REMOTE SENSING OF SNOW COVER IN THE ALPS - AN OVERVIEW OF OPPORTUNITIES AND CONSTRAINTS

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Introduction

Snow cover dynamics in the alpine region are of great importance for the regional climate, fresh water, hydropower generation, biodiversity, natural disasters, and tourism. The European Alps are a fragile ecosystem, in which snow cover is particularly sensitive to climate change. Thus, monitoring snow dynamics within the Alpine area may not only assist to determine local vulnerability, but also provide a regional assessment of the ongoing climate change.

Challenges for remote sensing in an Alpine environment

Remote sensing techniques face various challenges in mountainous regions: Complex terrain and persistent cloud cover limit the available observations, thus a high temporal resolution of satellite data is desirable. In figure 1, the DLR Global SnowPack is illustrated for the Alps, which is based on daily snow cover information derived from MODIS and AVHRR with a spatial resolution of 500 -1000 m.

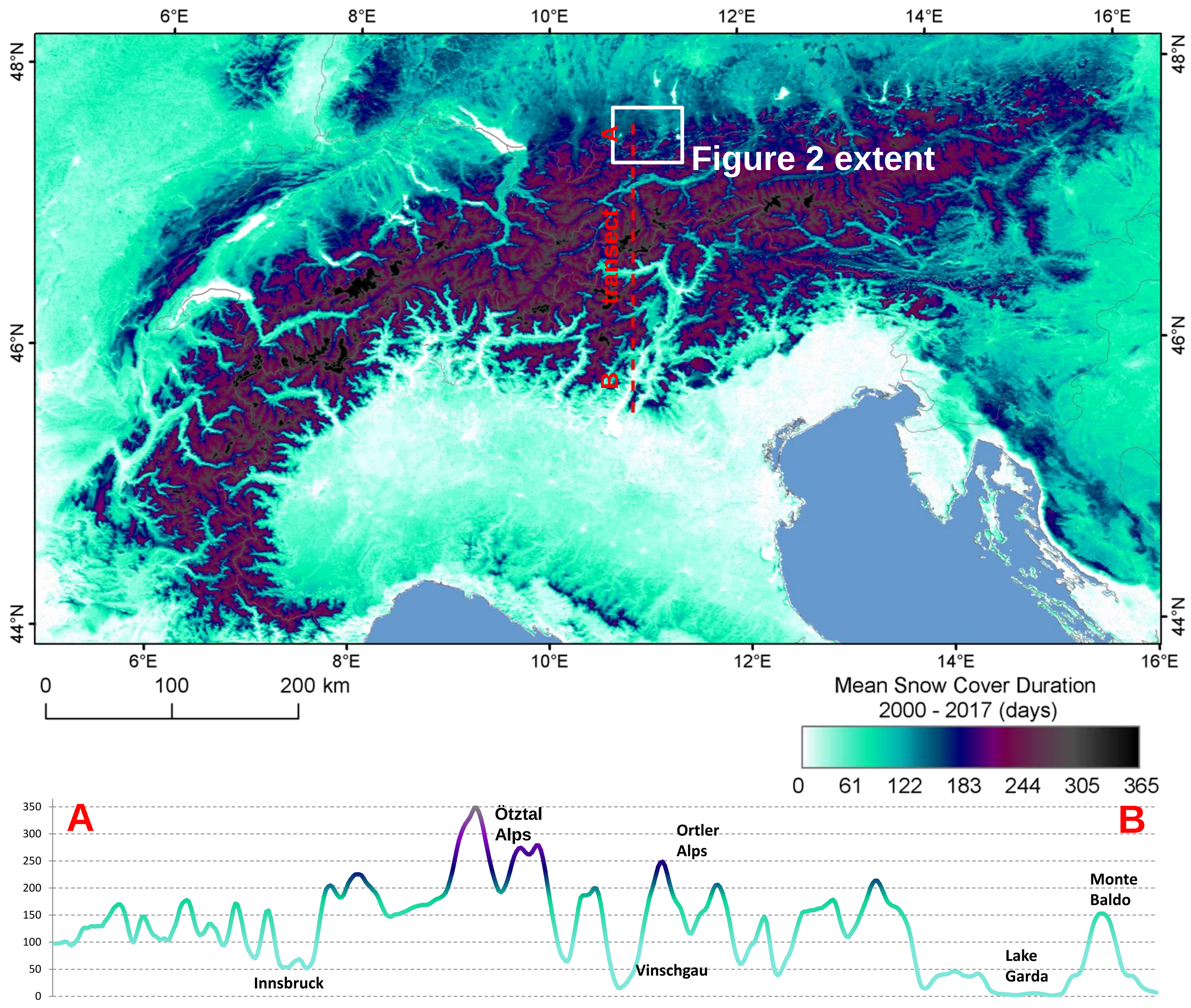

Fig. 1: Mean snow cover duration 2000 – 2017 for the Alps derived from Global SnowPack data and north-south transect through Innsbruck

The complex terrain in the Alps with shadow and mixed pixel effects due to considerable land cover change between narrow elevation zones limits the capability of medium resolution sensors to analyse snow cover developments in the Alps. High resolution Landsat and Sentinel-1 and -2 data can overcome this limitation. Figure 2 depicts the study region containing Innsbruck and Zugspitze (Fig. 2a), the Landsat-based snow cover classification (Fig. 2b), the Sentinel-1-based wet snow extent (Fig. 2c), and the combination of Landsat and Sentinel-1 (Fig. 2d).

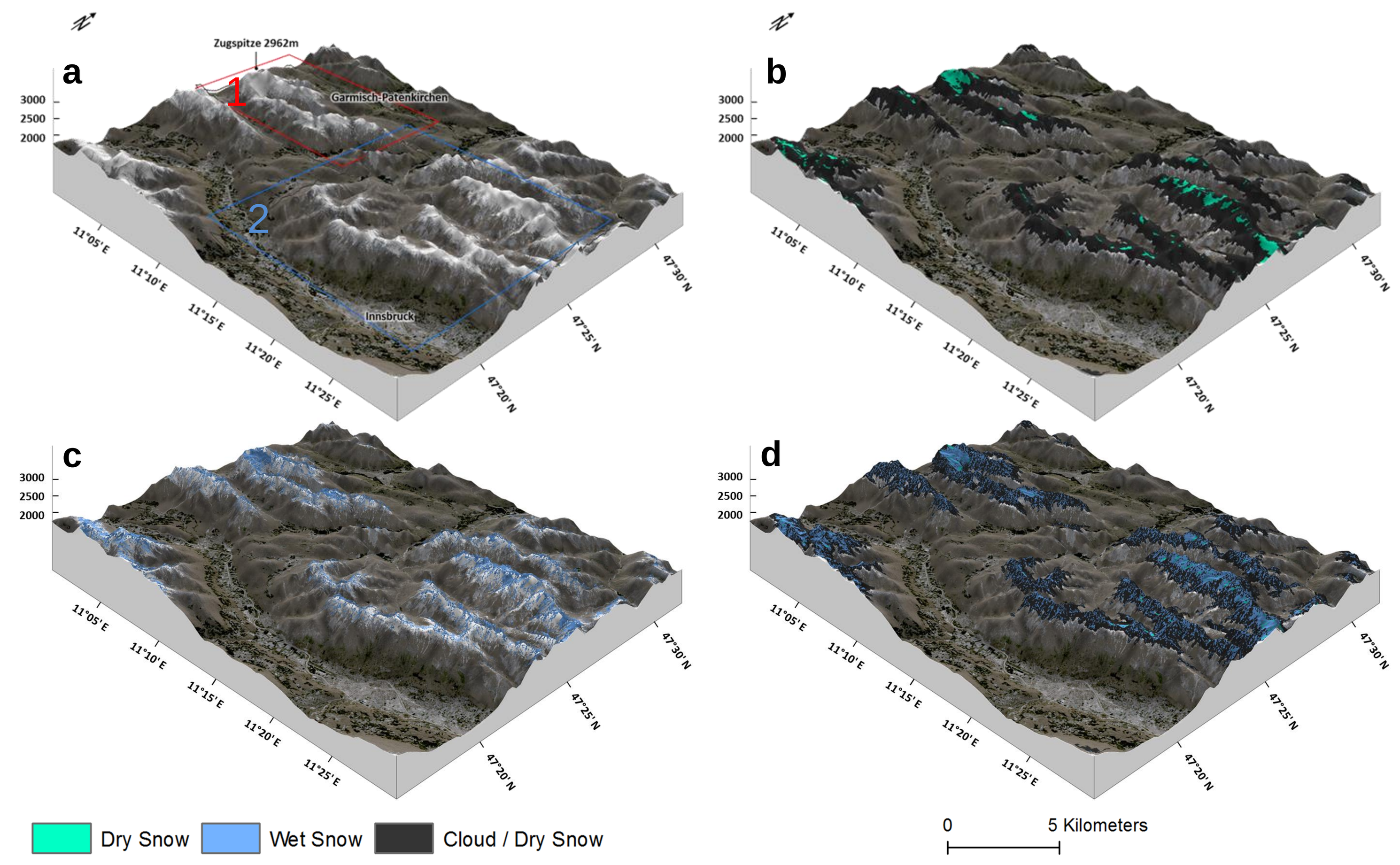

Fig. 2: Study area (a) and Snow Cover Area based on Landsat-8 (b), Sentinel-1 (c) and combination of Landsat and Sentinel-1 (d) for May 17th, 2017 (Landsat) and May 19th (Sentinel)

Snow Line Elevation based on high resolution data

The combination of optical (Landsat, Sentinel-2) and Radar-based (Sentinel-1) snow cover information helps reducing the gaps caused by clouds and the relatively poor temporal resolution. Based on the combined product, parameters such as the regional Snow Line Elevation (SLE) can be derived, which when calculated for several decades can describe the effect of climate change on the snow cover conditions.

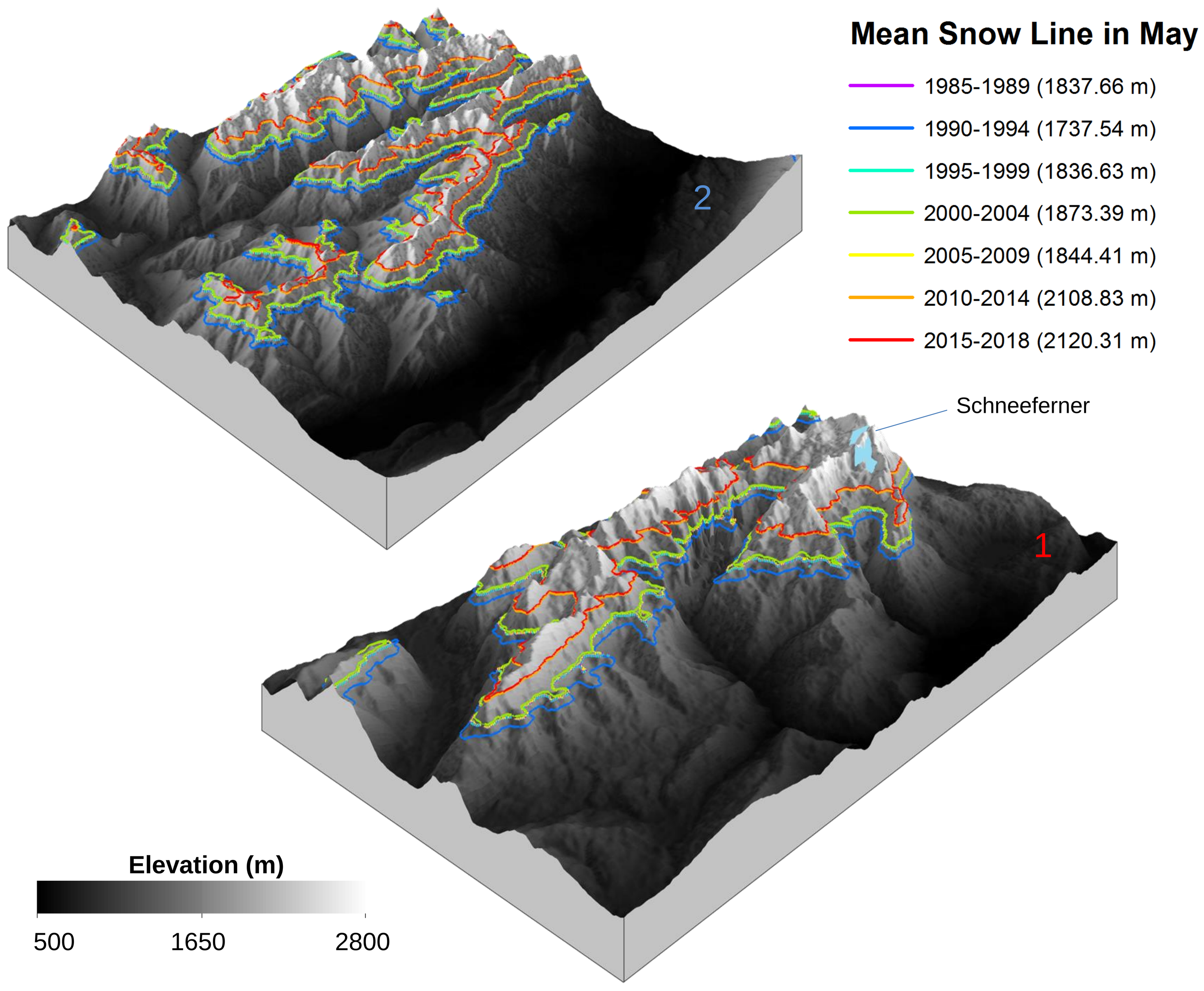

Fig. 3: 5-year Mean Snow Line elevations between 1984 and 2018, details from figure 2a

Discussion and Conclusion

Snow cover in the Alps is changing due to climate change, and in order to quantify this change and the subsequent processes, continuous observation over long time series is necessary. Medium resolution data (500 – 1000 m spatial resolution) is often too coarse to account for the processes occurring in more complex terrain. Higher resolution Landsat or Sentinel data (10 – 30 m) on the other hand lack the temporal resolution which is required to identify possible changes/trends in snow cover duration, onset, or melting of snow. Even though a combination of optical and Radar data from high resolution sensors reduces the data gaps caused by cloud cover, daily information about the snow cover extent and condition is not possible.

It is therefore inevitable to facilitate all available remote sensing data – medium resolution like AVHRR, MODIS, and Sentinel-3, as well as high resolution Landsat, Sentinel-1 and -2 – to address Alpine snow cover. Historical as well as contemporary data need to be processed and analyzed according to up-to-date algorithms and standards to identify possible trends. These trends might have significant influences on future water supply, glacier extents, tourism, natural disasters, and wildlife, and it is of utmost importance to quantify these effects as early as possible.

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