MEASUREMENT AND SIMULATION OF TOPOGRAPHIC EFFECTS ON PASSIVE MICROWAVE REMOTE SENSING OVER MOUNTAIN AREAS: A CASE STUDY FROM TIBETAN PLATEAU

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Introduction

Knowledge about the surface soil water content is essential because it controls surface water dynamics and land-atmosphere interactions. Especially in high mountain areas soil surface water content strongly controls infiltration and flood events. Although, satellite-derived surface soil moisture data from passive microwave sensors are readily available for most regions globally, mountainous areas are often excluded from these data (or at least flagged to be biased) due to the strong topographic influence on the retrieved signal. Even if a wide range of literature is available dealing with topographic effects on retrieved spaceborne brightness temperature no systematic analysis is reported. Therefore, we present a comprehensive analysis of topographic effects on retrieved brightness temperature in C-band using a two step approach. First, a well controlled field experiment was conducted using a mobile truck mounted C-band radiometer to analyze the impact of geometric and adjacent effects on the radiometer signal. Additionally, a comprehensive radio transfer model was developed accounting for both effects and tested on the ground-based data. In a second step, recorded AMSR-E data over the Tibetan Plateau were used to analyze the error associated by the impact of topography using the developed model.

Methodology

In general, mountainous landscapes will influence the brightness temperature (T_B) recorded by any spaceborne microwave sensor (Fig. 1). These so called "relief effects" can be described by geometrical properties and the complexity of terrain within the scene of observation. The topographic geometrical properties are generally composed by slope angles, aspects, altitudes, and zenith angles of the terrain.The complexity of the terrain is related to topographic roughness and the adjacent effect (i.e. the surface scattering radiation of multiple-hills), which can be derived from DEM. Based on the relief effects on microwave radiometry, we present a comprehensive analysis of topographic effects on retrieved brightness temperature in C-band using a two step approach.

◊ A well controlled field experiment in a synthetically hilly landscape was conducted using a mobile truck mounted C-band radiometer to analyze the impact of geometric and adjacent effects on the radiometer signal (Fig. 2). Additionally, a comprehensive radio transfer model was developed accounting for both effects and tested on the ground-based data.

◊ Recorded AMSR-E data over the Tibetan Plateau were used to analyze the errors of observed T_B and soil moisture retreival associated by the impact of topography using the developed model.

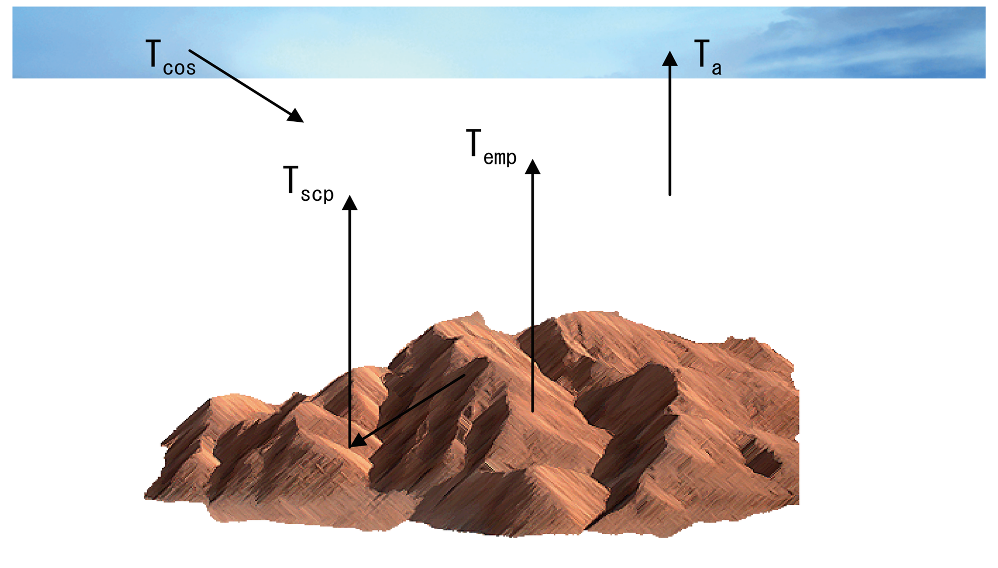
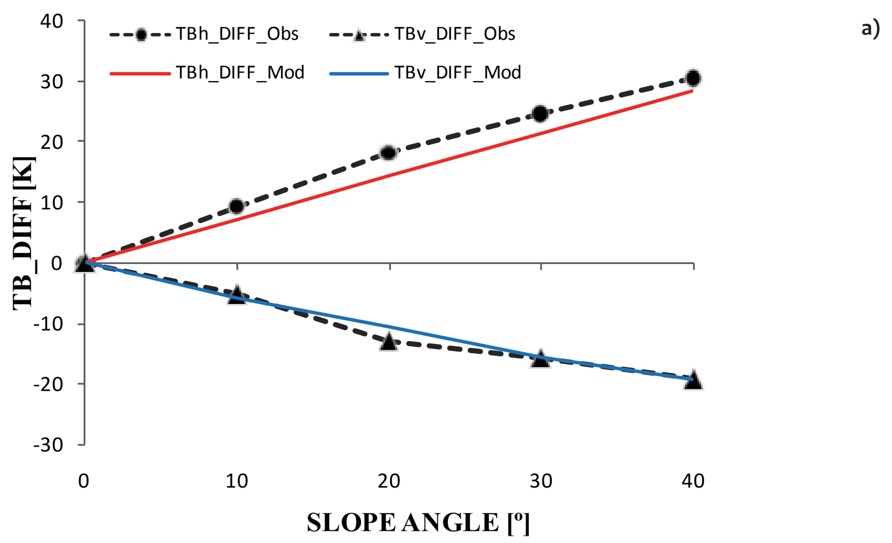


Fig.1. Components of the microwave radiation transfer over mountain areas with T_{cos} as the cosmic background radiation; T_{psc} scattered surface radiation, T_{pem} as the p-polarized emitted brightness temperature of the hemispheric halfspace, and T_a as the radiation from the upper to the lower halfspace.

Fig. 2. Two constructed conical hills perpendicular to the radiometer (slope angle of 40°) within the 4 m2 footprint of the TMMR. The visible footprint for TMMR is 1.5 x 1.5 m covered by one hill (left one), and the other hill (right one) stands out of the view to observe the adjacent effect on the visual field.

Results



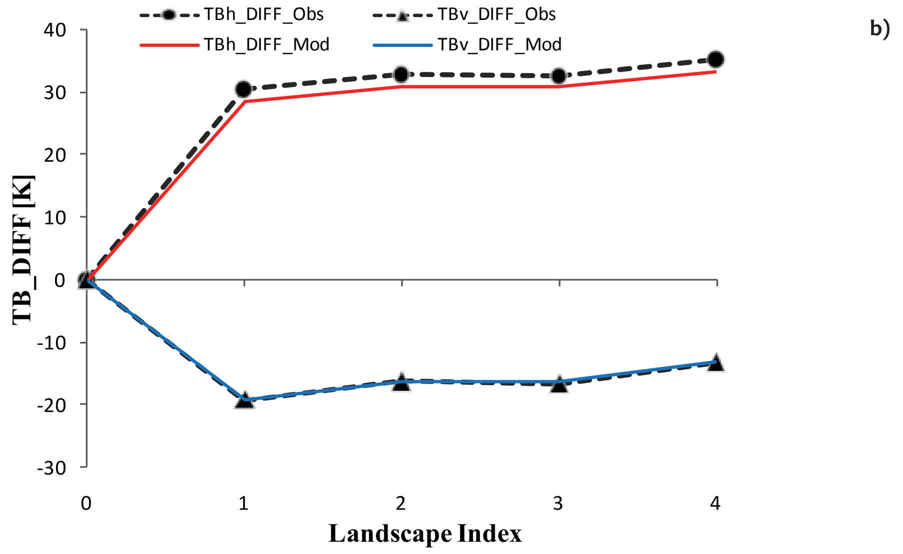
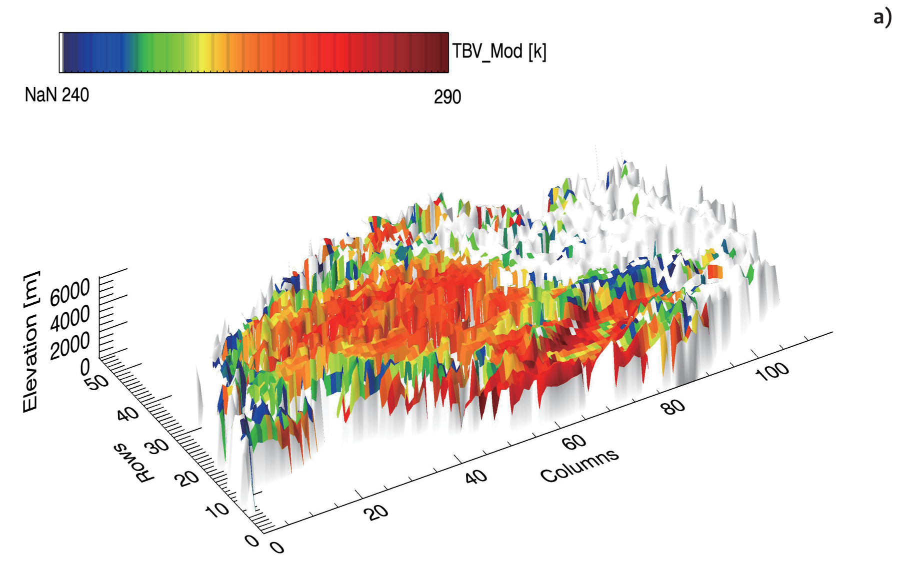


Fig. 3 The comparison of experimental measurements and simulation results. a) Observed geometry effect ($T_{B\_DIFF} = T_{B\_HILL} - T_{B\_FLAT}$) on single hills with different slopes (10 to 40°) at horizontal (T_{Bh_DIFF}) and vertical (T_{Bv_DIFF}) polarization; b) Observation of the adjacent effect ($T_{B\_DIFF} = T_{B\_MULT} - T_{B\_SINGLE}$) over various terrain scenes ranging from flat terrain (landscape index = 0), single hill (= 1), hills in a row perpendicular to the radiometer (= 2), hills in a row parallel to the radiometer (= 3), and hills within a triangle (= 4), and the slope angle for all hills was 40°.



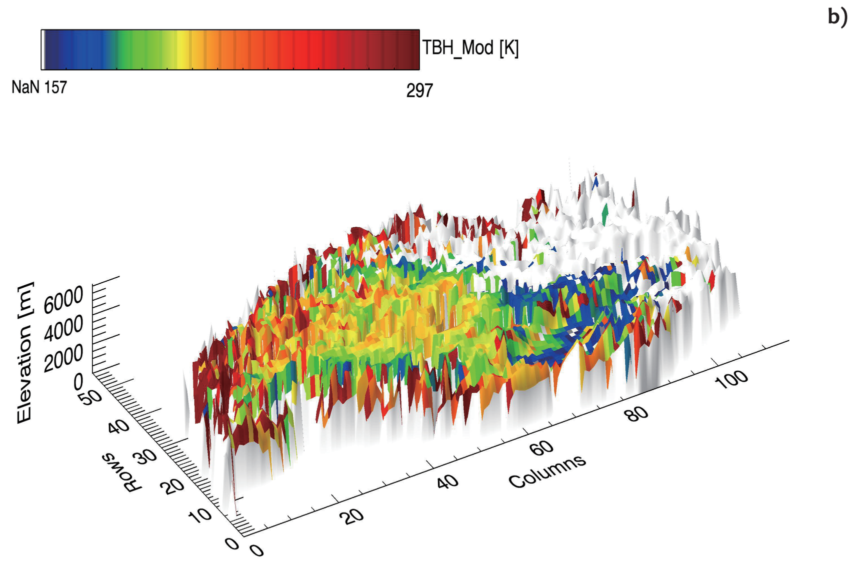
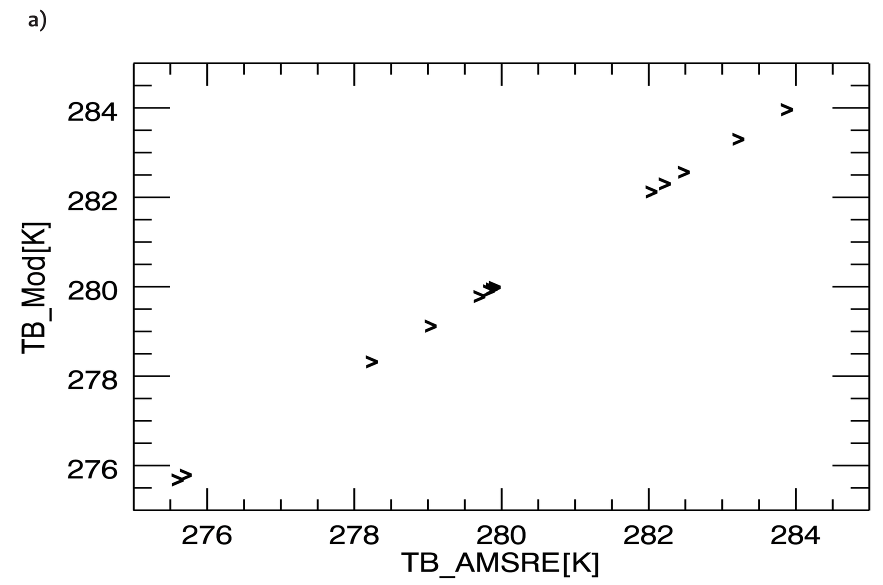


Fig. 4 Simulated brightness temperature at C-band for the Tibetan Plateau.



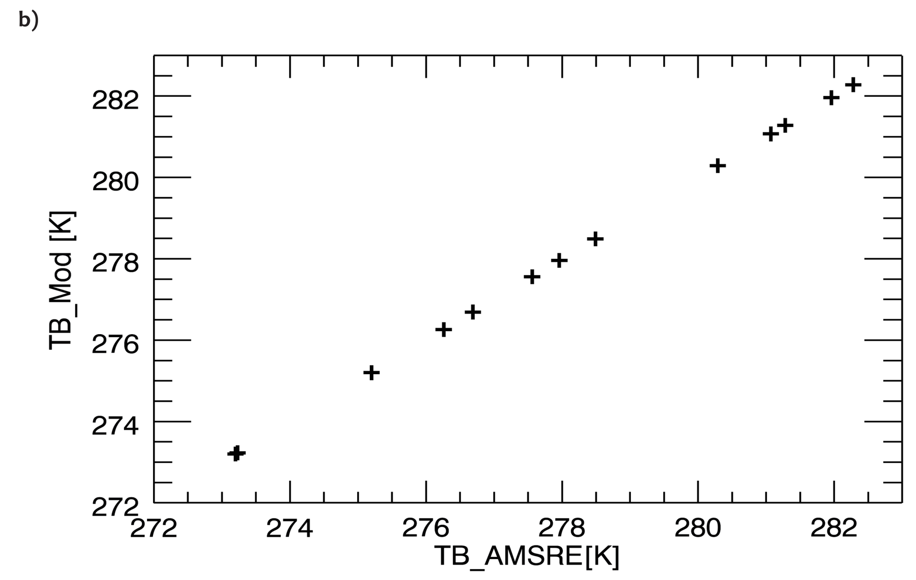
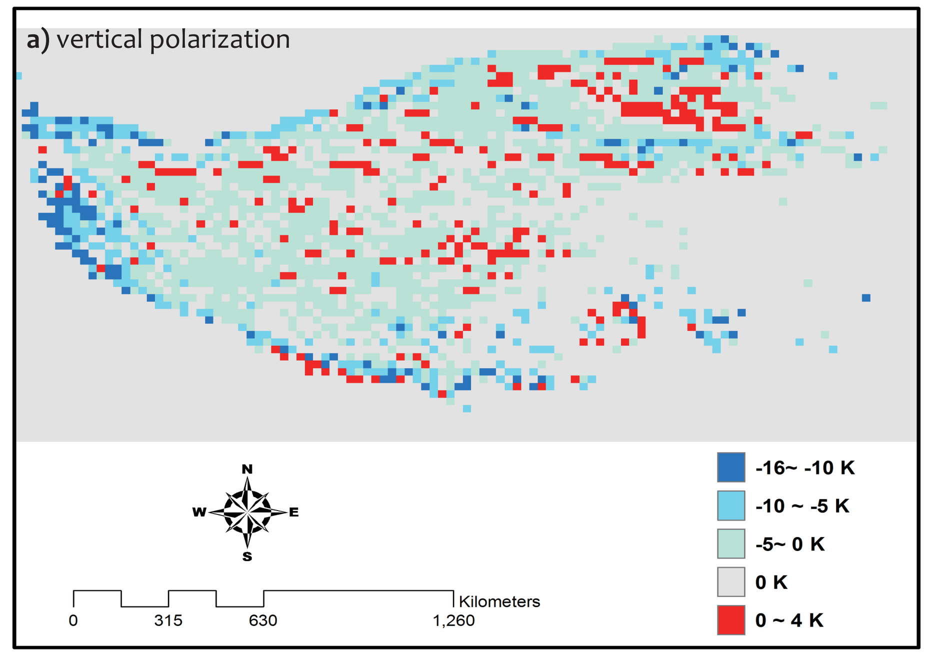


Fig. 5 Comparison between selected simulated and AMSR-E measured brightness temperatures (TB) over uncovered pixels with slopes >20° for a) vertical polarization (R^2 = 0.99, RMSE = 0.8 K) and b) horizontal polarization (R^2 = 0.99, RMSE = 0.6 K).



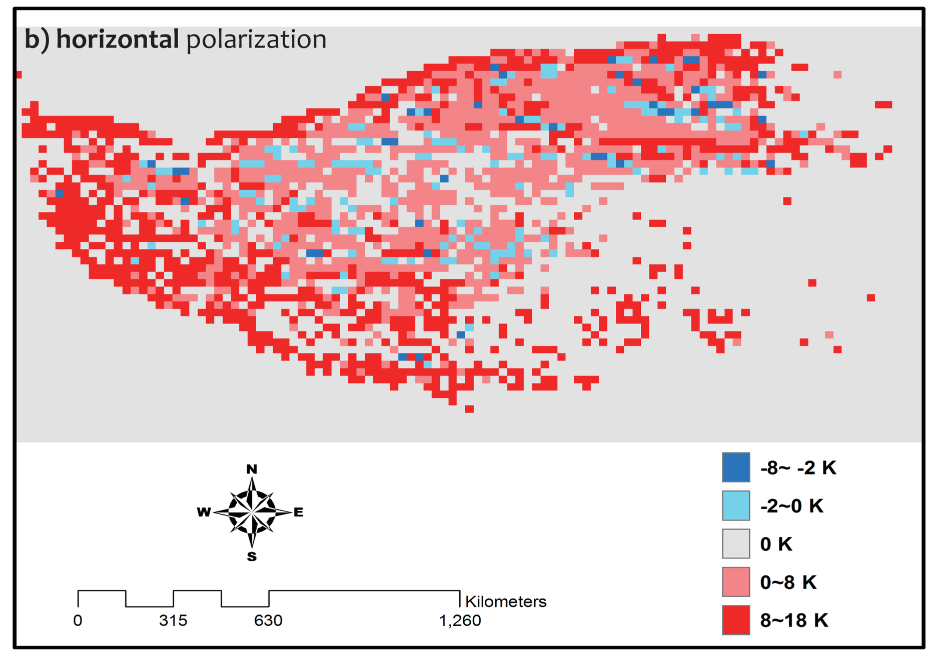


Fig. 6 Brightness temperature difference ΔTB between TB_relief and the flat reference TB_flat.

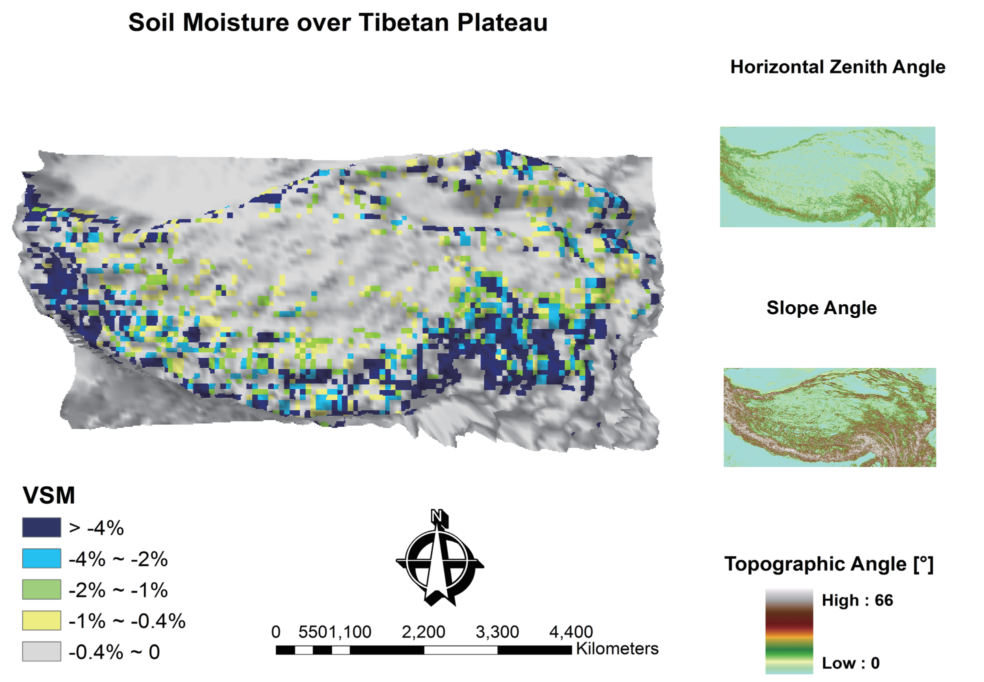


Fig. 7. Soil moisture difference (Mv_relief-Mv_flat) over Tibetan Plateau in volume % (VSM) with additional information about horizontal zenith angle, and slope angles computed from DEM.

Conclusions

In our study, we present a comprehensive but easy simulation approach accounting for topographic effects for radiometer measurements at C-band.In conclusion, we show that recorded spaceborne brightness temperatures are highly biased by topographic effects in mountainous regions using a comprehensive radio transfer model. Additionally, we suggest using this model in inversion mode for standard processing of higher level data products such as surface soil moisture.