A METHOD TO ESTIMATE SNOW WATER EQUIVELANT USING MULTI-ANGLE X-BAND RADAR OBSERVATIONS

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1. INTRODUCTION

High-resolution mapping of seasonal snow is greatly needed for modelling and validating surface to atmosphere exchange processes, climate research, and hydrological applications. Active microwave sensors, especially high-frequency radar systems, are highly sensitive to snow pack parameters, including Snow Water Equivalent (SWE). Active microwave remote sensing has become one of the most promising techniques to accurately monitor snow properties from regional to global scales. The optimum sensor parameters for SWE retrieval problem might be a combination of Ku and X-band frequencies, which have different penetration depths and sensitivities to snow properties, such as crystal size. Currently, there is a lack of Ku-band space-borne SAR system, however, it is still very interesting to make fully use of the available X-band space-borne SAR systems and develop relevant SWE inversion algorithms. Among the in-orbit satellites, the COSMO-SkyMed (Constellation of Small Satellites for Mediterranean basin observation), which consists of a constellation of four Low Earth Orbit mid-sized satellites, each equipped with a multi-mode high-resolution Synthetic Aperture Radar (SAR) operating at X-band, is capable of providing at least two opportunities in one day to access the same target site on the Earth under different incidence angles. In the following, a SWE inversion algorithm is developed for COSMO-SKymed, by availing of its fast revisit and variant incidence angles.

2. ESTIMATION OF SURFACE ROUGHNESS

To estimate SWE, the first step is to separate the contributions from soil and snow pack. The backscatter of soil surface can be well described by the AIEM model. However, besides the sensor configurations, such as frequency and incident angle, AIEM also requires multiple parameters to describe the soil surface, which are RMS height, correlation length, correlation function and soil dielectric value. It is desirable to develop a simple but accurate surface scattering model with minimum inputs based on COSMO-Skymed configurations. In order to develop such a model, AIEM was first used to generate a surface backscattering database that covers a wide range of soil moisture and surface roughness properties. Through analyzing the simulated backscattering data at different incident angles, it was found that the ratio of the square of the RMS height (s) and the correlation length (l) can be used to represent the effects of surface roughness. Therefore, we have one single parameter to describe surface roughness, namely A, and the radar backscattering signals from bare soil can be simply written as the product of A and Fresnel reflectivity at *p* polarization (V or H polarization) R_p as equation (1).

$$\sigma_{pp\_soil}{}^{0} = A(\theta, \text{roughness}) \cdot R_p(\theta) \tag{1}$$

Assuming that there is no vegetation and the soil conditions remain little changed for two observations from COSMO-Skymed before the snow season, both A and R can be directly calculated. By further assuming the surface roughness does not change during the snow season, the estimated A parameter can be used as a known variable in the SWE inversion problem.

3. PARAMETERIZED SNOW SCATTERING MODEL

Similar to surface scattering problem, the signals directly from snow are governed by a set of snow parameters, such as snow density, scatterer size, and depth. For inversion problems, we developed a parameterized snow scattering model for the multiple-angle X-band observations of COSMO-Skymed based on the analysis of snow scattering database, which was generated by using a high-order snow theoretical model [1-2]. The parameterized model can account for the multiple scattering effects inside snow layer at X-band radar observations and has a simple form similar to first-order radiative transfer model. The parameterization was carried out through regression techniques for snow volume scattering, ground scattering attenuated by snow and snow-ground interactions, respectively. The volume scattering component, for example, can be simply written as (2), where m1 to m5 are regression coefficients, ω is the scattering albedo and τ is the snow optical thickness.

$$\begin{aligned} \sigma_{v\_pp} &= C_v \cdot 0.75 \cdot T_{pp}^2 \cdot \omega \cdot \mu \left[1 - \exp(-2\tau / \mu)\right] \\ C_{v\_pp} &= m_1 + \exp(-\tau) \cdot m_2 \\ \log(\sigma_{v\_pq}) &= m_3 \cdot \exp(\log(\sigma_{v\_pp}) / m_4) - m_5 \end{aligned} \quad (2)$$

4. SWE INVERSION TECHNIQUE FOR COSMO-SKYMED

The SWE inversion technique is developed for COSMO-Skymed, based on its multi-temporal observations and the parameterized models developed in the previous sections. Figure 1 shows the characteristics of COSMO-Skymed overpass over a selected region (rectangle area) under SCANSAR mode. From 22:29 to 23:17 local time of Dec. 12, 2009, there are at least two observations available for the selected region, with different incidence angles. Assuming that the soil dielectric properties do not change significantly during the two adjacent observations, we have three unknown variable to be solved: soil moisture, snow optical thickness and scattering albedo to be solved. Similarly, we can acquire anther two observations for the selected region in the following day. If there is no significant precipitation during the four observations, we can further assume a stable snow conditions. Therefore, the optical thickness, scattering albeo as well as two soil moisture values of the consecutive days can be solved directly from the four single-polarization observations of COSMO-Skymed operated at SCANSCAR mode. Finally, SWE can be obtained through snow absorption optical thickness, which is linearly related to SWE and can be calculated by the total optical thickness and scattering albedo. The algorithm has been validated using a simulated database generated for COSMO-Skymed using the theoretical model, with the observation noise considered. The retrieval accuracy is acceptable, especially for the thick snow.

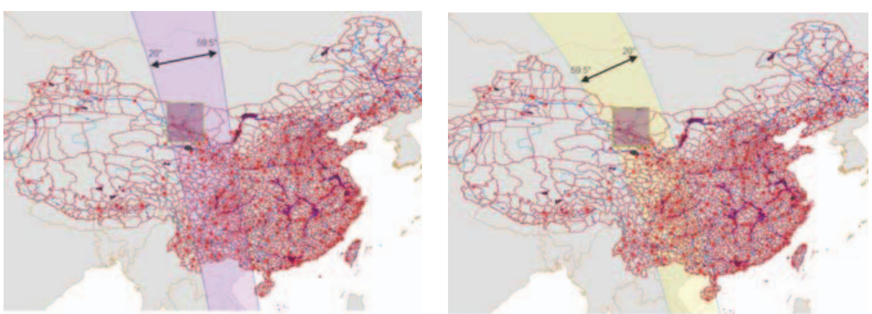

Fig. 1 The characteristics of COSMO-Skymed overpass over Heihe Watershed (rectangle area)
(Left: overpass of COSMO-Skymed1 over the selected area at 23:17, Dec.12,2002; Right: overpass of COSMO-Skymed2 over the selected area at 22:29, Dec.12,2002;)

5. REFERENCES

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