Unique algorithms for retrieving sea ice and soil moisture information using AMSR-E measurements

Sungwook Hong[1], Inchul Shin[1], Su-Mi Koh[1], and Jong-Seo Park[1]
[1]National Meteorological Satellite Center/Korea Meteorological Administration
국가기상위성센터 National Meteorological Satellite Center

Introduction

- The sea ice and soil moisture play a key role in the climatology and hydrology, respectively.
- The AMSR-E sensor onboard the AQUA satellite launched in 2002 is important to monitor various geophysical parameters including sea surface temperature, wind speed, precipitation, snow depth, sea ice and soil moisture.
- Recently, the NMSC/KMA has developed its own algorithms for retrieving the surface properties such as surface roughness and refractive index.
- In this study, we propose a unique algorithms for retrieving sea ice and soil moisture information using AMSR-E data based on the polarized reflectivities, surface roughness, and refractive index.

Background

- Hong approximation (Hong, 2009)

- An approximate relationship between $R_{S,V}$ and $R_{S,H}$.

$$R_{S,H} = R_{S,V}^{\cos^2\theta}$$

- Surface emissivity for **sea ice**

$$E_{V,Rough}(\mathrm{CH}) = \frac{T_{B,V}(6.9)}{T_{B,V}(\mathrm{CH})} E_{V,Rough}(6.9) \quad \text{.................................(1)}$$

where CH is the AMSR-E channel and $E_{V,Rough}(6.9)$ is 0.98 for ice and 0.56 for ocean.

- In this study, the mixed emissivity between the ice and water due to the climate change is defined using percentage of C_I in AMSR-E level-3 data as follows:

$$E_{V,Rough}(6.9) = E_{V,Rough}(6.9)_{ice} - \frac{R_{V,Rough}(6.9)_{ice} - R_{V,Rough}(6.9)_{water}}{100} \times [100 - C_I(\%)] \quad (2)$$

$$T_B = T_I C_I + T_O(1 - C_I)$$

where T_I and T_o are the T_B of sea ice and water surfaces, respectively.

- Surface emissivity for **soil moisture**

$$R_{R,p} = [QR_{S,q} + (1-Q)R_{S,p}] \times \exp\left[-\left(\frac{4\pi\sigma\cos\theta}{\lambda}\right)^2\right] \quad (3)$$

where σ is the surface roughness, Q is the polarization mixing ratio, and λ is the wavelength.

Data and Methods

DATA

- **Data for Sea ice**
  - AMSR-E daily level 3 25km brightness temperature (TB).
  - V and H polarized channels at 6.925, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz.
  - Sea Ice Concentration data product Version 2 [2].
  - Period : March 2003 – July 2011
- **Data for Soil moisture**
  - AMSR-E daily level 3 25km brightness temperature (TB).
  - Validation: soil moisture experiments (SMEXs) - 2003
    Period : July, 2003, Location: Georgia, Okahoma

Methods

- **Surface roughness**

- using Hong approximation and polarization ratio (Hong, 2010a,b; Hong and Shin, 2011)

$$\sigma \approx \frac{\lambda}{4\pi\cos\theta}\cdot\sqrt{\ln\left(\frac{R_{R,V}^{\cos^2\theta}}{R_{R,H}}\right)} \quad \text{..................(4)}$$

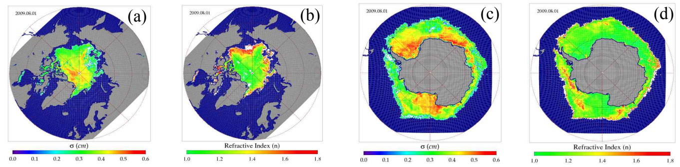
- **Estimation of refractive index** (Hong and Shin, 2010, 2011)

- Inversion of Fresnel equation
- We used the method presented by Querry (1969)

$$n = \sqrt{\frac{B^2 - A^2 + \sin^2\theta + \sqrt{(A^2 + B^2 - \sin^2\theta)^2 + 4A^2B^2}}{2}} \qquad k = \frac{AB}{2} \quad \text{..................(5)}$$

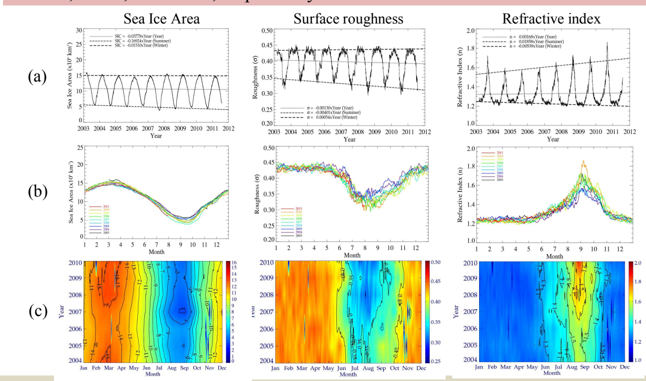
where $A = \sqrt{-B^2 - 2aB\cos\theta - \cos^2\theta}$ $\quad B = \frac{(a-b)\sin\theta\cot 2\theta}{ab + (1-a^2)\cos^2\theta - 1}$ $\quad a = \frac{R_V + 1}{R_V - 1}$ $\quad b = \frac{R_H + 1}{R_H - 1}$

Results

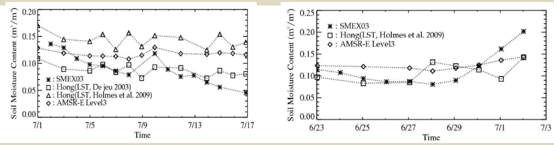


- Fig. 1. The small-scale roughness ((a) and (c)), and the real part of the refractive index ((b) and (d)) in the Polar regions on 1 August 2009.

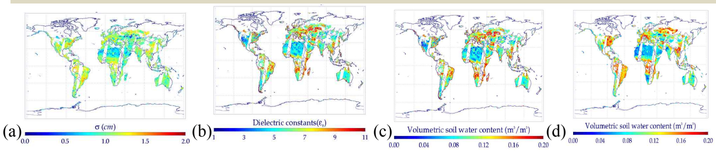
- The real parts of the refractive indices : dry, moist, and wet snow are approximately 1.016, 1.120, and 1.584, respectively.



- Fig. 2. Time series of the averaged roughness and refractive index. (a) Trends, (b) seasonal variation, and (c) annual variation of the monthly mean value in the Arctic region



- Fig. 3. Time series of SMEX03 field observations (0–7.5 cm), AMSR-E L3 soil moisture, and the retrieved soil moisture in the 6.9 GHz AMSR-E channel from (a) Oklahoma sites from July 2, 2003 to July 17, 2003. (b) Georgia sites from June 23, 2003 to July 2, 2003.



- Fig. 4. (a) roughness, (b) dielectric constant, (c) Volumetric soil water content (g/cm³) using Hong's algorithm and (d) AMSR-E level 3 products

Summary and Discussion

✓ Our investigation supports the sea ice is melting, and explains physically why the sea ice is reducing due to climate change based on the surface roughness and the refractive index.

✓ Our soil moisture algorithm estimates the soil moisture within the estimated accuracy of AMSR-E surface soil moisture, 0.06m3/m3, without requiring a priori information about the roughness and the dielectric constants of the surface.

References

Hong, S., 2009, Retrieval of refractive index over specular surfaces for remote sensing applications, J. Appl. Remote Sens., 3, 033560.

Hong, S., 2010a, Global retrieval of small-scale roughness over land surfaces at microwave frequency, Journal of Hydrology, 389, 121–126.

Hong, S., 2010b, Detection of small-scale roughness and refractive index of sea ice in passive satellite microwave remote sensing, Remote Sens. Environ. 114, 1136–1140.

Hong, S. and I. Shin, 2010, Global trends of sea ice: small-scale roughness and refractive Index, J. Climate 23, 4669–4676.

Hong, S. and I. Shin, 2011, A physically-based inversion algorithm for retrieving soil moisture in passive microwave remote sensing, Journal of Hydrology, 405, 24–30.

Querry, M. R., 1969, On direct solution of the generalized Fresnel reflectance equations. J. Opt. Soc.Am., 59, 876–877.

2nd AOMSUC Conference, Tokyo, Japan 5-9 December 2011