Developing on the Soil Moisture Index(SMI) for forecast by using AQUA AMSR-E

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Abstract

The Studying is on developing precision of the moisture information on a soil. We used the data of AQUA AMSR-E which were obtained by Direct Receiving System in Korea Meteorological Administration(KMA). Although we know the Soil Moisture Information(SMI) helps the numerical weather model to produce the realistic results, we couldn't do it for the problem on a spatial resolution of the data is too low to apply. So we've tried to develop in a spatial resolution by using the AMSR-E data with a Digital Elevation Model(DEM) and Normal Difference Vegetation Index(NDVI) from AQUA MODIS and compared the difference between their information in statics.

The result is more precise than the simple algorithm by a polarization ratio, and we could get the better result to use in forecast practically, if it's apply to get more detail in the vegetation temperature.

Keyword : Soil Moisture, AQUA AMSR-E, MODIS, NDVI

1. Introduction

For more precise forecast, it is necessary to get a more detail in spatial resolution information on soil moisture. But it's difficult to get it on surface directly by an optical scanner for various barriers as if vegetation.

So a microwave, which is relative long wavelength(λ) on AQUA AMSR-E is used for observing more precise soil moisture information(SMI), and applied vegetation index(VI) by MODIS in the study.

SMI to be result in study is would be better in spatial resolution than one to be used now for the forecast in KMA. Furthermore, since it is considered surface vegetation by VI & terrain effect by digital terrain model(DTM), so it is more reasonable to describe the information on a surface moisture.

It is supposed to be better effect in developing a forecast in KMA.

2 Study Area and Materials

The study is conducted in South Korea peninsula without sea around it, the coordinate is 124.53 E, 39.49 N at upper left and 129.80 N, 33.84 N at lower right corner(Fig. 1).

We used AQUA AMSR-E data in base for calculating SMI, AQUA MODIS and DTM data in addition for generating NDVI and Slop/Aspect data respectively.

The Advanced Microwave Scanning Radiometer for EOS(AMSR-E) as one instrument of AQUA satellite has a twelve channel in six frequency, and observes brightness temperatures at 6.925, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz. Vertically and horizontally polarized measurements in various spatial resolution from 5.4 km at 89.0 GHz to 56 km at 6.9 GHz.

The Earth-emitted microwave radiation is collected by an offset parabolic reflector 1.6 meters in diameter that scans across the Earth along an imaginary conical surface, maintaining a constant Earth incidence angle of 55 and providing a swath width array of six feedhorns which then carry the radiation to radiometers for measurement with 0.3 to 1.1 K radiometric sensitivity; vertical and horizontal polarization.

AMSR-E data is useful to measure precipitation rate, cloud water, water vapor, sea surface winds, sea surface temperature, ice, snow, and soil moisture.

The Moderate Resolution Imaging Spectroradiometer (MODIS) is an optical scanner on AQUA Satellite, which has 36 channels from 0.4μm to 14.5μm in spatial resolution 250m(ch1-2), 500m(ch3-7), 1km(ch8-36) as cross track scanning method.

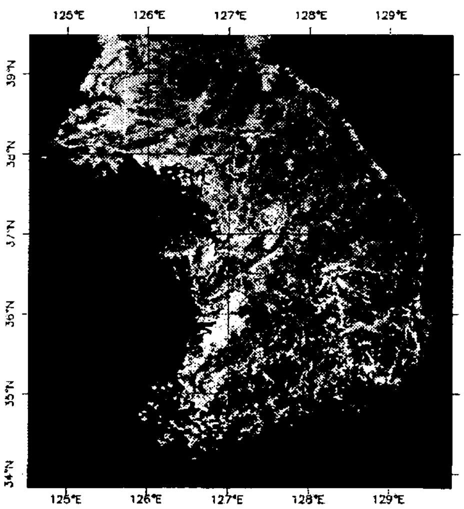

Fig 1. AQUA MODIS Ch1 image in study area

MODIS data is useful to derive products ranging from vegetation, land surface cover, and ocean chlorophyll fluorescence to cloud and aerosol properties, fire occurrence, snow cover on the land, and sea ice cover on the oceans.

Digital terrain model(DTM) data is the grid image in spatial resolution 1km from GLCF SRTM on web ftp.

AMSR-E and MODIS data were geolocated by geo file to get with the other data observed in AQUA Satellite simultaneously, and reform images by nearest neighbor as interpolation method to uniform as 1km * 1km pixel unit, which is important for comparing various data in spatial and useful to process in the program.

3. SMI & NDVI

In general, the simple SMI, which is calculated simply by band math of polarization on C-Band as follow is used for a forecast.

$$(V\text{-}Pol_{6.9GHz} - H\text{-}Pol_{6.9GHz}) / (V\text{-}Pol_{6.9GHz} + H\text{-}Pol_{6.9GHz})$$

It would not derive better information on soil moisture to be applied on forecast for the spatial resolution as 56 km at 6.9 GHz.

NDVI(Normalized Difference Vegetation Index) is generated by AQUA MODIS Ch 1(VIS-Red; 620-670 nm) & Ch 2(NIR; 841-876 nm) as follow (Fig. 2).

$$(Ch2 - Ch1) / (Ch2 + Ch1)$$

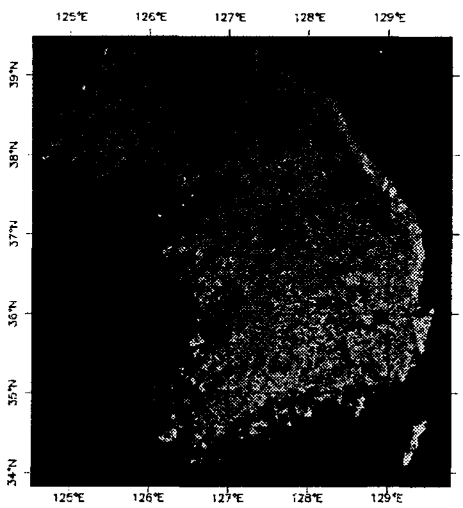

Fig 2. NDVI image by MODIS

4. Developing SMI

The process to calculate the subtle SMI is composed in 2 step. First step is to calculate the surface reflectivity (Υ_{op}) in dual polarization, the other step is to derivate the complex dielectric content(ε_r) by the function with a terrain effect.

In first step, the brightness temperature on bare soil(T_s) and vegetated soil(T_v) is used respectively.

And it is considered the optical depth(τ) and single scattering albedo(ω) with cos$i$ as terrain effect(μ) as follow.

$$\gamma_{op} = \frac{T_b - T_s * e^{-\frac{\tau}{\mu}} - (1-\omega) * T_v * (1 - e^{-\frac{\tau}{\mu}})}{e^{-\frac{\tau}{\mu}} * [-T_s + (1-\omega) * T_v * (1 - e^{-\frac{\tau}{\mu}})]}$$

T_s, T_v is calculated by NDVI(Normalized Difference Vegetation Index, 0~1 values) data from MODIS.

$T_s = T_{ka} / 0.95$ (T_{ka} is brightness temp.)

$T_v = T_s * (1\text{-NDVI}) * 0.1$

cos$i$ is calculated on the condition at the median point of the image as follow.

$\cos i = \cos(90-\theta_s)*\cos\theta_n + \sin(90-\theta_s)*\sin\theta_n*\cos(\varphi_s-\varphi_n)$

θ_s : sun elevation, φ_s : sun azimuth, θ_n : surface slop, φ_n : surface azimuth

i : incidence angle from the sun to a ortho surface (Jensen, 1996)

lat / lon : 37.0 N / 127.5 E, sun azimuth : 209.0°,
sun elevation : 40.4°, date/time : 2003.10.29 13:15

Since the observation time is too short to change of sun position, the value of sun azimuth & elevation is to be at the mean time on the image.

The consideration of terrain effect is applied just on optical depth(τ) only at vegetation, not in atmosphere, since it is used the long wavelength as if C-band.

the optical depth(τ) on vegetated surface is calculated as follow and used in the study.

$$\tau = \mu * \ln \frac{\{(Tb_{x_v} - Tb_{x_h})/(0.5*(Tb_{x_v} + Tb_{x_h}))\}}{0.05}$$

Tb_{xv}, Tb_{xh} is the brightness temperature to be observed at X-band on vertical and horizontal polarization respectively. A upper content in log is meant the polarization index at X-band, a lower content is said the polarization index at X-band in bare soil as 0.05 constant value, which is obtained by empirical method in the previous study.

Finally we could get a data on the surface reflectivity (Υ_{op}) in dual polarization and correct it as follow to consider terrain effect in H and V polarization.

$\Upsilon_{sh} = [(1\text{-}Q)* \Upsilon_{ov} + Q* \Upsilon_{oh}]*\exp(\text{-}H)$

Q : slop ratio (0-1), H : height ratio on max.

$\Upsilon_{oh(v)}$: the surface reflectivity in H, V polarization

It is different with the consideration of terrain effect as μ, which is just applied on the optical depth at a vegetated surface, since it is the consideration of terrain effect on dual polarization.

As a result, we calculated complex dielectric content (ε_r) as follow with the surface reflectivity after terrain effect correction(Υ_{sh}).

$$\varepsilon_r = [\frac{\cos\theta * (1 - \sqrt{\gamma_{sh}})}{\gamma_{sh} + 1}]^2 + \sin^2\theta$$

θ : incidence angle from the sun to a ortho surface

It's necessary to normalize for a comparison within various sites objectively as below.

$\text{SMI} = (\varepsilon_{r\_i} - \varepsilon_{r\_min})/(\varepsilon_{r\_max} - \varepsilon_{r\_min})$

ε_{r_i} : ε_r on pixel i, ε_{r_min} & ε_{r_max} : a minimum value ε_r on sea & bare soil

5. Results

The SMI data would be calculated in previous process, we could see the difference between images (Fig. 3 & 4).

As you can see, the SMI data to develop with NDVI and DTM in the study is classified in more various than the simple SMI data to calculate by C-band math. But they are similar on a distributed phase.

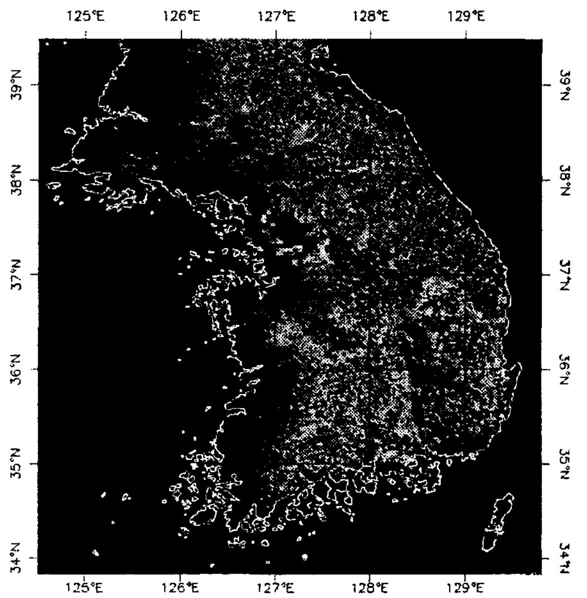

Fig 3. The developed SMI data with NDVI & DTM

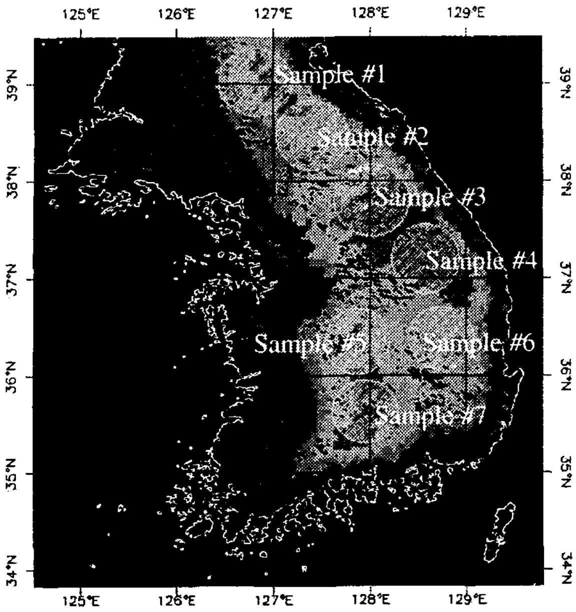

Fig 4. The simple SMI data with C-band math.

The problem area to be closed a sea, where is contained error by the diffraction effect on C-band is excluded in comparing the SMI data.

In fig.3 & 4, as the color is changed from yellow to blue, the value of SMI is lower. The mountainous area in east and south is lower on SMI generally.

It is selected 7 samples area to compare the SMI data by calculating stats value as fig. 4, the mean and std. value is calculated on it respectively.

As you can see in table 1, the developing SMI data is higher in mean and std. value than the simple SMI data.

Why mean values are higher on the SMI data to be developed in the study is the terrain and vegetation effect on surface is considered. The temperature on vegetation surface is 3~4° lower than bare soil, and the value on soil moisture is affected by it.

In the result of table 1, it is important to notice that the std. value of developed SMI is higher than the other for applying vegetation and terrain effect. It is meant to be more various and get a more detail information on SMI.

Table 1. The comparison of the SMI data in stats

		Simple SMI		Developed SMI	
Sample No.	Area (km^2)	Mean	Std.	Mean	Std.
1	4200	0.2691	0.0419	0.4999	0.0879
2	4186	0.2694	0.0474	0.3641	0.0875
3	4564	0.2533	0.0646	0.3613	0.1101
4	3958	0.2547	0.0544	0.3344	0.0999
5	3414	0.2692	0.0396	0.3185	0.1053
6	3522	0.2581	0.0625	0.3603	0.1041
7	3414	0.2634	0.0434	0.3322	0.0874

6. Conclusion

In the study, We could get the more detail information on SMI than the simple SMI to be calculated by only C-band for applying NDVI and DTM. It is supposed to be taken up a precision of forecast in long time scale. There is a problem in the study not to be considered exactly terrain effect, since it is applied cos*i* on homogenous surface assumption. If it is applied it on Non-Lambertian surface, the SMI data would be more reasonable than now.

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