

Aufeis in the Upper Indus Basin – time-series analysis for the detection of seasonal cryosphere components

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Introduction

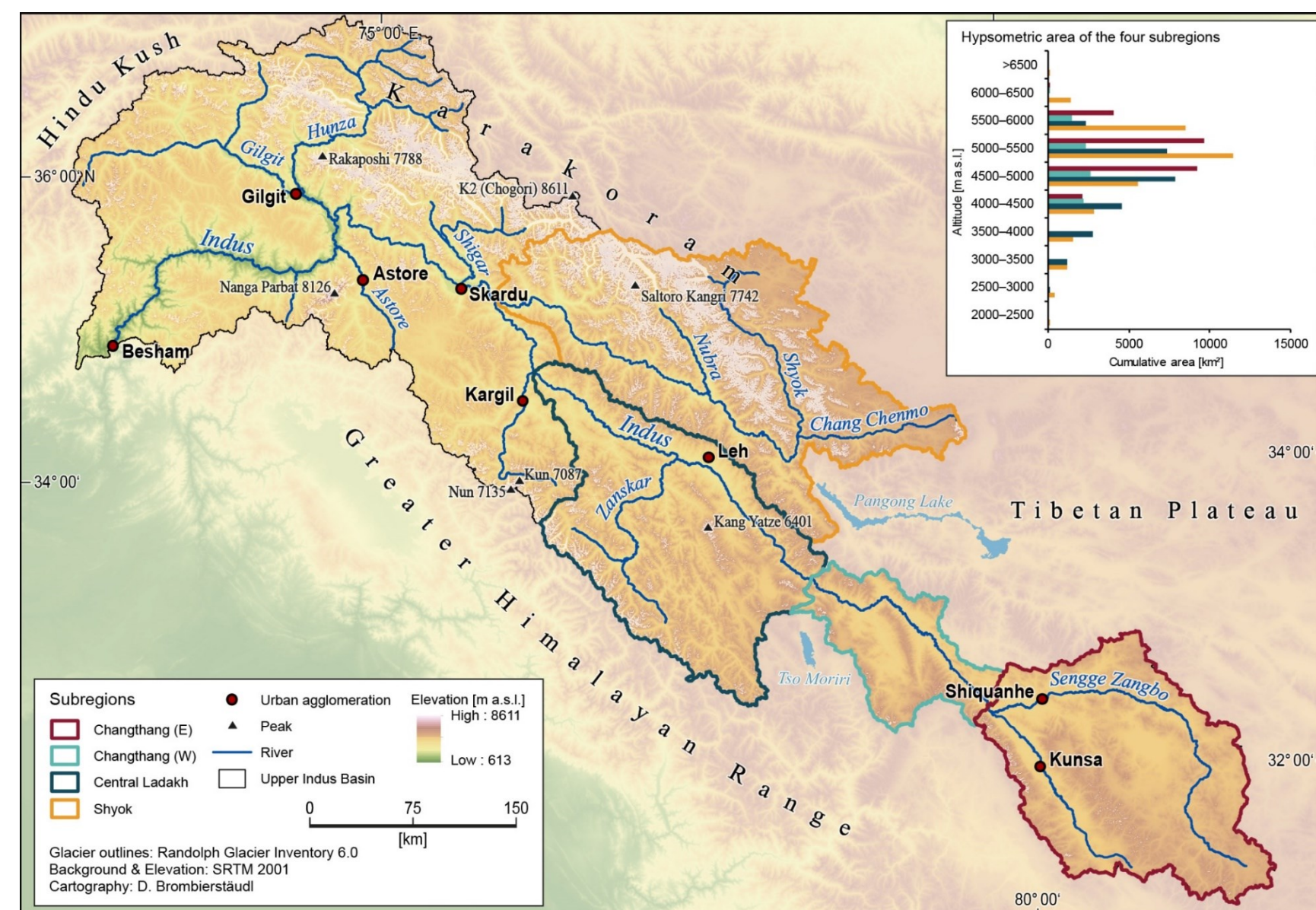
In the semi-arid high mountains of the Upper Indus Basin (UIB), meltwater supply from the cryosphere is vital for irrigated agriculture and hydropower generation. A neglected cryosphere component that might be crucial for local irrigation systems is *aufeis*, which appears as a sheet-like formation of ice layers, created by successive and laminated freezing of flowing water. The process is also a prerequisite for ice reservoirs in Central Ladakh.

This study aims to redress the lack of knowledge about this seasonal phenomenon by creating an inventory of *aufeis* and analysing its spatial distribution, including the role of topographical parameters.



Study area

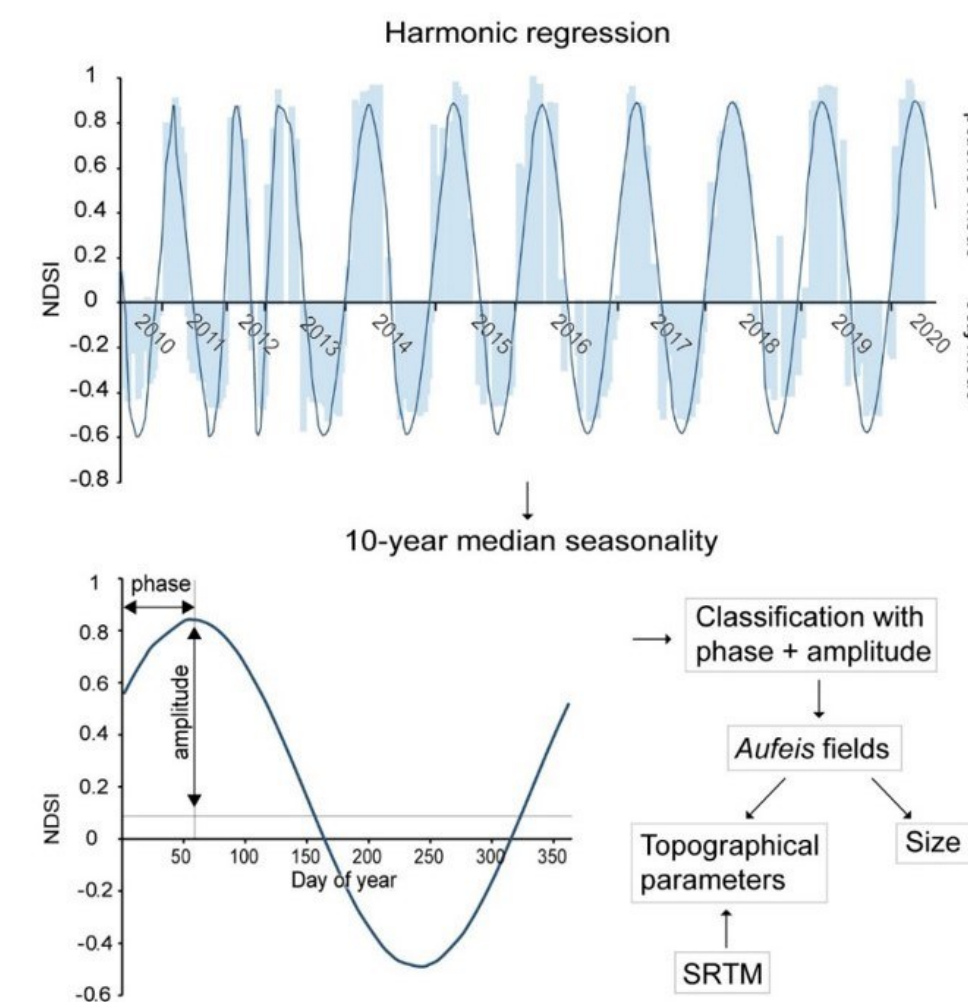
The UIB is a cold-arid high mountain region and expands over an area of 166,000km². Temperature and precipitation decrease from south to north and west to east; elevation increases towards the Tibetan plateau.



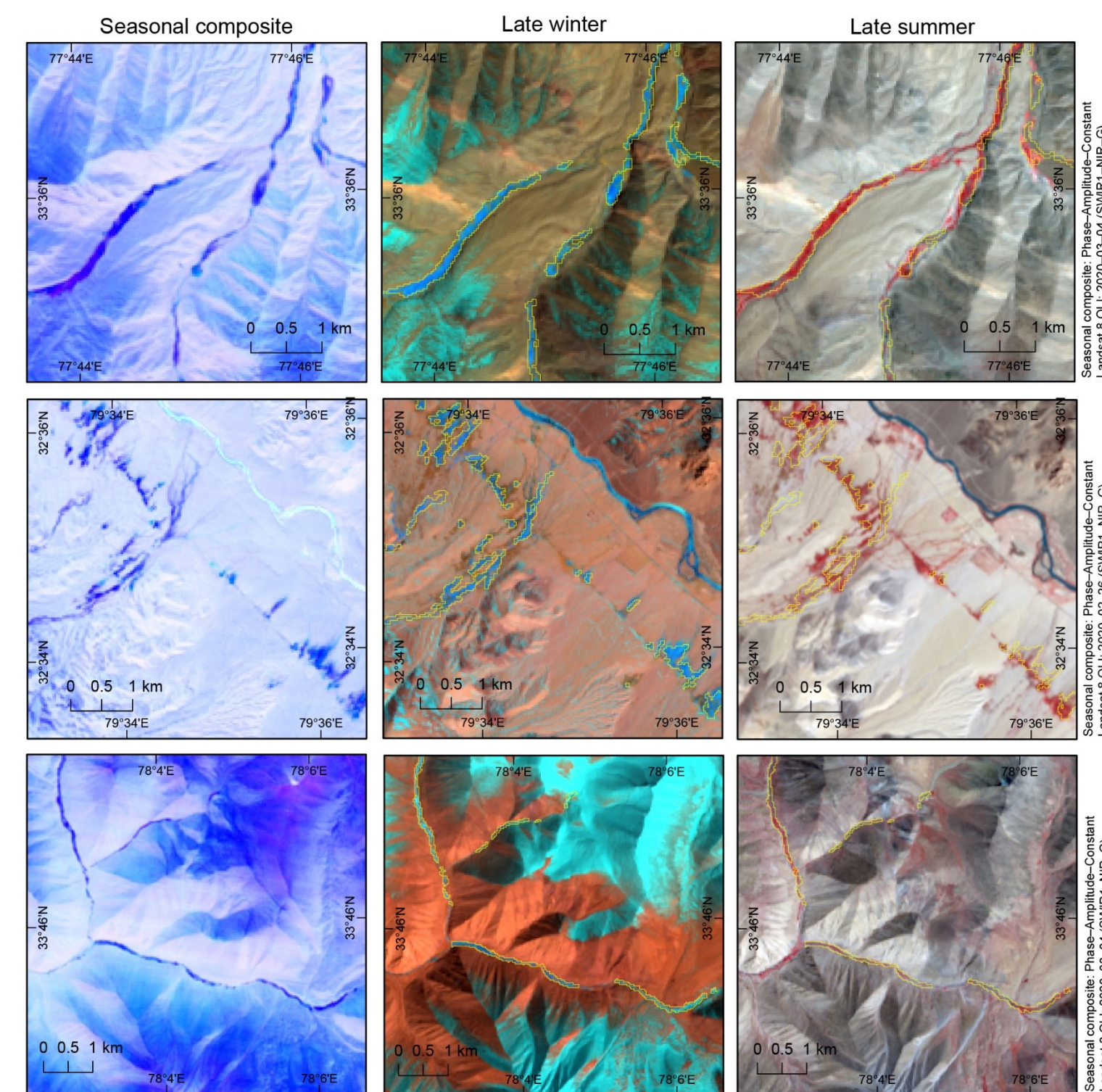
Agriculture is dependent on cryosphere-fed meltwater irrigation systems, which are affected by unreliable water availability. The population has developed sophisticated adaption strategies to cope with the seasonal water scarcity (e.g. ice reservoirs).

Data & Methods

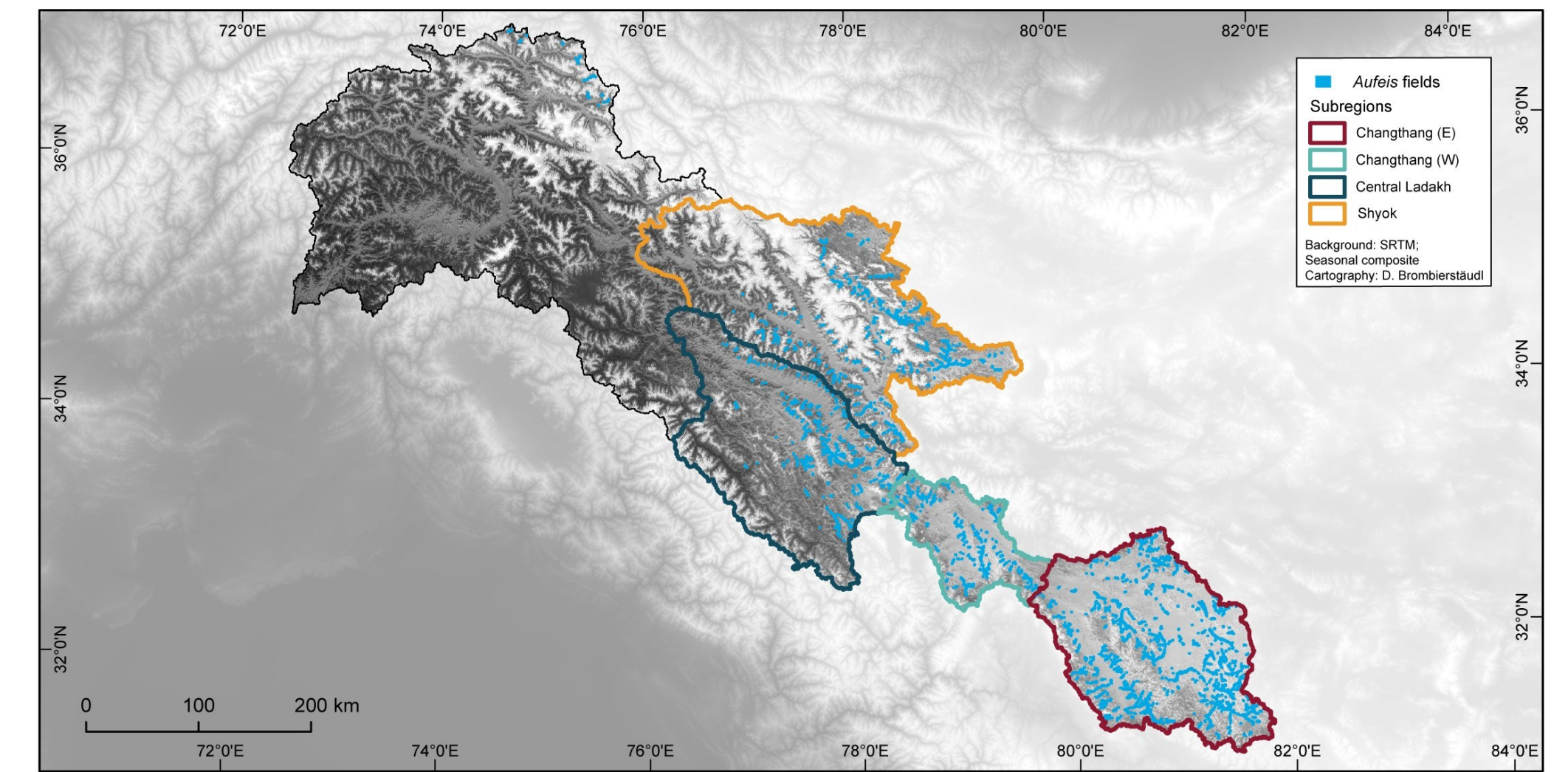
The analysis is based on a Landsat time-series using imagery from 2010 to 2020, supported and validated by several field campaigns carried out between 2014 and 2020. In total, 8274 images covering 22 Landsat tiles over the whole UIB were used and processed with the Google Earth Engine platform.



Aufeis shows distinct seasonal characteristics, therefore a harmonic regression time-series approach with the NDSI as a proxy for ice presence was used to model the seasonal wave. Classification was performed by using a semi-automatic threshold approach based on phase angle and amplitude information.



Results



In total, more than 3700 *aufeis* fields in the whole Upper Indus Basin were detected, covering an area of about 298 ± 38 km². The spatial distribution of their occurrence indicates a distinct elevation range between 4000 and 5500 m a.s.l. and is marked by a pronounced longitudinal increase to the east. Cold-arid conditions seem to facilitate its formation, as its number and size increase towards the Tibetan Plateau.

However, to fully understand the role and importance of *aufeis* in climate-sensitive high mountain regions, more detailed hydro-climatic assessments including studies on permafrost distribution are needed.

