ESTIMATING HI-RESOLUTION SOIL MOISTURE DATA USING THE *HP* MODEL COUPLED WITH LANDSAT-8 AND SMAP DATASETS

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1. Introduction

Soil moisture for fragile wetland ecosystem is very significant. Knowing the moisture, one can better understand the wetland and protect it better. The traditional manual measurement of soil moisture (e.g., the tensiometer method) is time-consuming and arduous. It cannot provide the timely information of the large region.

The Soil Moisture Active and Passive (SMAP) project is a wide-swath L-band soil moisture mission that estimate soil moisture over a wide range of vegetation conditions and at fine spatial resolution. Unfortunately, the radar of the SMAP mission malfunctioned shortly after the operation of SMAP in space. Even though the microwave radiometer still works, the soil moisture data at fine resolution become unavailable. Coupled with available data from operational satellite sensors (e.g., the Landsat-8), the soil moisture data can be derived. Thus, the goal of this study is to assess the accessibility of the model for soil moistures estimation with the Landsat and SMAP L-band radiometer datasets, paving path for the estimation at fine spatial resolution.

2. Study Area and Datasets

The Zoige wetland, China is roughly within 101º45' E and 103º25' E in longitudes, and 32º10' N and 34º10' N in latitudes. The region has frigid continental monsoon climate due to its high altitude.

Landsat 8 data of Zoige alpine wetland acquired on 2 November 2015 are downloaded. Then, a subimage of 90km (high) by 135km (wide) is extracted and used as the study area. The spatial resolution of the Landsat 8 data is 30m × 30m for multispectral bands. The SMAP brightness temperature of the same day are downloaded. The soil moisture data downloaded from NASA at https://search.earthdata.nasa.gov/search have the spatial resolution of 9 km ×9 km. Since there are no in situ soil moisture or soil moisture data in fine resolution, soil moisture data at 9 km by 9 km is modeled for the purpose of the accuracy assessment.

3. METHODOLOGY

When the central frequency of a radar system is low (e.g., L-band), the *HP* model can be simplified as [1]

$$R_p = H_P \cdot r_p \tag{1}$$

where H_p is the surface roughness coefficient. R_p is surface effective reflectivity. Subscript p stands for the polarization of the model. The Fresnel reflectivity r_p in different polarization can be expressed as

$$r_h = \left| \frac{\cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \right|^2 \tag{2}$$

$$r_v = \left| \frac{\varepsilon \cdot \cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\varepsilon \cdot \cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \right|^2 \tag{3}$$

where θ stands for the radar incidence. ε is the soil dielectric constant. With the simulated ε [2], r_p in different polarization also can be expressed as

$$r_h = r_v^A \tag{4}$$

where A is unknown. Combining (1) and (4), one can obtain

$$\frac{R_v^A}{R_h} = \frac{H_v^A}{H_h} \tag{5}$$

And name is as $H_{index} = \frac{H_v^A}{H_h}$. The relationship of H_v, H_h, and H_{index} can be expressed as [2]

$$f(H_{index}) = \left(\frac{R_v}{r_v}\right)^B - \left(\frac{R_h}{r_h}\right)^C \tag{6}$$

R_v and R_h can be obtained from the ratio of the brightness temperature and land surface temperature. The surface temperature comes from Landsat-8 TIRS data that have the spatial resolution of 100m × 100m.

The soil moisture can be affected by the surface vegetation cover. One way to remove the influence is to use the normalized difference vegetation index (NDVI) data. The mean NDVI value derived from Landsat-8 TIRS data in the study area is 0.1 or less. Thus, the vegetation influence on the soil moisture estimation is ignored. The soil moisture of bare soil is considered. Using the Hallikainen model, one can express ε as [3]

$$\varepsilon = \left(a_0 + a_1 \cdot S_s + a_2 \cdot C_c\right) + \left(b_0 + b_1 \cdot S_s + b_2 \cdot C_c\right) \cdot m_v + \left(c_0 + c_1 \cdot S_s + c_2 \cdot C_c\right) \cdot m_v^2 \tag{7}$$

where a_i, *bi*, and *ci* (i=0, 1, 2) are constants. According to the Harmonized World Soil Database (HWSD) v1.1 (http://westdc.westgis.ac.cn), sand content, S_s and clay content, C_c, are set as 0.74 and 0.1, respectively.

4. Results

4.1 Model parameterization

Using the SMAP satellite parameters, intervals of surface roughness parameters, and soil dielectric constant [2], we simulate the relationship between r_v and r_h . Figure 1 shows the relationship. Then, A is estimated as 0.5889, and (6) becomes

$$\left(\frac{R_v}{r_v}\right)^{0.4} - \left(\frac{R_h}{r_h}\right)^{0.8} = 0.8643 H_{index}^{\ 3} - 4.062 H_{index}^{\ 2} + 6.541 H_{index} - 3.359 \tag{8}$$

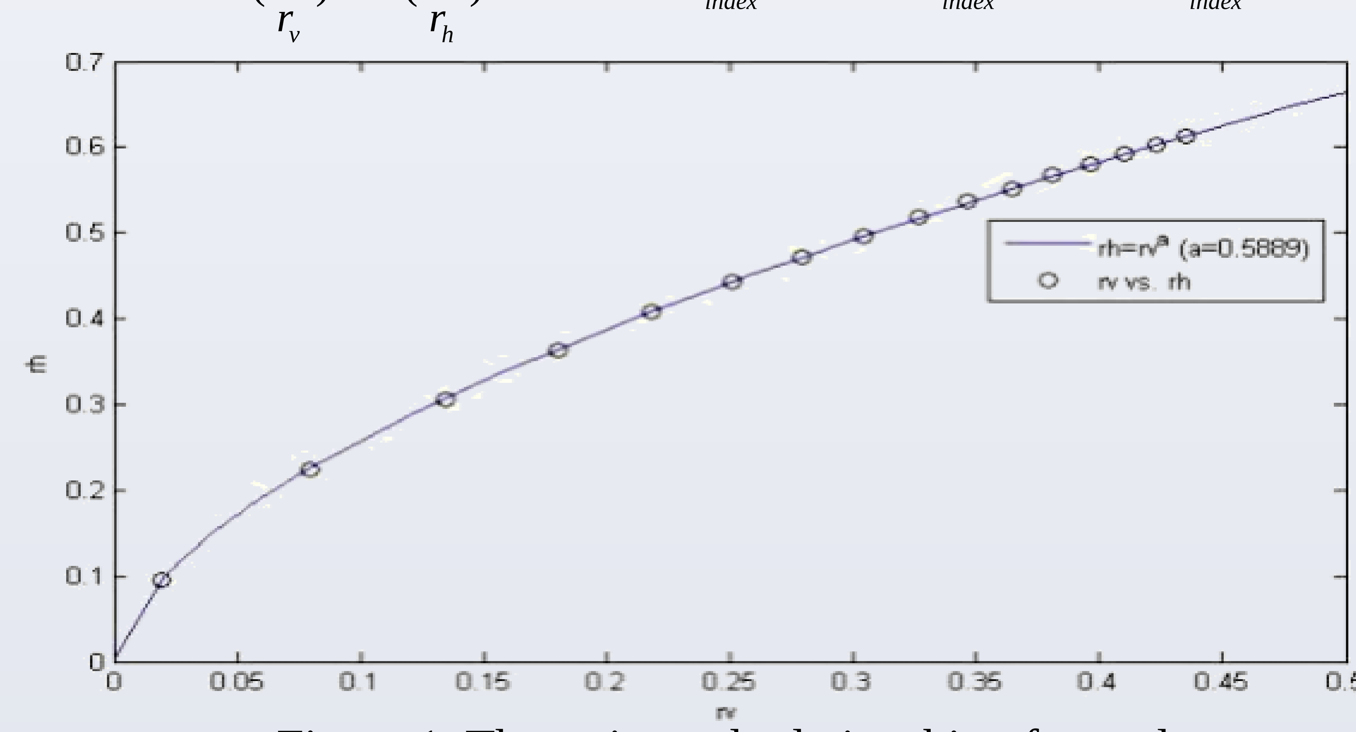

Figure 1. The estimated relationship of r_h and r_v.

4.2 Estimated soil moisture data

Figure 2a was the modeled volumetric soil moisture content of the study area. The content varied from 0.0567 to 0.4108. Figure 2b showed the extracted soil moisture data(https://search.earthdata.nasa.gov/search). In comparison, the spatial patterns might be similar. The maximum value of each dataset occurred near the center, but the minimum value in the eastern region. Quantitatively, the spatial correlation coefficient of both images was 0.8287 (n = 150). The mean value of the absolute difference of both datasets was 0.0349. The result should be satisfactory. Thus, coupled with high resolution optical data, the developed method should be theoretically feasible to model the soil moisture data at fine spatial resolution.

Figure 2. (a) Modeled soil moisture data at the study area, and (b) soil moisture data extracted from US/NASA dataset.

5. Conclusion

The soil moisture data of Zoige alpine wetland, China were obtained by using the HP model coupled with SMAP radiometer and Landsat-8 datasets. To simplify the estimation procedure, the vegetation impact on the soil moisture was ignored. Thus, the late fall season (e.g., November of 2015) was chosen. In comparison of the modeled soil moisture data and the external data of the study area, the spatial patterns of both datasets might be similar. Their spatial correlation coefficient was 0.8287. Thus, it should be feasible to use the method to estimate soil moisture at fine resolution.

6. References

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