

Calibrating Mono-and Bi-static TomoSAR Data from the TomoSense Campaign

Yanghai Yu¹, Stefano Tebaldini¹, Mingsheng Liao²

1 National Space Science Center, Chinese Academy of Sciences, Beijing, China; 2 Politecnico di Milano, Milano, Italy; 3 Wuhan university, Wuhan, China; [Project ID. 95358 Geophysical and geodetics retrieval from SAR data stacks over natural scenarios]

Introduction

The ESA TomoSense campaign aimed to advance forest parameter retrieval techniques for future spaceborne SAR missions by acquiring multi-baseline, fully polarimetric L-band bistatic SAR data over Germany’s Eifel National Park. These acquisitions enabled three-dimensional forest structure analysis using SAR Tomography (TomoSAR). Key challenges included bistatic clock synchronization errors and trajectory inaccuracies, notably due to the absence of a time-synchronization link. This paper introduces a four-step calibration methodology that integrates monostatic and bistatic interferometry with natural scatterers. First, clock mismatches are resolved by calibrating bistatic datasets against the corresponding monostatic reference. Second, single-baseline time-varying baseline errors are inverted using partially calibrated single-pass bistatic InSAR data. Third, multi-pass time-varying baseline errors are estimated through multi-baseline monostatic and bistatic InSAR data stacks. Finally, baseline-direction positioning errors are corrected while accounting for target height uncertainties. The results validate the method’s efficacy, demonstrating enhanced interferometric coherence, improved tomographic reconstruction, and higher vertical resolution in fused monostatic-bistatic TomoSAR imaging.

Methodology

The suboptimal correlation level of the initial TomoSense data stack precludes simultaneous estimation of all pronounced errors. To address this limitation, we adopt a phase calibration strategy, partitioning the error correction into four sequential steps based on their distinct characteristics. The core principle of this approach lies in iteratively refining the datasets by refocusing the original data with the correction term obtained from each step. The calibration architecture employs a cascaded workflow to progressively refine datasets through four sequential stages:

- **Step-1:** estimate nominal clock drift errors in each bistatic images by calibrating them against their corresponding monostatic counterparts from the same pass via multi-squint InSAR (MSInSAR), and refocusing the bistatic image with correction term;
- **Step-2:** estimate the single-pass baseline error between monostatic and corresponding bistatic image pair after partial calibration;
- **Step-3:** invert and correct time-varying trajectory errors across the entire mono- and bi-static dataset, ensuring precise alignment of the data stack through multi-pass MSInSAR.
- **step-4:** inverts inherent APC offsets using a bistatic implementation of the phase center double location (PCDL) algorithm.

Study area and experimental results

The ESA TomoSense campaign provides 3D remote sensing datasets characterizing a temperate Forest in Germany\cite{tebaldini2023}. Multi-frequency and full-polarization SAR surveys were conducted using the radar system owned by MetaSensing. The main radar parameters of the surveys are listed in the following Table. This study focuses on calibrating L-band data to address challenges in processing multi-baseline mono- and bi-static SAR data stacks. The L-band was selected to enhance the interpretation of forest vertical structure and leverage its reduced susceptibility to temporal decorrelation, a major limitation affecting C-band datasets

Parameters	P-band	L-band	C-band
Range resolution[m] (Δr)	5	3	1.5
Azimuth resolution[m] (Δx)	≈ 1	≈ 1	≈ 0.6
Vertical resolution[m] (Δh)	5 to 10	< 5	< 5
Acquisition mode	Mo	Mo & Bi	Mo & Bi

Mo:monostatic mode; Bi: bistatic mode.

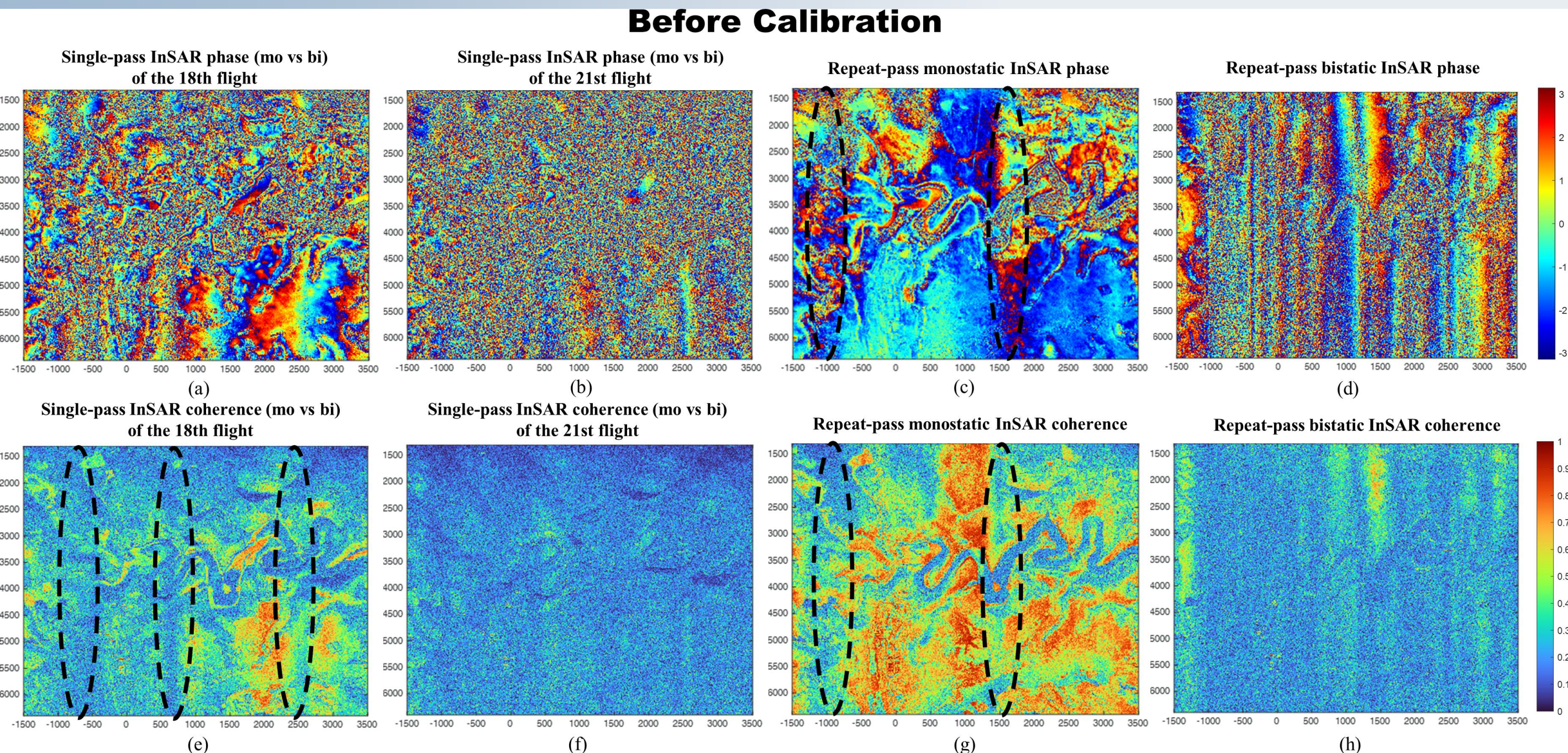


Figure 1. Interferometric phase (upper panels) and coherence magnitude (lower panels) maps generated by the data acquired from the 18th and the 21st flights before calibration: subfigures (a) and (e) display the single-pass InSAR maps between monostatic and its corresponding bistatic images (we refer to this combination as "mo vs bi" hereafter) along the 18th flight; subfigures (b) and (f) give the InSAR results between mono- and bistatic images along the 21st flight; subfigures (c) and (g) exhibit the repeat-pass interferometric information between the monostatic images acquired from these two passes; subgraphs (d) and (h) present the interferometric results between the bistatic images acquired from these two flights. The black dashed lines indicate the artifacts related to residual motion errors.

Contact

Email: yuyanghai@nssc.ac.cn; stefano.tebaldini@polimi.it

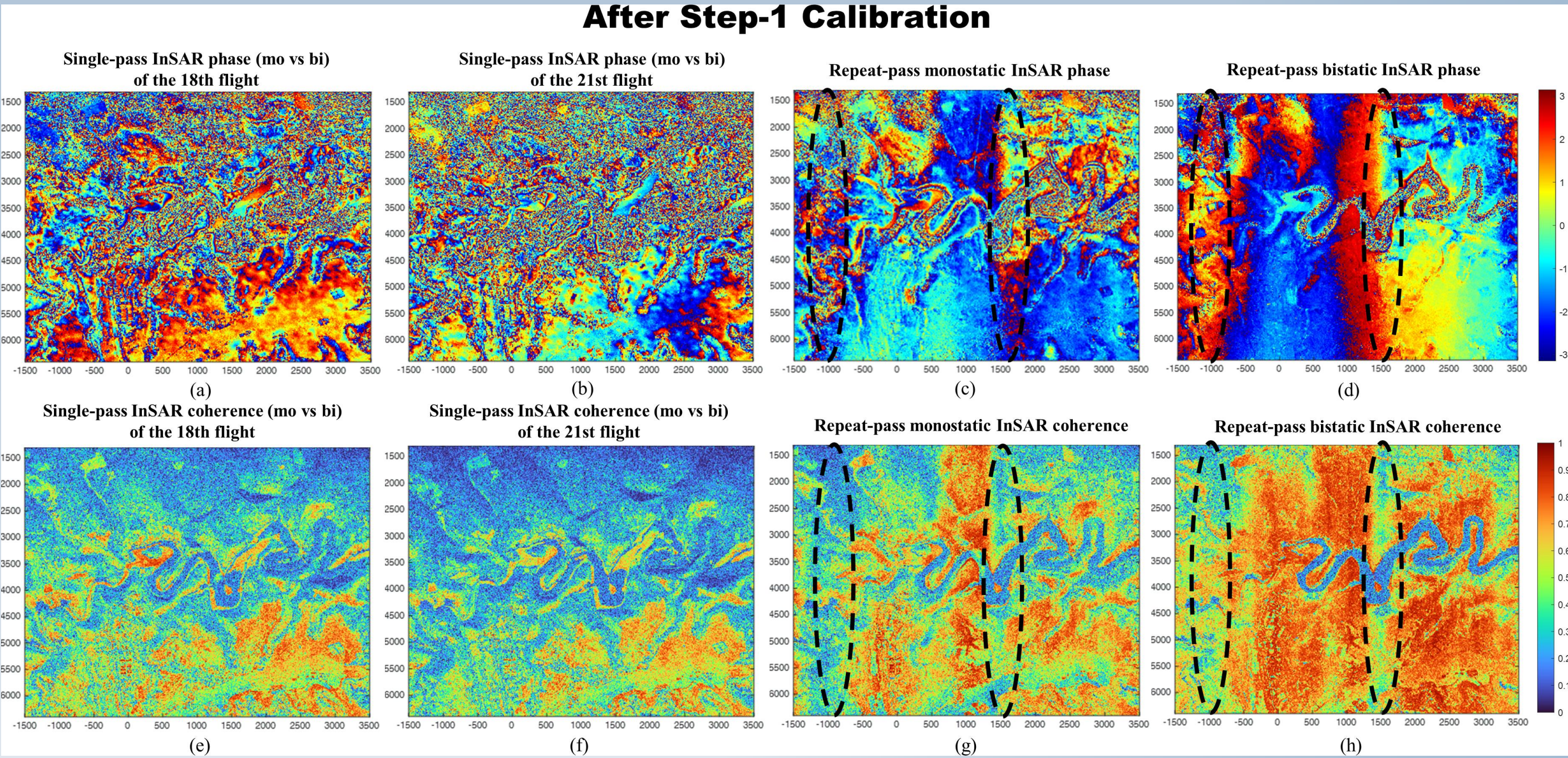


Figure 2. Interferometric phase (upper panels) and coherence magnitude (lower panels) maps after the first step calibration where the black dashed lines indicate the remaining residual motion errors after the first step calibration.

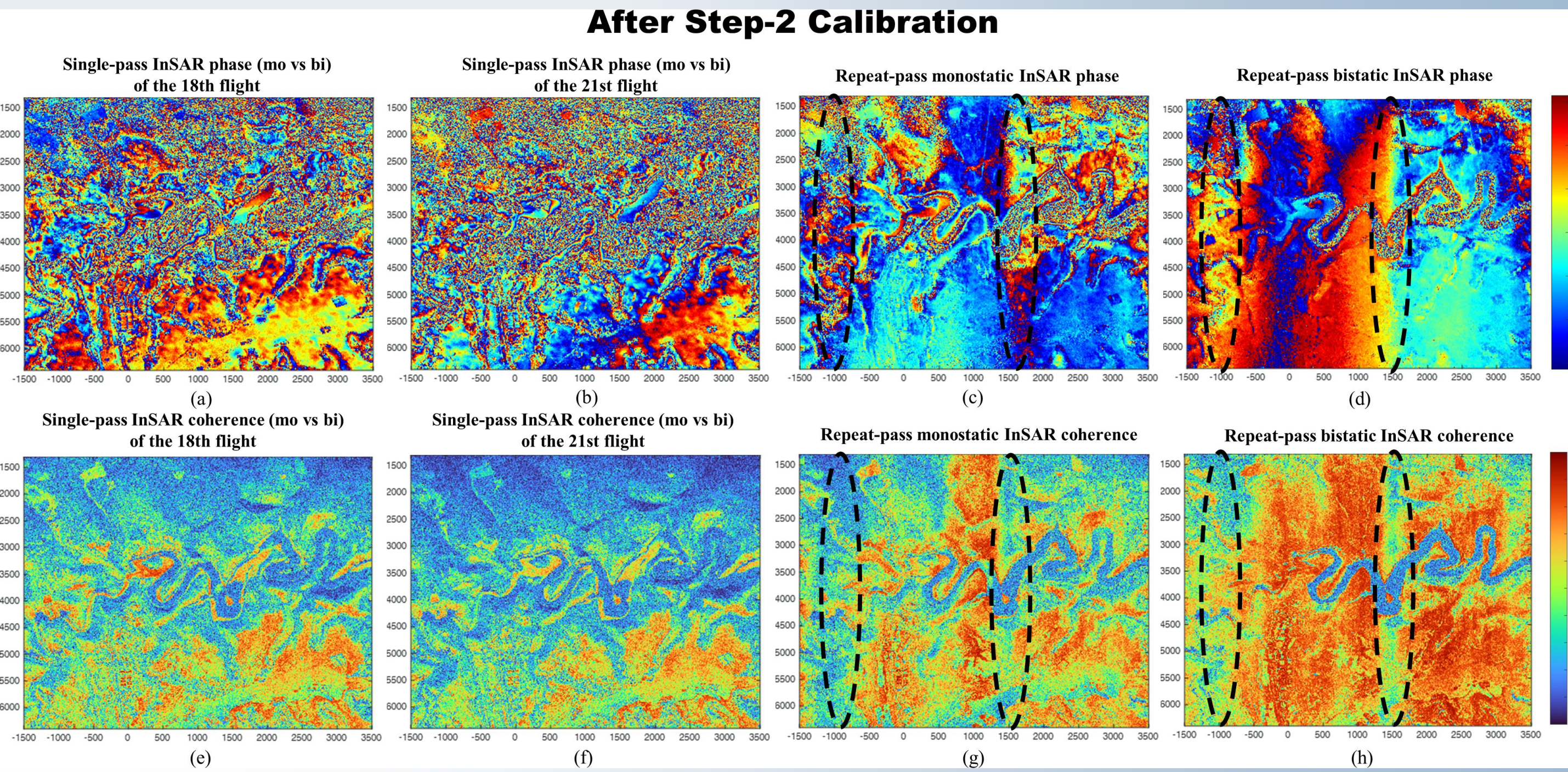


Figure 3. Interferometric phase (upper panels) and coherence magnitude (lower panels) maps after the first two step calibration

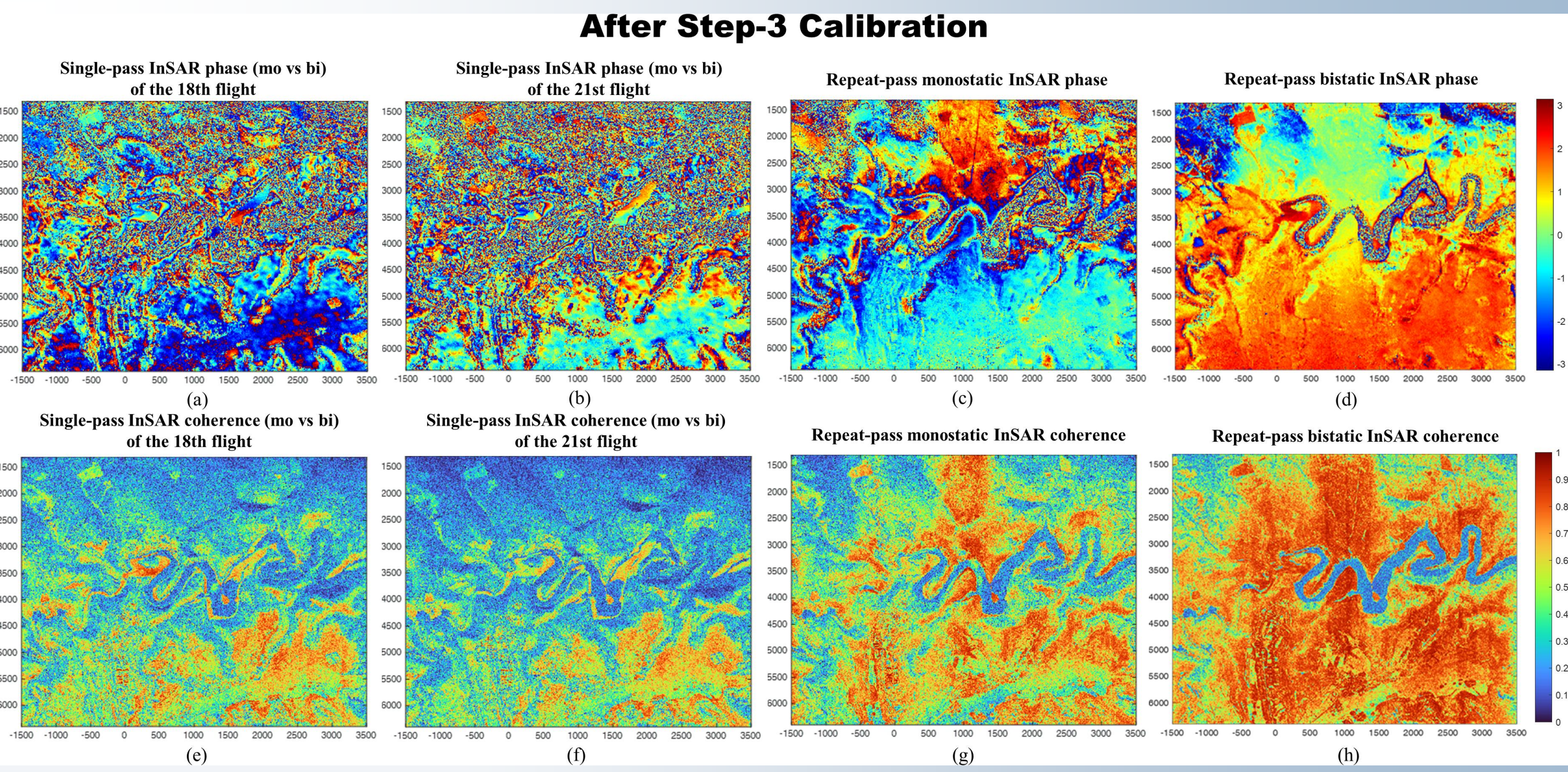


Figure 4. Interferometric phase (upper panels) and coherence magnitude (lower panels) maps after three calibration steps.

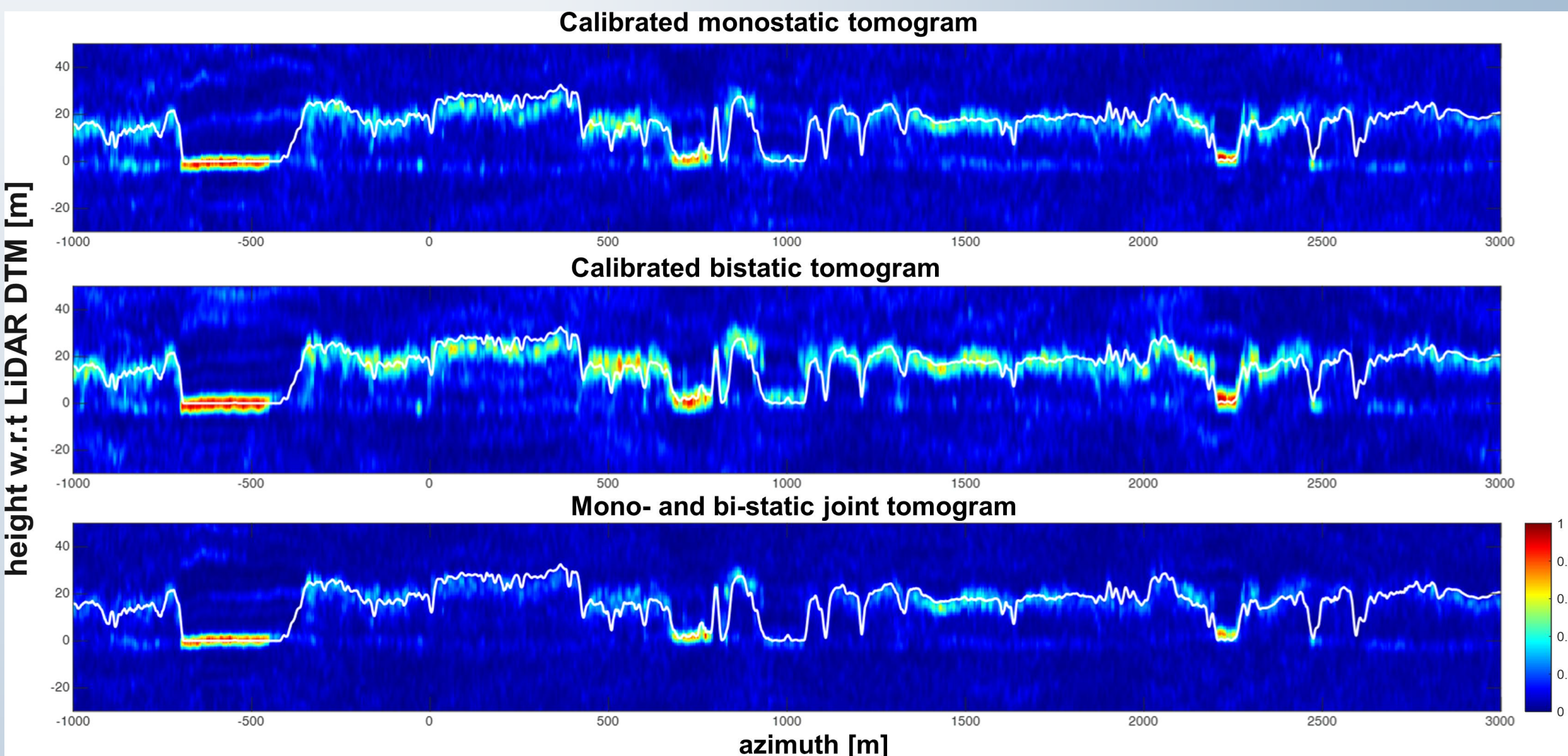


Figure 5. Three different types of tomographic profiles were generated by using (top) calibrated monostatic data, (middle) calibrated bistatic data, (bottom) both mono- and bi-static data at a fixed ground-range position $y_0 = 1700$ m. The white line denotes LiDAR forest height. For better interpretation, each azimuth sections were normalized such that the maximum imaging metric within the section is 1.

Conclusions

- In this paper, a four-step calibration procedure is proposed to calibrate mono- and bistatic tomographic data in the presence of trajectory and clock drift errors.
- Further efforts are dedicated to phase calibration over the natural scenarios under very-high resolution and in the presence of temporal evaluation of investigated targets.