Response to Reviewer 2:

Thank you for your valuable comments, we will work to incorporate them to improve our revised manuscript, specifically the validation between TanDEM-X derived ice thickness and CLIMo simulations.

1. My first impression is that this manuscript may fit better in the scope of the Cold Region Science and Technology (CRST) Journal. Because “TanDEM-X immediate interferometry” is largely a remote sensing technology for EO measurement.

We submitted our manuscript to The Cryosphere considering its EGU connection and the use of TanDEM-X developed by an ESA member (DLR). We feel that the manuscript reflects the quantification of a Cryosphere variable using remote sensing observations. The focus of the paper also incorporates thermodynamic modeling of freshwater ice, which The Cryoshpere has extensively published in the past (Li et al., 2023).

2. Once a remote sensing-based LIT product is available, it should ideally be validated against in situ observations. In this study, the retrieved LIT was primarily compared with CLIMo simulations, which may contain systematic errors or biases.

We thank the reviewer for this important comment and agree that contemporaneous in situ observations provide the most rigorous validation for remotely sensed LIT products. We would like to clarify that the primary objective of this study is not to develop an operational LIT product, but rather to investigate the feasibility of using immediate interferometric approaches to derive ice thickness, and the physical relationship between the TanDEM-X interferometric phase center and lake ice thickness using a unique immediate interferometric dataset. As such, this work should be regarded as an exploratory proof-of-concept study.

To strengthen the validation, we have expanded the comparison between CLIMo simulations and available field observations that fell outside the TanDEM-X acquisition extents. In addition to the two lakes originally presented, we will compare CLIMo simulations with in situ ice thickness measurements from six lakes (Table 1) in the Barrow region (Figure 1) from Arp et al., 2018 (Four additional lakes were not included in the preprint due to they are located outside of TanDEM-X acquisition footprint). These lakes demonstrate that CLIMo reproduces the regional lake ice thickness with good agreement, as shown in Table 1, the average ice thickness observed in six lakes at April 7th 2015 is 1.39m, very similar to CLIMo 25% - 50% scenario ranging from 1.31 to 1.4 meters.Therefore, CLIMo provides a reasonable independent reference for evaluating the TanDEM-X retrievals. Also we will note to readers that the comparison between CLIMo and TanDEM-X derived ice thickness only demonstrated that InSAR-based methods show promise in this case study to extract ice thickness, but the RMSE and other metrics does not represents true errors between ground truth and TanDEM-X derived ice thickness.

We will also note that CLIMo has been extensively applied and validated for shallow thermokarst lakes in northern Alaska and other and other tundra environments dominated by *thermokarst lake development (e.g., Surdu et al., 2014, 2015; Antonova et al., 2016), providing confidence that it captures the regional thermodynamic evolution of lake ice despite the inherent uncertainties.*

3. The treatment of snow is unclear, and the CLIMo snow scenarios are insufficiently justified.

We thank the reviewer for this valuable comment. We did not explicitly include a snow layer in the conceptual workflow because X-band microwave signals are expected to penetrate dry Arctic snow with relatively little attenuation (Gunn et al., 2015). Furthermore, the TanDEM-X retrieval estimates the lake water level using shoreline elevations corrected by the LiDAR-derived shoreline–water level difference, thereby minimizing the influence of the snow layer on the estimated ice thickness. Any residual influence of snow on the interferometric phase center would contribute primarily to the systematic underestimation discussed in the manuscript and would not affect the agreement between the 99.7th percentile retrieval and the CLIMo simulations shown in the boxplots.

Regarding the CLIMo snow-cover scenarios, we agree that selecting the 25% and 35% scenarios based on only two lakes was insufficient. We have therefore expanded the validation using additional field measurements from six lakes in the Barrow region (Table 1). This comparison demonstrates that CLIMo reasonably reproduces regional lake ice thickness, with simulated snow depths ranging from approximately 19 to 32 cm. Based on these results, we will revise the manuscript to evaluate the 25% (20cm snow depth), 35%(26cm snow depth), and 50% (32cm snow depth) snow-cover scenarios. As shown in Table 1, the 50% snow scenario produces ice thickness (1.31 meter) that are very similar to those of the 35% scenario (1.34 meter), further supporting the robustness of the selected range of snow conditions.

4. How applicable is this methodology in practice? The study uses TanDEM-X data acquired more than a decade ago.

We appreciate the reviewer's comments regarding the practical applicability of the proposed methodology. We will revise the manuscript to clarify that the TanDEM-X pursuit-mode dataset used in this study represents a unique data opportunity rather than an operational observing strategy. TanDEM-X was originally developed for bistatic SAR interferometry, with its primary scientific objectives including the generation of a global digital elevation model, rather than lake ice thickness retrieval (Rizzoli et al., 2017). Consequently, suitable immediate interferometric acquisitions over lake ice are rare, and coordinated field measurements corresponding to these acquisitions are generally unavailable.

We therefore emphasize that this work is intended as an exploratory investigation of the physical mechanism linking the interferometric scattering phase center to lake ice thickness, rather than the development of an operational retrieval algorithm. Although TanDEM-X pursuit-mode acquisitions are no longer routinely collected, the physical understanding established in this study provides a foundation for future bistatic interferometric missions. In particular, the upcoming ESA Harmony mission, which will acquire passive bistatic observations using the *current-era Sentinel-1 C-band signal pulses, offers an exciting opportunity to extend and further develop this retrieval concept for future lake ice thickness studies.*

We would also like to emphasize that, although this study is exploratory rather than the development of an operational LIT product, we believe it makes an important scientific contribution to the remote sensing of lake ice. Compared with radar altimetry, which has recently progressed toward operational LIT retrieval algorithms, relatively few studies have investigated the use of InSAR for quantitative lake ice thickness retrieval, despite its considerable potential. In particular, bistatic InSAR offers the capability to provide spatially continuous, high-resolution observations over entire lakes, complementing the track-based measurements of current radar altimeters that are limited in areal coverage and spatial resolution, often only covering large lakes (e.g. Great Slave Lake, Mangilli et al., 2022, Beckers et al., 2017; Li et al., 2023).

Minor Comments:

(a) The structure of the paper can still be improved. Chapter 2 belongs to Data and Methods. Section 5.4 (Future directions) may fit better into the Conclusion chapter.

We thank the reviewer for the helpful suggestion. We will revise the manuscript structure accordingly.

(b) Figure 2 needs to be explained in more detail. Also consider drawing frames of these three parts as background in the diagram.

We thank the reviewer for this suggestion. We will revise Figure 2 by improving the graphical layout, adding background frames to distinguish the three major components of the workflow, and expanding the figure caption and corresponding text in the manuscript to provide a more detailed explanation of each processing step.

(c) The third part (3) is not fulfilled in this study; see my major comments 1).

We thank the reviewer for this observation, we will improve our validation parts, mentioned in major comments.

(d) The Discussion is rather subjective; can the authors provide quantitative discussions, e.g., to compare this study with other remote sensing products?

We thank the reviewer for this valuable suggestion. We will revise the Discussion section to include more comparisons with existing remote sensing approaches, including radar altimetry-based LIT retrieval methods. We will compare how other studies validated their remote sensing-derived ice thickness and RMSE.

(e) The quality of some figures can still be improved, e.g., the figure legends and labels are hardly visible in Fig. 7 and Fig. A1.

We thank the reviewer for pointing this out. We will improve the quality of the figures in our revised manuscript.

Figure 1. Location of six lakes at Utqiagvik where ice thickness and snow measurements were collected.

Lakes & CLIMo simulation	Ice Thickness (cm)	Snow Depth (cm)
BRW_100 (Emaiksoun)	**138**	**19.65**
BRW_103	**148**	**22.75**
BRW_104	**140**	**27.05**
BRW_106	**152**	**22.4**

BRW_107 (WT Lake)	**130**	**24**
BRW_130	**127**	**32.05**
Average of six lakes	**139**	**25**
CLIMo 25%	140	20
CLIMo 35%	134	24
CLIMo 50%	131	32

Table 1. Comparison of in-situ measurements (Bold) and CLIMo simulations

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