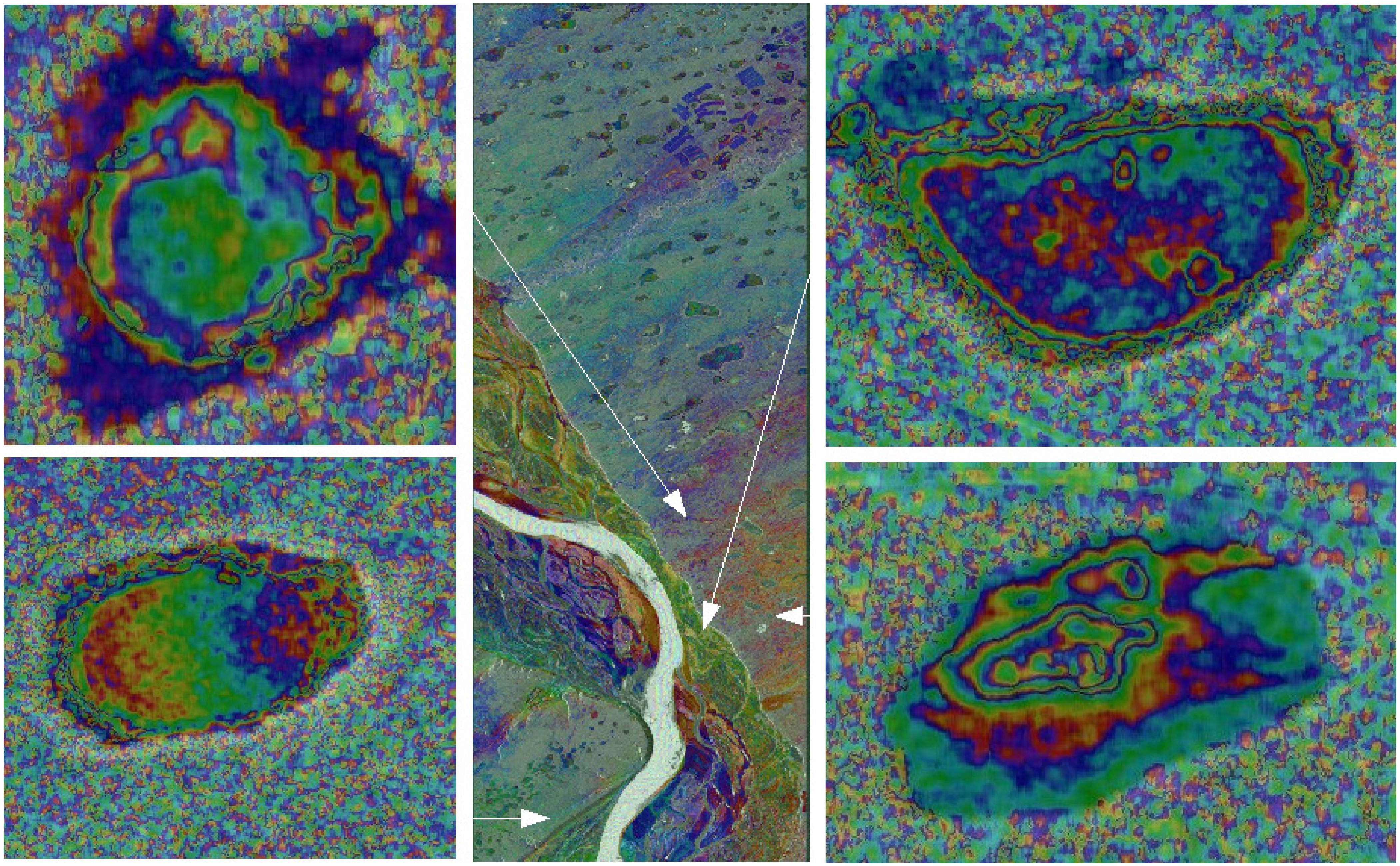
- ➜ Deterministic phase over the all dataset for successive pairs
- ⇨ Minimise phase error/noise term



Investigation of the Data

Localized surface movement

- Quite continuous time behaviour (integrated over 3 months)



➜ Alaces & small thermokarstic depressions: **+ varying ice thickness?**

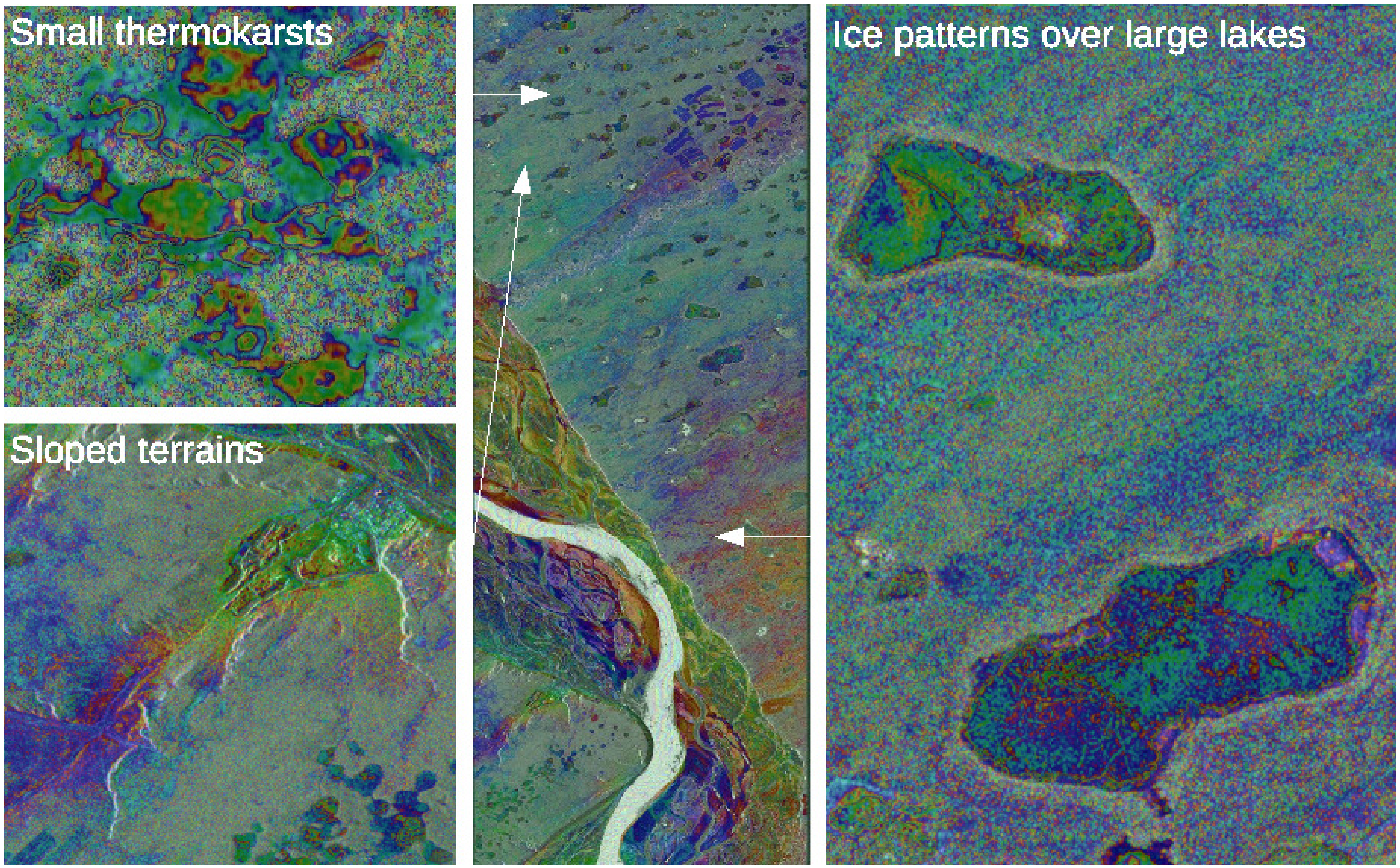
➜ Slow mass movements (horizontal component)

Garestier et. al. 2015

Investigation of the Data

Localized surface movement

- Quite continuous time behaviour (integrated over 3 months)



➜ Alaces & small thermokarstic depressions: **+ varying ice thickness?**

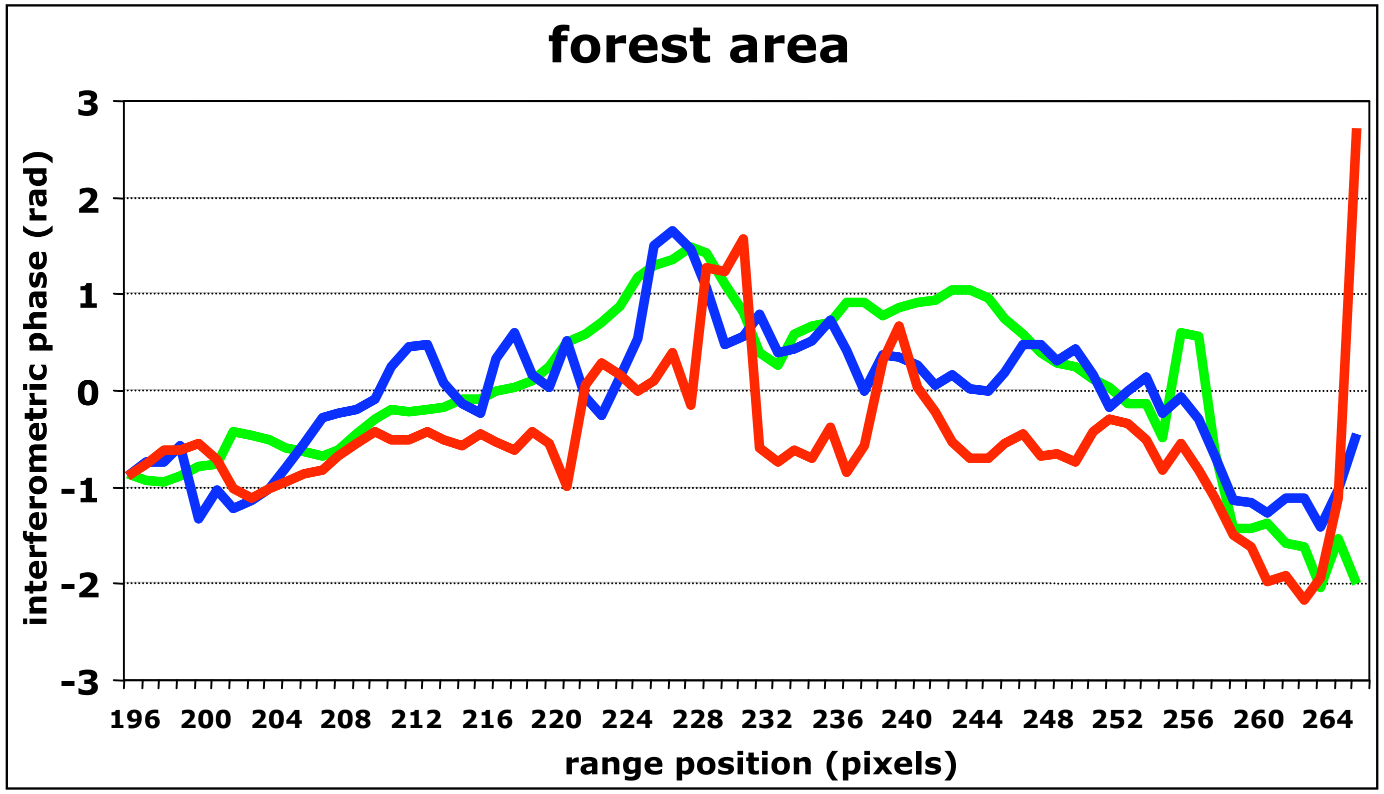
➜ Slow mass movements (horizontal component)

Garestier et. al. 2015

Phase Estimation over Low Coherence Areas

Decorrelation Source

- Temporal decorrelation (γ_t)
- Low signal-to-noise ratio (γ_{SNR})
- Bad SAR processing
- Baseline decorrelation(γ_{Bl})
- **Volume decorrelation** (γ_v)



E-SAR, L-Band, Oberpfaffenhofen/Germany

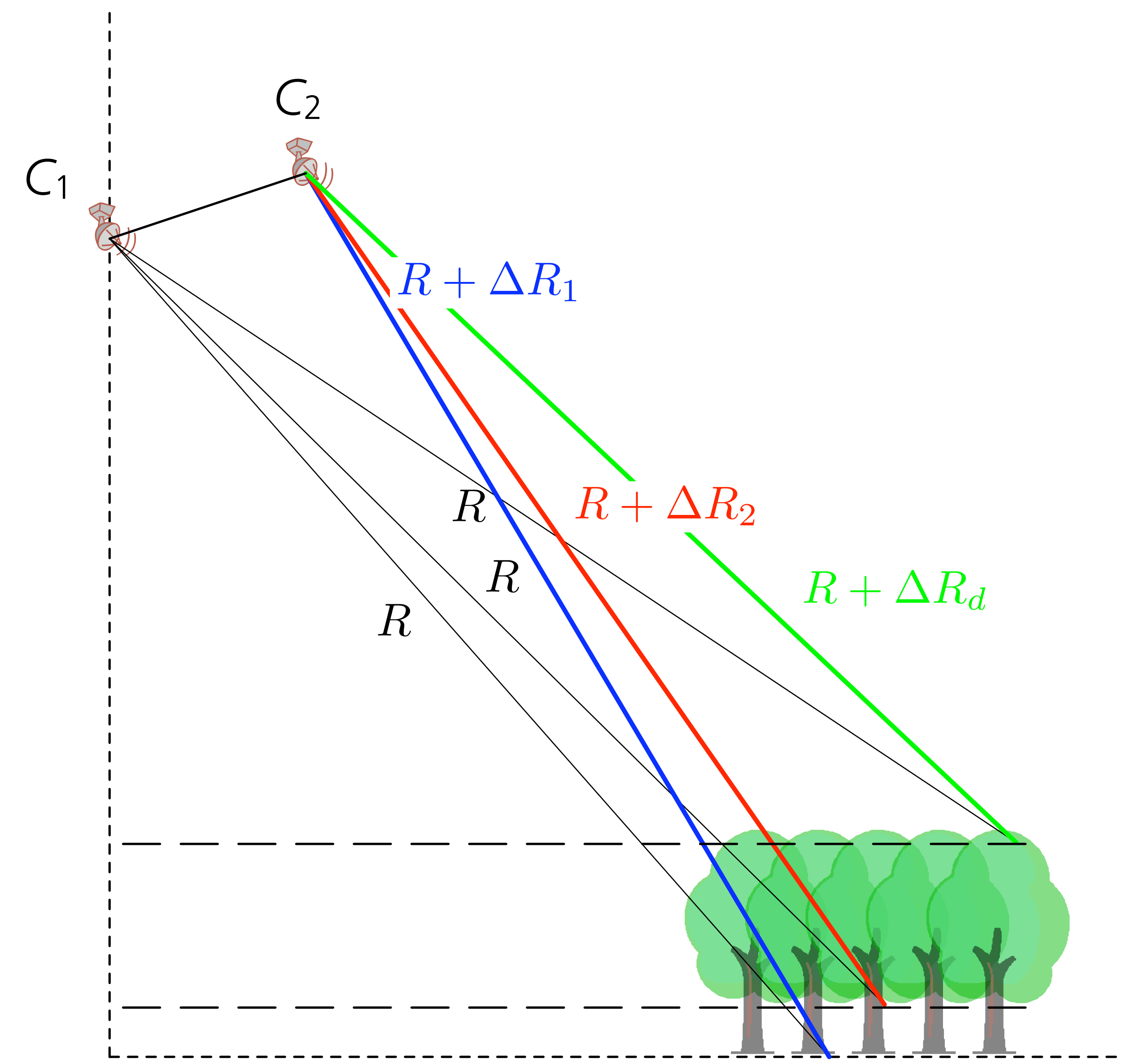
Guillaso et. al. 2005

ESPRIT* - The Signal Model

2 fully polarimetric sensor C_1 and C_2 ⇒ received polarimetric signal s_1 and s_2:

$$s_1^{pq} = \sum_{k=1}^{d} \sigma_k \zeta_k^{pq} \mathrm{e}^{i\frac{4\pi}{\lambda}R} + n_1^{pq}$$

$$s_2^{pq} = \sum_{k=1}^{d} \sigma_k \zeta_k^{pq} \mathrm{e}^{i\frac{4\pi}{\lambda}(R+\Delta R_k)} + n_2^{pq}$$



p, q	Polarization channel (e.g. *HH*, *HV*, *VV*)
d	Number of local scatterers ($d \leq 2$)
σ	Amplitude of the observed scatterer
ζ	Polarization state
R	Slant range distance
ΔR_k	Slant range difference
n	Additive gaussian noise

Yamada et. al. 2001, Guillaso et. al. 2003

*Estimation of signal parameters via rotational invariance techniques

ESPRIT* - Phase Center Estimation

Vector notation

$\vec{s}_1 = [s_1^{HH}, s_1^{HV}, s_1^{VV}]^T = \mathbf{A}\vec{\sigma} + \vec{n}_1$ → Observed signal master track

$\vec{s}_2 = [s_2^{HH}, s_2^{HV}, s_2^{VV}]^T = \mathbf{A\Phi}\vec{\sigma} + \vec{n}_2$ → Observed signal slave track

$$\Downarrow$$

$\vec{k} = \begin{bmatrix} \vec{s}_1 \\ \vec{s}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{A} \\ \mathbf{A\Phi} \end{bmatrix} \vec{\sigma} + \begin{bmatrix} \vec{n}_1 \\ \vec{n}_2 \end{bmatrix} = \bar{\mathbf{A}}\vec{\sigma} + \vec{n}$ → Interferometric target vector

$$\Downarrow$$

ESPRIT Algorithm

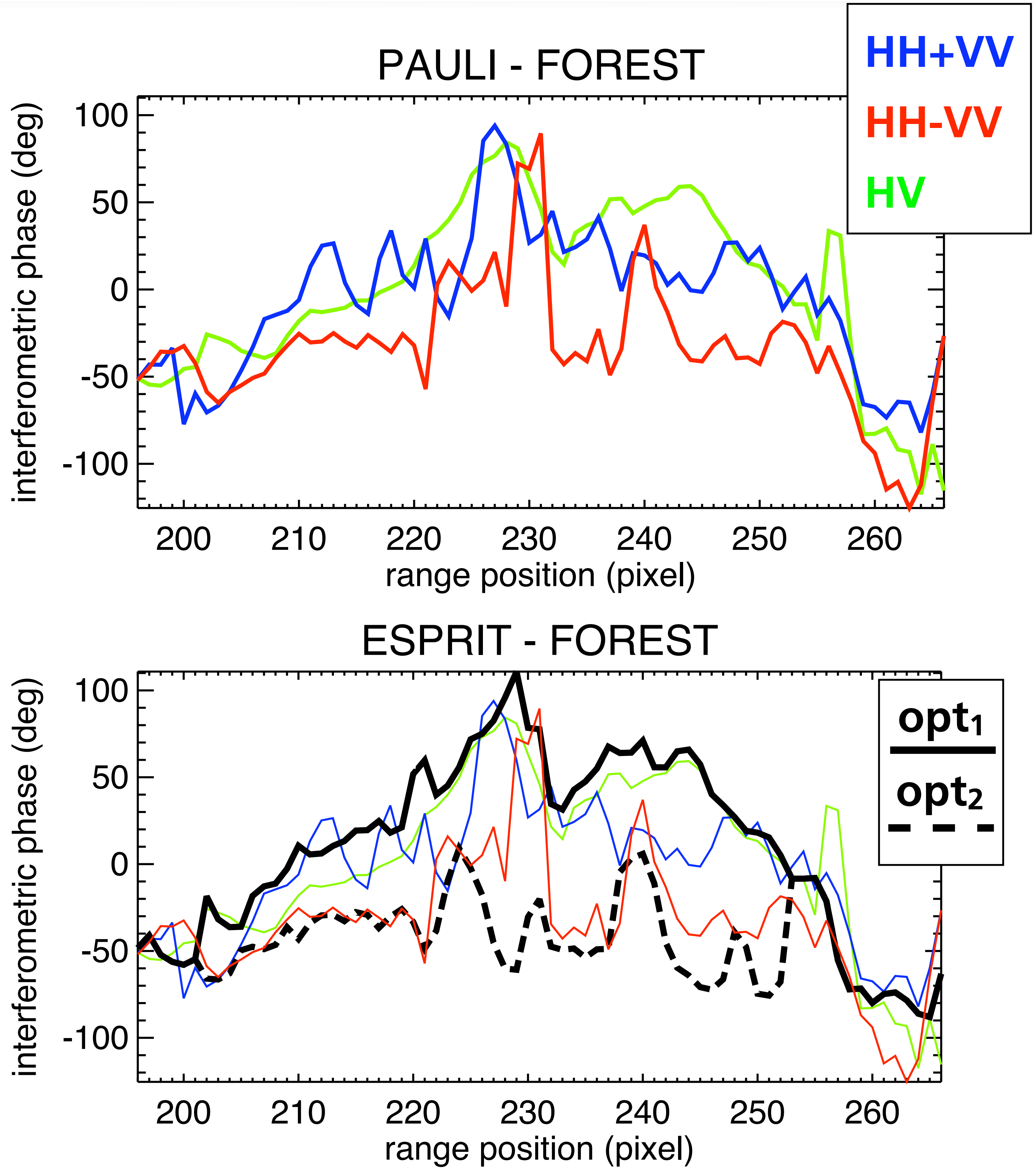
$$\Downarrow$$

$$\hat{\mathbf{\Phi}} = \begin{bmatrix} e^{i\Delta\phi_1} & 0 & \dots & 0 \\ 0 & e^{i\Delta\phi_2} & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \dots & 0 & e^{i\Delta\phi_d} \end{bmatrix}$$

Roy et. al. 1989

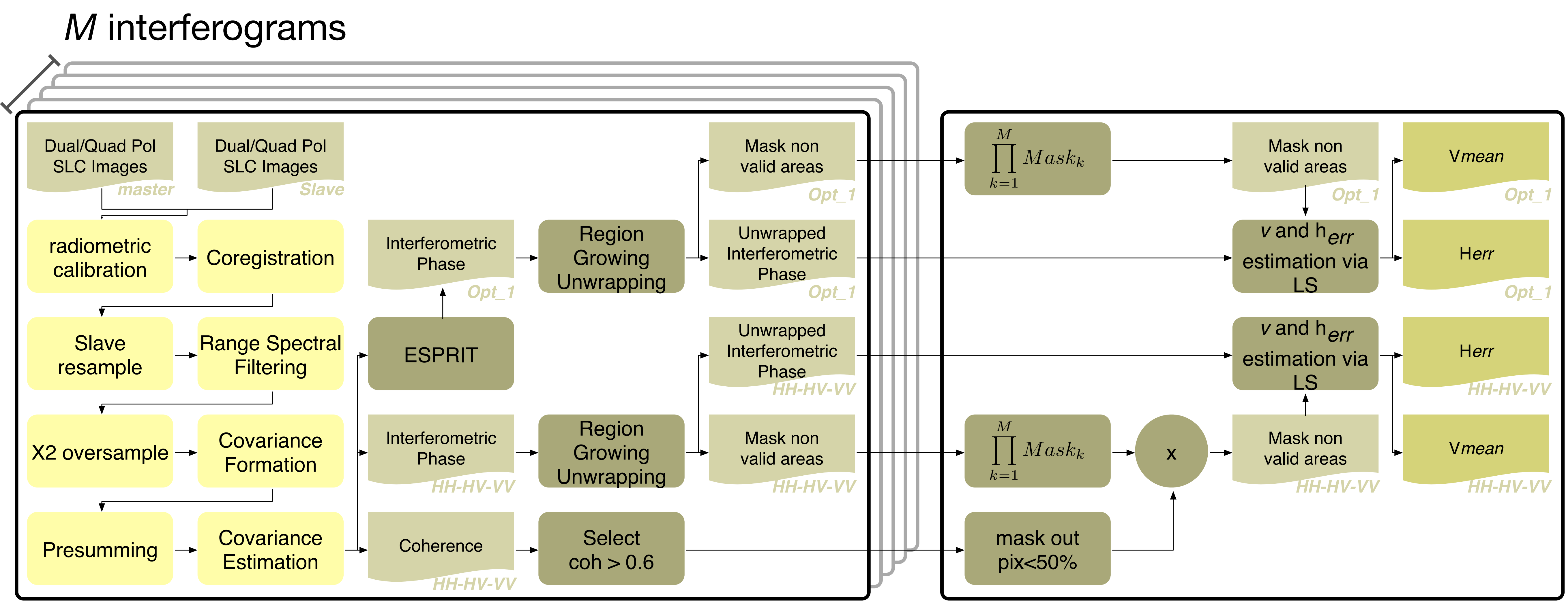
*Estimation of signal parameters via rotational invariance techniques

ESPRIT - Experimental Results



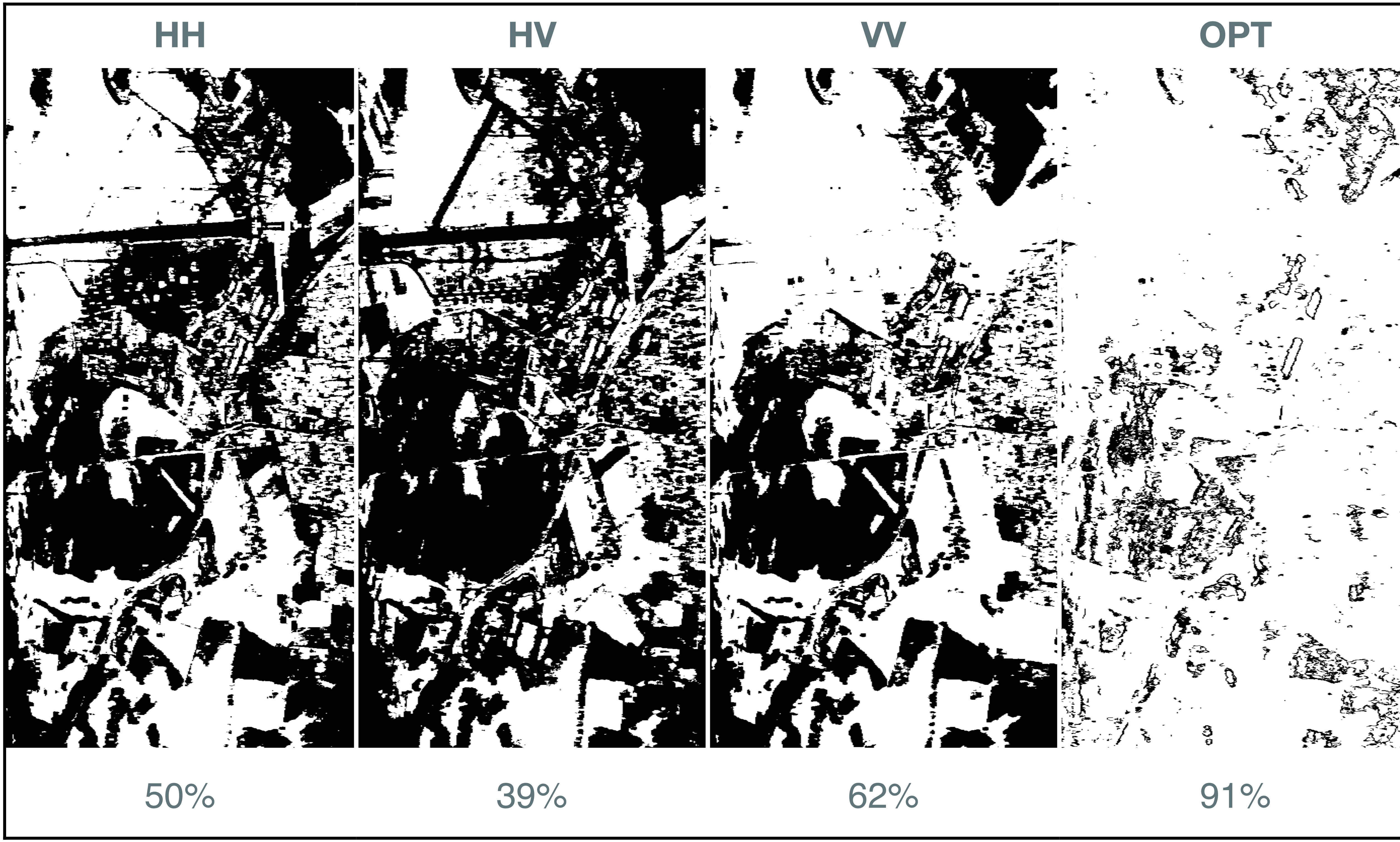
Guillaso et. al. 2005

ESPRIT - Processing Chain

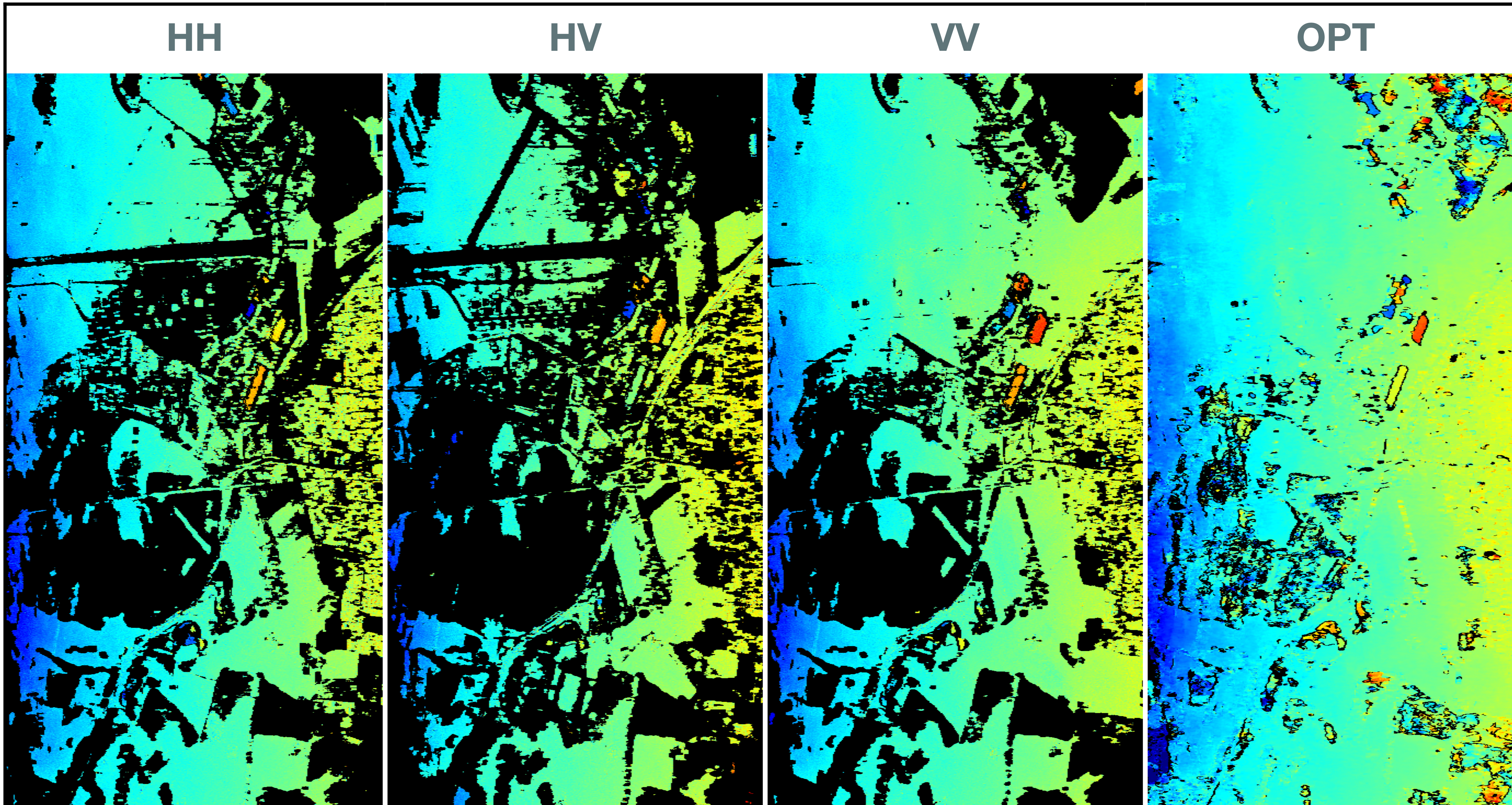


P.Prats, A. Reigber, J. J. Mallorquí, R. Scheiber and A. Moreira, "Estimation of the Temporal Evolution of the Deformation Using Airborne Differential SAR Interferometry," *IEEE TGRS*, Vol. 46, No. 4, 2008.

ESPRIT - Increase of the Valid Area

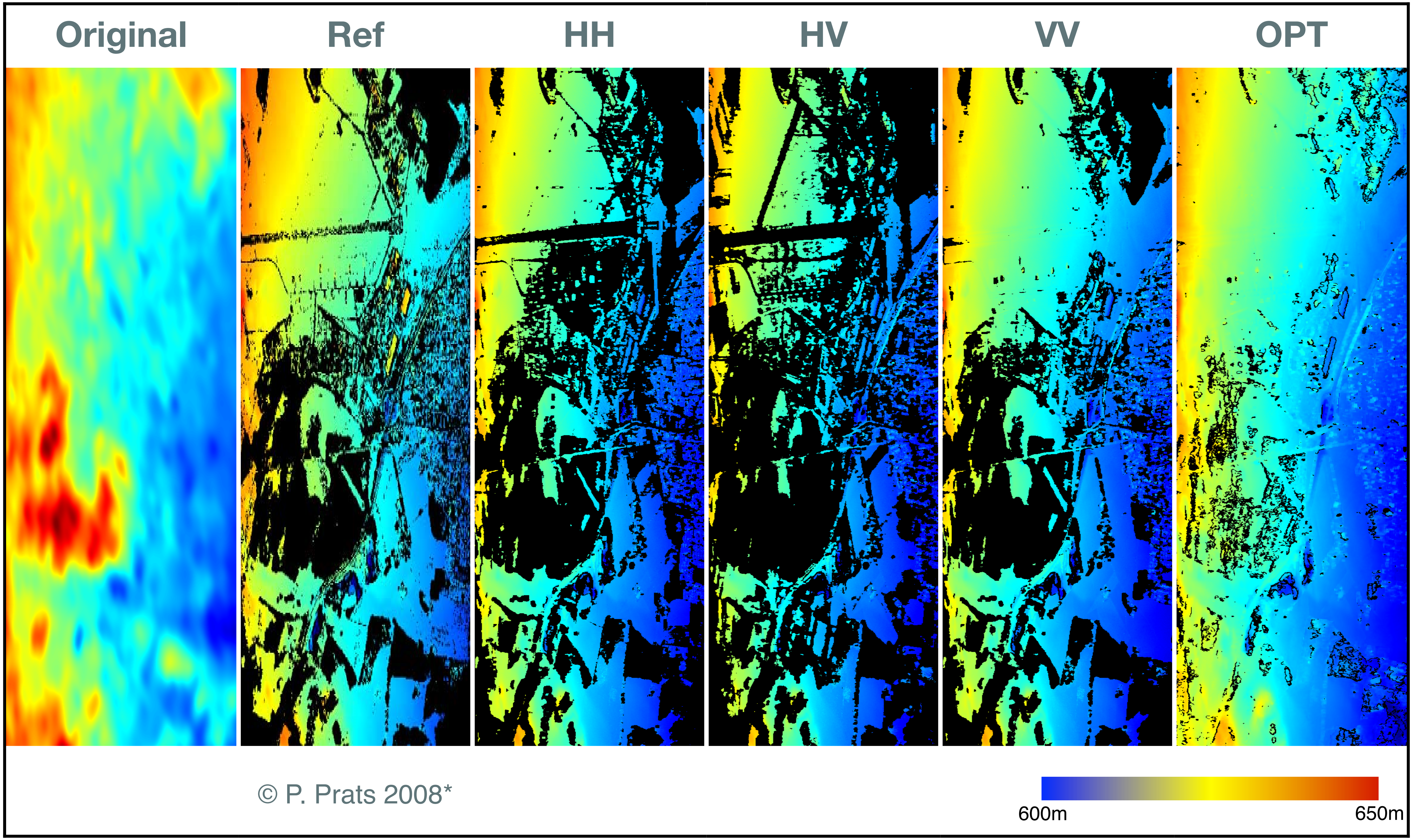


ESPRIT - Estimation of the Mean Deformation Velocity



Orbital errors: ramp => Need correction!

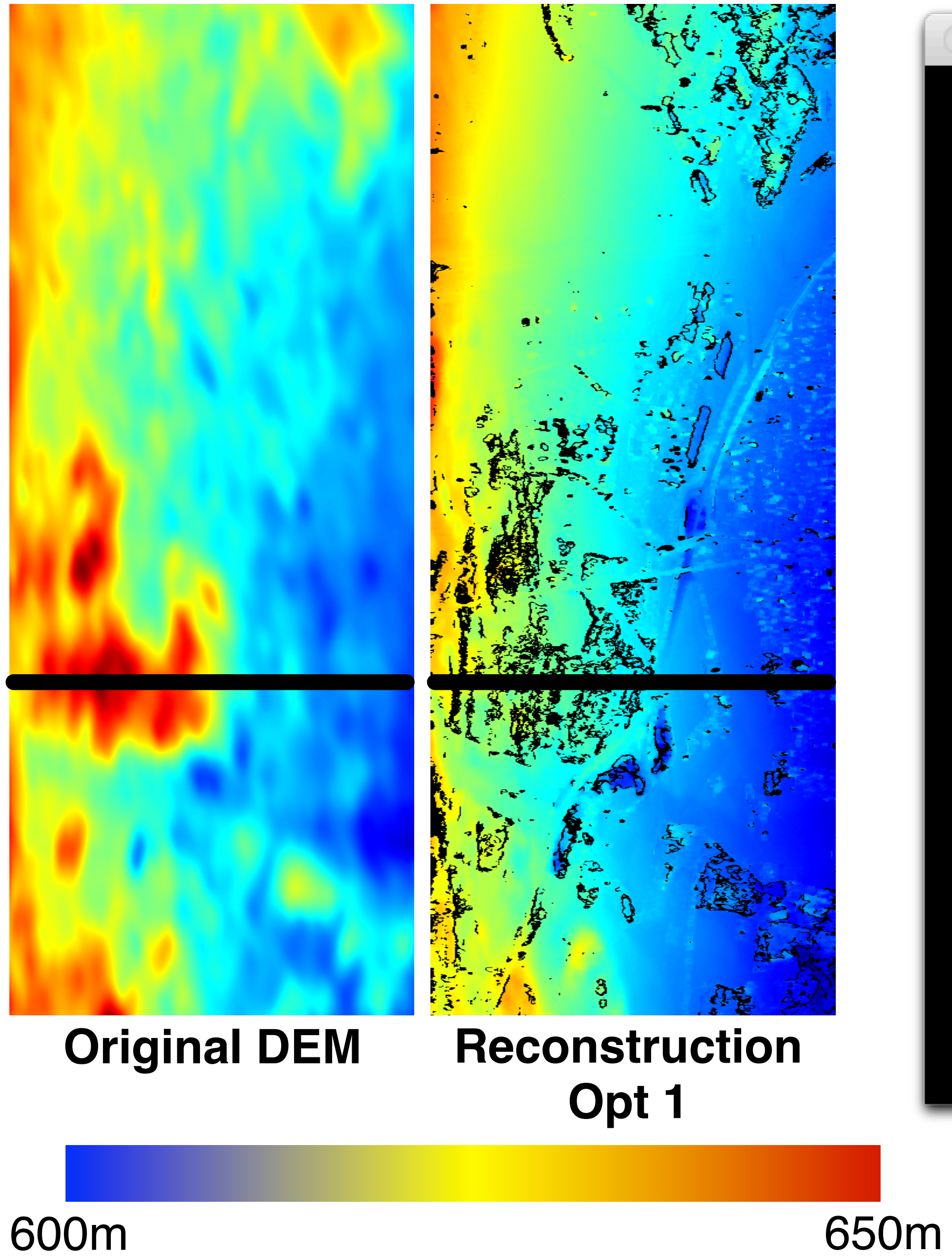
ESPRIT - DEM Correction

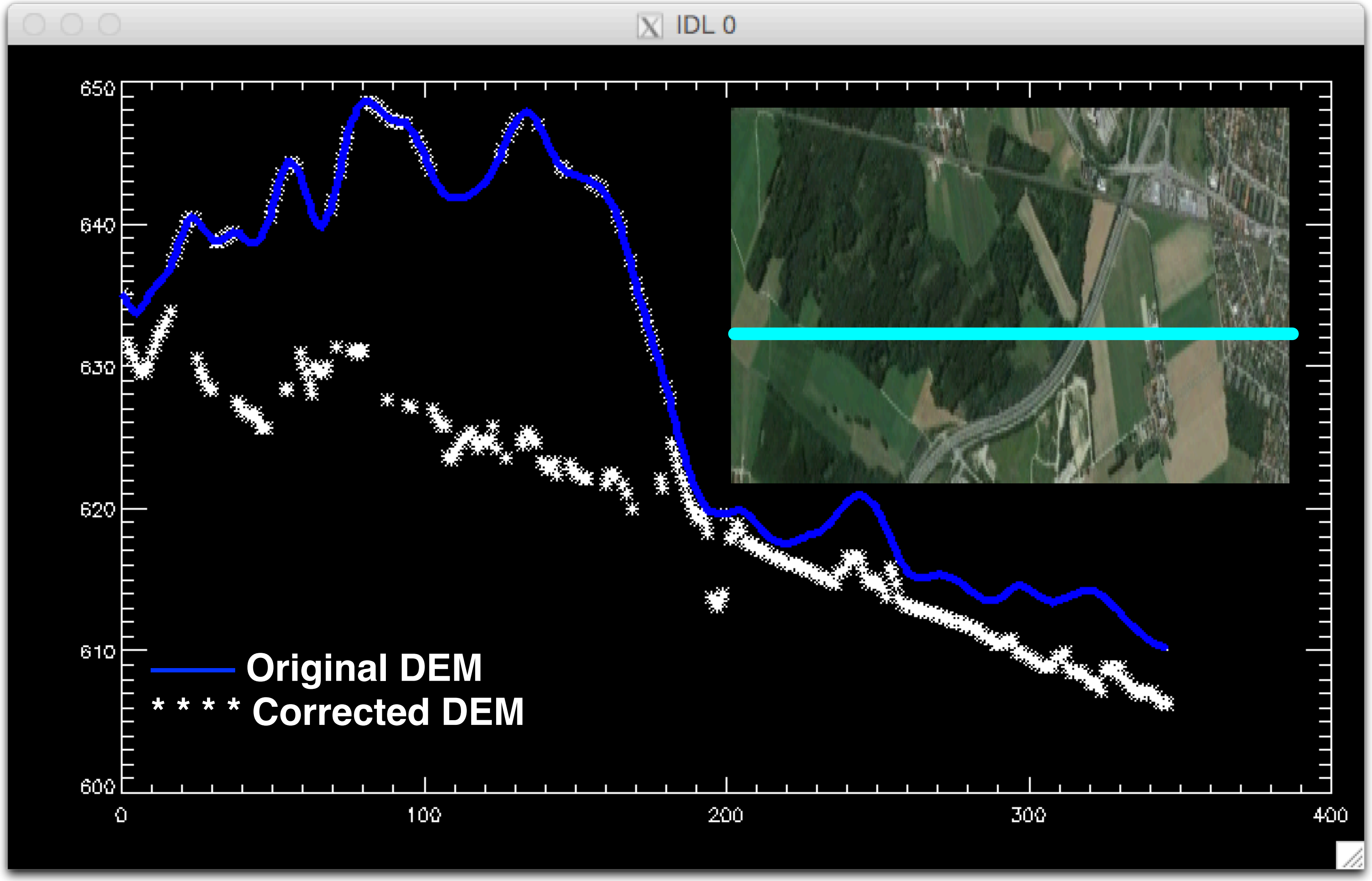


*P.Prats, A. Reigber, J. J. Mallorquí, R. Scheiber and A. Moreira, "Estimation of the Temporal Evolution of the Deformation Using Airborne Differential SAR Interferometry," *IEEE TGRS*, Vol. 46, No. 4, 2008.

ESPRIT - DEM Correction

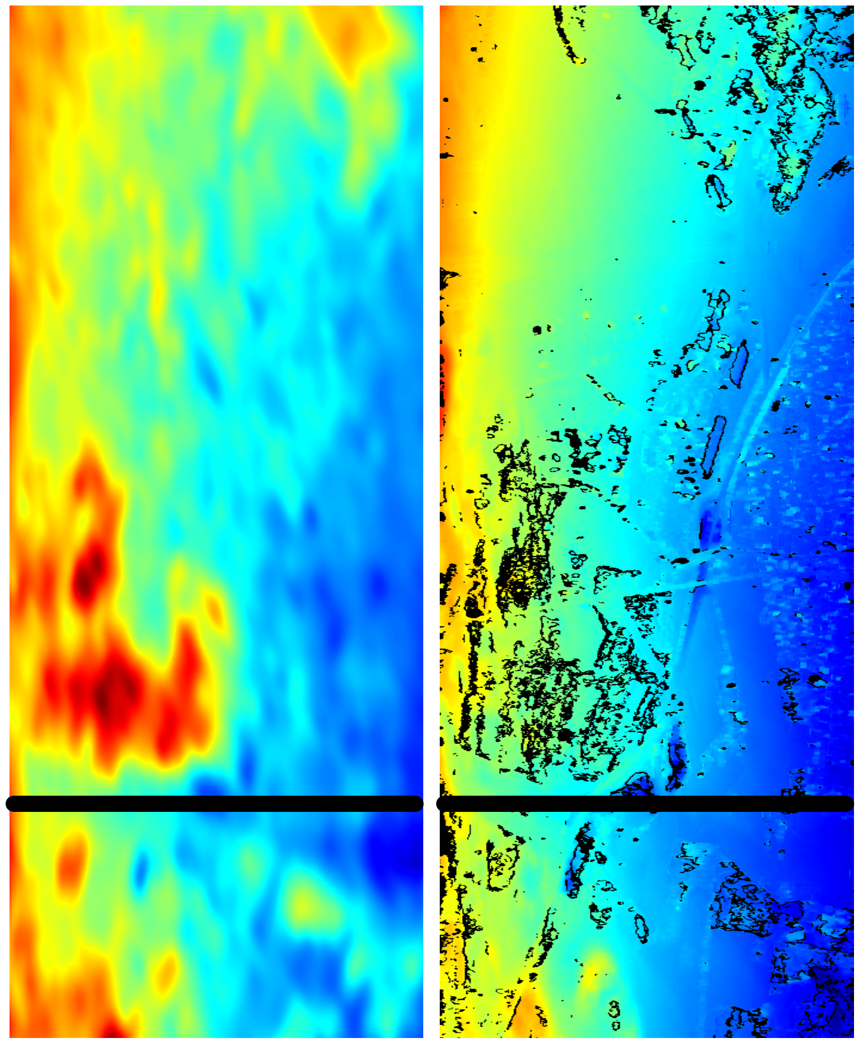
Profiles





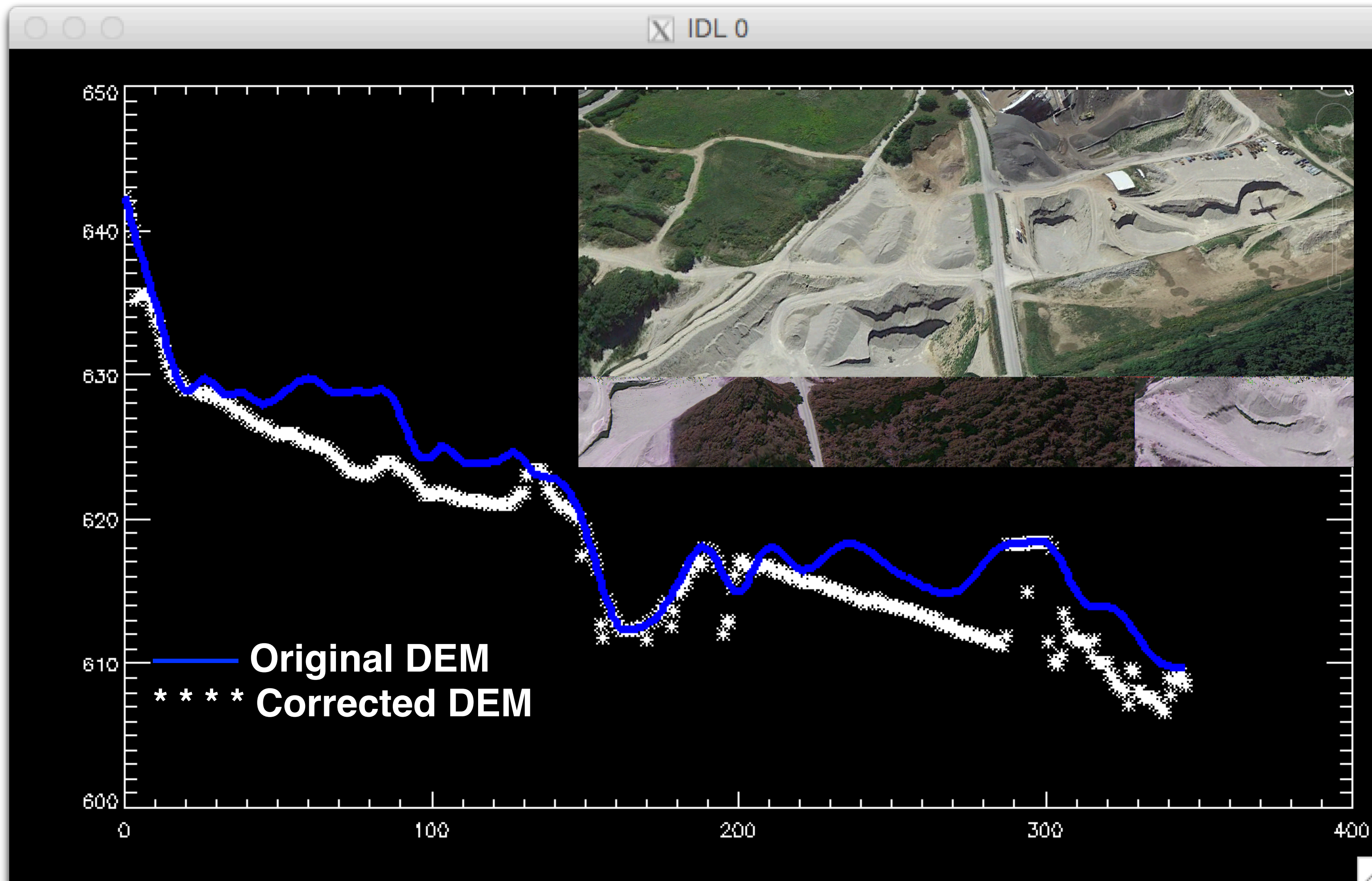
ESPRIT - DEM Correction

Profiles



Original DEM **Reconstruction Opt 1**

600m 650m



Conclusions & Perspectives

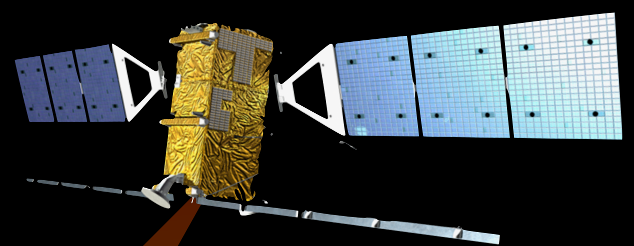
Conclusions

- Survey of permafrost environment by means of SAR data
- First results over the Yakutsk region
- Preliminary study over low coherence area using the ESPRIT approach

Perspectives

- Implementation of ESPRIT in the Yakutsk dataset
- Quantitative validation of the approach
- Use of polarimetric technique to estimate biophysical parameters.

Thank you for your attention.



contact: stephane.guillaso@tu-berlin.de