TOPOGRAPHIC EFFECTS ON SPACEBORNE RADIOMETRIC OBSERVATIONS AND POSSIBLE CORRECTION STRATEGIES

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1. INTRODUCTION

Microwave radiometry of land should carefully account for large-scale relief effects, when applied to hilly or mountainous areas. Variations in topography influence the upwelling brightness temperature (T_B) measured by a satellite radiometer in several ways. The optical depth of the atmosphere is modified, the radiometer observation angle becomes a function of the surface slope, parts of the scene may be shadowed, radiation can be reflected from one tilted surface to another and a depolarization effect occurs.

The effects listed above should be accounted for and, possibly, corrected or at least mitigated in order to remotely sensing bio-geophysical parameters, such as soil moisture. Indeed, algorithms for retrieving soil moisture assume a flat topography.

In previous studies, we developed a simulator of satellite microwave radiometric observations of mountainous scenes, able to operate at different frequencies and observation angles. This simulator allowed us to carry out an analysis aiming at quantifying the errors in satellite microwave radiometric imaging of a terrain with a complex relief. Two radiometer configurations, both characterized by a conical scan, were assumed. For the first one, we took as reference the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), supposing a sensor observing the Earth at 55° from an altitude of 705 Km. For the second configuration, we considered an instrument operating at L-band, with an observation angle of 40° and orbiting at 670 km of altitude, similar to that conceived for the radiometer aboard the future Soil Moisture Active-Passive (SMAP) mission.

In this work we aim at modeling the errors induced by relief in order to yield an approach to correct them, or, at least, to account for the topography effects in an error budget when retrieving soil moisture or correcting the surface background. To do this, the trends of the difference between the antenna temperature calculated for a mountainous scene and that computed for a flat terrain versus parameters representing the topography, such as local observation angle, slope and height standard deviation are analyzed. From this analysis, an attempt to establish a relationship between the T_B variations due to relief and the parameters mentioned above is performed.

2. THE SIMULATOR

The numerical simulation of a radiometric observation of a mountainous area is based on the following formula, which expresses the P-polarized upwelling T_B (T_{BP}), where P may be H (horizontal) or V (vertical), measured by a satellite radiometer as:

$$T_{BP} = (T_{emP} + T_{scP})t + T_{UP} \tag{1}$$

where T_{emP} is the emitted component, t is the atmospheric transmittance, T_{UP} is the atmospheric upwelling radiation, and T_{scP} is the downwelling radiation scattered by the considered surface. The atmospheric radiative parameters have been derived from ECMWF data acquired throughout year 2000. An average of the data relative to clear sky has been performed for this purpose.

As for the emitted component, it has been modeled as done in [1] by exploiting the emissivity model proposed by the investigation of Wang et al. [2] and the soil permittivity model by Dobson et al. [3]. As far as the scattered component of the downwelling radiation is concerned, it has been assumed as the sum of a coherent component and an incoherent diffuse component. The former depends on the specular reflectivity of the surface, the latter depends on the cosine of the scattering zenith angle and is proportional to the irradiance incident on the surface. To discriminate between the irradiance due to the elevated terrain and sky radiation, as well as to determine the horizon of every DEM facet, a procedure based on a sort of ray-tracing algorithm has been implemented [4].

The simulator assumes as inputs a digital elevation model (DEM), the soil parameters (moisture, roughness, temperature, composition) and the instrument parameters (frequency, observation angle). In addition the atmospheric radiative quantities (mean radiative temperatures and transmittance) are used. For each DEM element it firstly computes, the local incidence angle, the rotation of the polarization plane, the emissivity. The number of DEM facet elements included in the antenna IFOV is determined too [1]. Successively, the simulator calculates the horizon of every facet, the specular direction with respect to the observation one and the radiation coming from specular direction (from sky, or from another facet of the terrain). Finally, it integrates the radiation coming from below the horizon and from the sky, thus deriving the diffuse component of the scattered signal [4].

3. THE RELIEF EFFECTS

To quantify and possibly mitigate the relief effects, we have focused our analysis on a mountainous area in the Alps (Northern Italy) and we have derived the topography from a DEM of Italy having a spatial resolution of 250×250 m. We make reference to two the quantity $T_P - T_{P\_flat}$, which is the difference between the brightness temperature calculated by applying our simulator and that computed for a flat terrain (having the same roughness, moisture and composition) located at an altitude equal to the average of the heights of the DEM facets within the antenna IFOV. $T_P-T_{P\_flat}$ permits the evaluation of the topographic effects at sub-pixel scale on spaceborne radiometric observations.

Plots of $T_P-T_{P\_flat}$ have been produced as function of the parameters representing the topography. These plots are expected to give indications on the way to correct the influence of the relief on the observations of microwave radiometers. Preliminary results seem to indicate that $T_H-T_{H\_flat}$ is correlated to the average value of the slope angle within the antenna IFOV and to the standard deviation of the local incidence angle (θ_l). $T_V-T_{V\_flat}$ is correlated to the standard deviation of the aspect angle (ϕ) within the antenna IFOV. Fig. 1 shows a plot of $T_H-T_{H\_flat}$ versus θ_l, while fig. 2 shows a plot of $T_V-T_{V\_flat}$ versus ϕ.

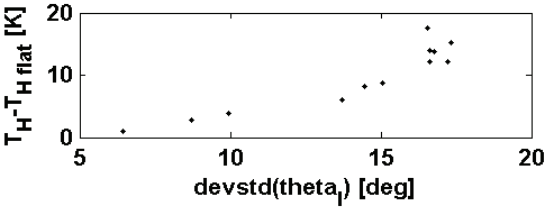

Fig. 1 $T_H-T_{H\_flat}$ versus θ_l for a terrain with terrain with volumetric moisture equal to 0.25, standard deviation of the surface height equal to 0.73 cm and dry soil density equal to1.3 g/m^3. The fractions of sand and clay have been assumed equal to 32% and 25%, respectively, and the soil temperature has been supposed 296 K.

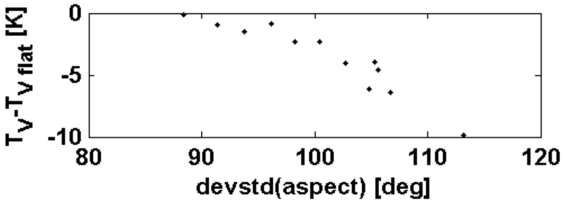

Fig. 2 $T_V-T_{V\_flat}$ versus θ_l (volumetric moisture: 0.25; standard deviation of the surface height: 0.73 cm; dry soil density:1.3 g/m^3; sand: 32%; clay: 25%; soil temperature: 296 K).

4. REFERENCES

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